Exporting Behavior under Quality Constraints*

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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. Exporting requires satisfying quality constraints that are not present in the domestic market. 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,

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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. The possible channels are various. For example, export growth might allow firms to take advantage of unexploited economies of scale (Krueger 1998, Demiroglu 2008). Also, it might 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. Thus, understanding the determinants of firms’ export performance can also contribute to enhancing the effectiveness of those 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 identifying 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). In either case the models share the property that the endowment of this attribute perfectly predicts firms’ revenue (henceforth our measure of firm size) and export status. Moreover, the models predict a threshold firm size above which all firms export (and below which none do).

Although these models parsimoniously explain the salient fact that exporters tend to be large

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1The 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.
(Clerides et al. 1998, Bernard and Jensen 1999) the prediction of a threshold firm size for export, 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 standardized by industry). Though this fraction increases with size, there are still 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 the lack of a one-to-one relationship between firm size and export status observed in the 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 export quality constraints. In the presence of these constraints, there are firms with high productivity and low caliber which are large in size but refrain from exporting because they find the cost of satisfying the constraints excessively onerous. In turn, firms with low productivity and high caliber might be 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.

Our assessment of the model’s empirical relevance relies on empirically testing the set of predictions it generates. 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, 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

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2We 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.
(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 firm’s optimal choice of quality.

First, we solve for the industry equilibrium in the closed economy and in a benchmark case of an open economy with no export quality constraints. In both cases, productivity (ϕ) and caliber (ξ) can be combined into a single “ability” parameter η (η = η(ϕ, ξ)), such that key variables of interest can be expressed only 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 isomorphic to Melitz’s (2003) model. A threshold ability η determines survival, while a threshold ability η_u determines firms’ participation in the export market. The isomorphism with Melitz’ model is appealing as it makes the case with no export quality constraints a transparent benchmark.

Next we analyze the full model, where we assume that firms are required to meet a minimum quality requirement to export. Although simplistic, this assumption captures a wealth of evidence suggesting that export success is associated with firms’ ability to satisfy export quality constraints. While different reasons – discussed later – can be invoked to justify the existence of those constraints, our aim in this paper is not to identify their particular source but rather to identify their presence, examining its impact on firms’ export behavior.

In the presence of export quality constraints, our model delivers predictions that depart 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 might differ even for firms with the same η. Conditional on η, firms with high caliber (and low productivity) find the quality constraint not binding. In contrast, this constraint binds for firms with low caliber (and

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3A similar assumption is made by Rauch (2007).
4The 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 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). Studies in international trade, using census or large firm-level datasets, 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).
high productivity), which might decide to remain exclusively oriented to the domestic market to avoid a costly investment in quality upgrading. Therefore, firms of identical size (i.e. revenue) in the closed economy might 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 our model firm size is not sufficient information to infer export status. In particular, a non-exporter might be as large as a firm with smaller domestic sales but positive exports (the former firm would have high $\varphi$ and low $\xi$; the latter low $\varphi$ and high $\xi$). This prediction can explain the heterogeneity in export behavior within size percentiles observed in Figure 1.

Third, the model predicts systematic differences between exporters and non-exporters conditional on firm size. In particular, exporters sell products of higher quality and at higher prices. This prediction is substantially different from results of recently proposed single-attribute models with quality heterogeneity (Baldwin and Harrigan 2007, Johnson 2008, Kugler and Verhoogen 2008), which predict that exporters sell products of higher quality and at higher prices unconditionally. Since in those models firm size, quality, prices, and export status are all monotonically-related variables, once size is conditioned upon there is no variation in the other variables left to explain. Thus, in a regression framework where quality or price are the dependent variables and size is controlled for, the coefficient on an export dummy should be zero.

Our model, in contrast, predicts a positive coefficient on the export dummy in such a specification. Indeed, export status helps to explain firms’ quality and price even after size is conditioned upon. In addition, to the extent that higher quality products require more intensive use of skilled labor and capital, the coefficient on the export dummy should also be positive in a similar specification with average wage or capital intensity as the dependent variable. While in the literature it is customary to propose and estimate empirical specifications as those just described (e.g. Bernard and Jensen 1999, Fajnzylber and Fernandes 2006, Iaccovone and Javorcik 2008, Kugler and Verhoogen 2008) this paper is the first to provide a theoretical foundation that justifies their use.

We test the predictions of our model employing firm-level data for manufacturing in four countries: India, the United States, Chile, and Colombia. For India and the U.S. the datasets include product-level information on revenue and quantities sold that can be used to derive per-unit prices by product. For Chile and Colombia, the datasets do not include such information but contain information on firms’ wages and capital that can be used to obtain complementary evidence for our ancillary predictions on factor use.
Our analysis of the data shows that, consistent with the predictions of our model, exporters charge higher prices, pay higher wages and are more capital intensive after size is controlled for. We find that the results are mostly consistent across countries and robust to a number of alternative specifications. We undertake a number of tests to address potential concerns about measurement error in revenue, as well as to rule out potential alternative explanations of our results.

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. In section 5.2.2, we discuss why none of these models can explain all the facts we document here.

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.

2.1 The closed economy

2.1.1 Set up

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):

\[ q_j = p_j^{-\sigma} \lambda_j^{\sigma-1} \frac{E_j}{P}, \quad \sigma > 1, \]  

where $j$ indexes product varieties while $p_j$ and $\lambda_j$ are, respectively, the price and quality of variety $j$. Each firm produces only one variety, so $j$ also indexes firms. $E$ is the (exogenously given) level of expenditure, and the “price aggregator” $P$ is defined as $P \equiv \int p_j^{1-\sigma}\lambda_j^{\sigma-1}dj$. Since $\sigma > 1$, the price aggregator $P$ is inversely related to product prices.

Product quality is modeled as a demand shifter that captures all attributes of a product – other than price – that consumers value. The demand system (1) solves a consumer maximization problem with a Dixit-Stiglitz utility function defined in terms of quality-adjusted units of consumption, $\tilde{q}_j = q_j\lambda_j$, and quality adjusted prices $\tilde{p}_j = \frac{p_j}{\lambda_j}$. Thus, firm revenues, $r_j = p_jq_j = \tilde{p}_j\tilde{q}_j$, can be expressed as:

$$r_j = \frac{\tilde{p}_j^{1-\sigma}E}{P}.$$  

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

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”, $\varphi$, which reduces variable production costs – conditional on quality. Productivity enters the marginal cost function in the following form:

$$c(\lambda, \varphi) = \frac{c}{\varphi}\lambda^\beta, \quad 0 \leq \beta < 1,$$

where $c$ is a constant parameter. $\beta$ is lower than unity – i.e. marginal costs increase with quality but not excessively fast – to ensure concavity of the profit function. Also, marginal costs are assumed to be independent of scale and increasing in product quality ($\lambda$).

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

$$F(\lambda, \xi) = F_0 + \frac{f}{\xi}\lambda^\alpha, \quad \alpha > (1 - \beta)(\sigma - 1),$$

where $F_0$ is a fixed cost of plant operation and $f$ is a constant.\(^8\) Attaining higher quality requires paying higher fixed costs. Moreover, the condition that $\alpha > (1 - \beta)(\sigma - 1)$, imposed to ensure concavity, implies that fixed costs grow sufficiently fast with quality. Conditional on attaining a given quality level, the fixed costs are lower for high-caliber firms.\(^9\)

\(^7\) $P^{1-\sigma}$ is the cost-of-utility index for a CES utility function.

\(^8\) In Appendix 4, we derive $c$ and $f$ as a function of deeper parameters.

\(^9\) This approach to modeling quality captures the trade-offs present in Yeaple (2005) and Bustos (2005), where the adoption of a superior technology reduces marginal costs but requires firms to incur a fixed cost. In a world with
2.1.2 Firm’s optimal choice of price and quality

Firms choose price and quality to maximize post-entry profits, $\Pi$, which are the difference between operative profits, $\Pi_0$, and fixed costs. The first order condition with respect to price yields the standard constant mark-up result of CES demand: $p_d = \frac{\sigma}{\sigma - 1} \frac{c}{\varphi} \lambda_d$. Using this result, the first order condition with respect to quality yields:

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

(5)

where $\alpha' \equiv \alpha - (1 - \beta) (\sigma - 1) > 0$. Both productivity ($\varphi$) and caliber ($\xi$) have a positive impact on quality choice since they reduce, respectively, marginal costs and fixed costs of quality production.

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

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

(6)

Conditional on $\varphi$, high caliber firms sell their products more expensively because they produce higher quality and hence have higher marginal costs. Instead, the effect of productivity on price conditional on $\xi$ is ambiguous. On the one hand, productivity lowers marginal costs and thus prices. On the other hand, it induces a higher quality choice, which in turn raises marginal costs and prices. Whether one or the other effect dominates depends on the sign of $\alpha - (\sigma - 1)$. In equation (6), prices depend on the value of two parameters. Therefore, they are not monotone functions of productivity, size, and export status, as predicted by quality-based models with a single heterogeneous factor (Baldwin and Harrigan 2007, Johnson 2008, Kugler and Verhoogen 2008).

2.1.3 The cut-off function

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

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

(7)

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

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

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

(8)

no export quality requirements, under our demand assumptions this type of investment would be isomorphic to one that shifts out the demand curve.

Subindex $d$ denotes “domestic” firms, those that only sell in the domestic market (all firms are $d$ in this section).
where \( J \equiv \left( \frac{\sigma - 1}{\sigma} \right)^{\frac{\alpha'}{1 - \beta}} \left( \frac{1 - \beta}{\alpha} \right)^{\frac{\alpha'}{\alpha - \alpha'}} \). Profits also are 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, \( \varphi \) and \( \xi \), this condition results in a survival cut-off function:

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

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

A convenient way of summarizing information about firms’ productivity and caliber is to define their “ability” \( \eta \) as (we include \( c \) and \( f \) in the definition of \( \eta \) only for notation compactness):

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

The model has the property that both revenue and profits can be expressed as functions of \( \eta \) alone:

\[
r_d(\eta) = \eta H \left( \frac{E}{P} \right)^{\frac{\alpha'}{\alpha}} \quad \text{and} \quad \Pi_d(\eta) = \eta J \left( \frac{E}{P} \right)^{\frac{\alpha}{\alpha}} - F_0.
\]

The main implication of this property is that \( \eta \) is a summary statistic for \( \varphi \) and \( \xi \) in both functions, which depend on these heterogeneous factors only through \( \eta \). Thus firms with equal \( \eta \) – such as those along \( \xi(\varphi) \) – obtain equal revenue and equal profits regardless of their particular combinations of \( \varphi \) and \( \xi \). 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 \( \eta \) as a single productivity draw that determines entry-exit decisions: firms survive iff \( \eta \) is above a cut-off value \( \eta \), determined so that \( \Pi_d(\eta) = 0 \). This cut-off value satisfies \( \eta = \eta(\varphi, \xi(\varphi)) \).

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11 Equation (2) implies this is also true for pure prices. Firms with higher (lower) \( \eta \) charge lower (higher) pure prices.

12 This property stems from the fact that the two components of the profit function, \( \Pi_o(\lambda) \) 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.
2.1.4 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 \( \varphi \) and \( \xi \) from a bivariate probability distribution with density \( v(\varphi, \xi) > 0 \) on the support \([0, \varphi] \times [0, \xi]\).

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

\[
\Pi(P) = \int_{0}^{\varphi} \int_{\xi(\varphi, P)}^{\xi} \Pi_d(\varphi, \xi, P) v(\varphi, \xi) \, d\xi d\varphi = f_e. \tag{11}
\]

Equation (11) is the condition for industry equilibrium. Solving for \( P \) in a closed form would require assuming a particular shape of the bivariate distribution \( v(\varphi, \xi) \). We prefer not to make such an assumption and keep the analysis general. In Appendix 1.a, we demonstrate that a solution for \( P \) in equation (11) exists and is unique.

Once \( P \) is determined, we can solve for the equilibrium prices, quality levels, revenues, profits, and cut-off values. The probability of surviving is given by \( P_m = \int_{0}^{\varphi} \int_{\xi(\varphi, P)}^{\xi} v(\varphi, \xi) \, d\xi d\varphi \), where a higher value of the cut-off function \( \xi(\varphi, P) \) implies a lower probability of successful entry. The productivity and caliber joint density functions conditional on surviving is simply \( h(\varphi, \xi) = \frac{1}{P_m} v(\varphi, \xi). \)

\( P \) can be expressed as aggregating across productivity and (surviving) caliber levels rather than across firms. Making appropriate substitutions we obtain

\[
P = \int_{j} p_j^{1-\sigma} \lambda_j^{\sigma-1} \, dj = M^{\frac{\alpha'}{\alpha}} HE^{\frac{\alpha'-\alpha}{\alpha}} (\tilde{\eta})^{\frac{\alpha'}{\alpha}}, \tag{12}
\]

where \( \tilde{\eta} = \int_{0}^{\varphi} \int_{\xi(\varphi, P)}^{\xi} \eta(\varphi, \xi) h(\varphi, \xi) \, d\xi d\varphi \) is the (weighted) average ability of surviving firms. Solving for \( M \) yields \( M = HE^{\frac{\alpha'-\alpha}{\alpha}} P^{\frac{\alpha}{\sigma}} \tilde{\eta}^{-1} \). Since the right-hand-side of this equation is increasing in \( P \), in equilibrium tougher market competition is associated with a larger number of entrants.

2.2 The open economy with unconstrained export quality

As a benchmarking exercise, in this section we examine the open-economy equilibrium in a two-country world economy where export quality is unconstrained. Our analysis focuses on the equilibrium cross-sectional configuration of firm characteristics within a country rather than on differences
across countries or the effects of trade liberalization. We find that, as in the closed economy, in this “unconstrained” open-economy case the model can also be collapsed into a model with only one source of heterogeneity à la Melitz (2003).

The industry has the same structure in the foreign country as in the home country. However, the parameters $F_0^*, c^*, f^*, f_e^*$, and $E^*$ (denoted with asterisks) are allowed to be different. The joint density function from which firms draw their productivity and caliber is $v^*(\varphi, \xi) > 0$, defined on the support $[0, \bar{\varphi}] \times [0, \bar{\xi}]$. The (endogenously determined) price aggregator is $P^*$. We describe the equilibrium 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 $\tau$. 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 is $q^w = q + q^*$, the sum of domestic and foreign demand. Total demand is determined by $q^w = p^{-\sigma} \lambda^{\sigma-1} W$, where $W = \frac{E}{P} + \tau^{-\sigma} \frac{E^*}{P^*}$. Exporter’s optimal quality, revenues, and profits are given by the following expressions:

$$
\lambda_u(\varphi, \xi) = \left[\frac{1 - \beta}{\alpha} \left(\frac{\sigma - 1}{\sigma}\right)^{\sigma} \left(\frac{\varphi}{c}\right)^{\sigma-1} \frac{\xi}{f} W\right]^{\frac{1}{\sigma}} \tag{13}
$$

$$
r_u(\eta) = \eta HW^\frac{1}{\sigma}, \quad \Pi_u(\eta) = \eta JW^\frac{1}{\sigma} - F_0 - f_x. \tag{14}
$$

Equations (13) and (14) are analogous to equations (5) and (10), which still determine quality, revenue and profits for firms that do not export. In particular, $\eta$ is also a summary statistic for $\varphi$ and $\xi$ in the revenue and profit functions of exporters. Thus, as in the closed economy iso-ability curves are also iso-revenue curves and iso-profit curves.

Define as $\Delta_u \Pi \equiv \Pi_u - \Pi_d$ the difference in profits between exporting and not exporting. Using (10) and (14), this difference can also be expressed as a function of $\eta$:

$$
\Delta_u \Pi(\eta) = \eta JA - f_x, \quad A = \left[W^\frac{1}{\sigma} - \left(\frac{E}{P}\right)^\frac{1}{\sigma}\right] > 0. \tag{15}
$$

Firms choose to export if $\Delta_u \Pi(\eta) \geq 0$. Setting $\Delta_u \Pi(\eta) = 0$ and solving for $\eta$, we obtain an export cut-off value, $\eta_u^*$, such that only firms with ability above this value export. This cut-off value also
determines the export cut-off function

$$\xi_u(\varphi) = \frac{f_x}{JA} \alpha - \alpha' f\left(\frac{\varphi}{c}\right) \alpha - \alpha'$$

which satisfies $\eta_u = \eta(\varphi, \xi_u(\varphi))$. Since $\eta$ is constant along $\xi_u(\varphi)$, this cut-off function is also an iso-revenue curve and an iso-profit curve.

Figure 2 shows the equilibrium configuration of firms in the open economy with unconstrained export quality. Firms with caliber below $\xi(\varphi)$ ($\eta < \eta_u$) exit the market. Firms with caliber between $\xi(\varphi)$ and $\xi_u(\varphi)$ ($\eta \leq \eta < \eta_u$) are active in the domestic market but do not export. Firms with caliber above $\xi_u(\varphi)$ ($\eta \geq \eta_u$) sell domestically and also export.

Since $r_d(\eta)$, $r_u(\eta)$, and $\Delta_u \Pi(\eta)$ are all monotone functions of $\eta$, firm size (revenue) is a perfect predictor of export status. In particular, all firms smaller than $r_d(\eta_u)$ do not export while all firms larger than $r_u(\eta_u)$ have positive foreign sales. This stark prediction of the unconstrained model is illustrated in Figure 3, where the fraction of exporting firms is displayed as a step function of firm size. This prediction implies that conditional on a given revenue level, all firms have the same export status. This implication is common to all single-attribute models of firm heterogeneity.

Finally, we note that quality decreases as we move down an iso-revenue curve. To see this, consider iso-revenue curve $\xi^k(\varphi)$, defined so that $r_u(\varphi, \xi^k(\varphi)) = k$. Solving for $\xi$ and substituting into equation (13), we obtain $\lambda_u(\varphi, \xi^k(\varphi)) = B\left(\frac{\xi}{c}\right)^{-\frac{\alpha - 1}{\alpha - \alpha'}}$ ($B$ is a function of constant parameters).

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 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 (2008) find that Mexican firms increase their average prices two years before they start exporting, which suggests a process of quality upgrading in preparation to export. Evidence of the existence of export quality requirements is also provided by studies in international management. Using firm-level surveys in developed and developing countries, these studies document firms’ need to upgrade quality as a crucial re-

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13 We assume that $f_x > (F_0A) / (E^A)$ to ensure that $\xi_u(\varphi) > \xi(\varphi)$.

14 No firm has revenue in the interval $(r_d(\varphi, \xi_u(\varphi)), r_u(\varphi, \xi_u(\varphi)))$.

15 In Arkolakis (2008), $r_d(\eta_u) = r_u(\eta_u)$ as the fixed export cost to reach the first consumer is arbitrarily small.
quirement for exports. Finally, 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 constraints are various. First, higher income countries tend to consume higher-quality goods (Hallak 2006, 2008) and therefore are likely to set higher minimum quality standards. Firms that ship their products to higher income countries should then find those standards more stringent. Second, transportation costs are proportionally higher for low-quality goods (Alchian and Allen 1964, Hummels and Skiba 2004). Therefore, below some minimum quality threshold they can be prohibitive. Third, export quality requirements might take the form of management quality certification requirements (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 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 constraints by simply assuming that firms need to attain a minimum quality level to be able to export. We do not intend to uncover the particular source of these constraints in this paper. Rather, our aim is to assess their common implications for the export behavior of firms. Thus, we favor a modeling choice that, although very stylized, generates predictions that are robust to the various potential determinants of export quality constraints.

2.3.1 Characterization of the equilibrium

We examine the open-economy equilibrium in a two-country world economy with minimum export quality requirements. Firms need to attain at least quality level $\lambda$ to be able to export (the minimum is $\lambda^*$ for foreign firms exporting to the home country). Except for the minimum export quality, the “constrained” environment maintains all features of the unconstrained one. We keep our focus on the cross-sectional configuration of firm characteristics within a country.

The equilibrium is represented in Figure 4. We describe its main features here and leave its formal characterization to Appendix 2. As in the unconstrained equilibrium (see Figure 2), firms

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16 See 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).
below $\xi(\varphi)$ do not survive (region I) while firms between $\xi(\varphi)$ and $\xi_u(\varphi)$ are only active in the domestic market (region II). Similarly, firms with sufficiently high combinations of $\varphi$ and $\xi$ are (unconstrained) exporters (regions V.a and V.b). In the constrained equilibrium, however, there is a new set of firms that would otherwise export with quality $\lambda_u < \Lambda$ but now are forced to choose between upgrading their quality or not participating in the export market. Among those firms, some refrain from investing and remain domestic (region III) while others upgrade quality and export (region IV).

The curve $\xi_u(\varphi)$ is no longer the export cut-off function. As firms’ unconstrained choice of quality decreases along $\xi_u(\varphi)$, quality is above the minimum export requirement only on its left part – where it coincides with the new export cut-off function – but drops below the minimum once it reaches some threshold productivity value ($\varphi_\Lambda$). Similarly, firms’ unconstrained quality choice is below the minimum for all firms in the shaded areas delimited by $\xi_u(\varphi)$ and $\xi_\lambda(\varphi)$, the isoquality curve for $\lambda$. Those firms would otherwise find it profitable to sell abroad but in the presence of the export quality requirement they are forced to upgrade quality if they wish to export.\footnote{\xi_u(\varphi) can be thought of as the (hypothetical) export cut-off function for a single firm if the restriction were removed only for that firm (removing it on all firms together would change $P$ and hence shift $\xi_u(\varphi)$).}

In case firms in that area decide to export, they invest just enough to reach quality $\Lambda$. Thus, their marginal cost is $\frac{\xi \varphi \lambda^\beta}{\varphi}$ and their price is $p_c(\varphi) = \frac{\varphi}{\sigma-1} \frac{\xi \lambda^\beta}{\varphi}$ (subindex $c$ denotes “constrained” firms). Revenues and profits are, respectively,

$$r_c(\varphi) = \left(\frac{\sigma - 1}{\sigma} \frac{\varphi}{c}\right)^{\sigma-1} \Lambda^{\alpha-\alpha'} W, \quad \Pi_c(\varphi, \xi) = \frac{1}{\sigma} \left(\frac{\sigma - 1}{\sigma} \frac{\varphi}{c}\right)^{\sigma-1} \Lambda^{\alpha-\alpha'} W - \frac{f}{\xi \lambda^\alpha - f_x - F_0}$$

Since $\xi$ does not affect quality choice for constrained exporters, its value has no effect on marginal costs, prices, or revenues. However, it has an effect on profits since firms with higher caliber find it less costly to attain $\Lambda$. Define $\Delta \Pi_c \equiv \Pi_c(\varphi, \xi) - \Pi_d(\varphi, \xi)$. The export cut-off function $\xi_x(\varphi)$ is now implicitly defined by $\Delta \Pi_c(\varphi, \xi_x(\varphi)) = 0$. This function cannot be solved in closed form. However, in Appendix 2 we demonstrate that its slope is negative and that it is located between $\xi_u(\varphi)$ and $\xi_\lambda(\varphi)$. Firms in region III find that upgrading quality to satisfy the export requirement is too onerous. In contrast, firms located in region IV invest in quality upgrade to meet the export requirement. These firms are the constrained exporters.

In the case of the foreign country the analysis is analogous. In Appendix 1.b we prove existence and uniqueness of the equilibrium in this world economy.\footnote{Setting $\Lambda = \Lambda^* = 0$, the proof also demonstrates equilibrium existence and uniqueness for the unconstrained case.}
2.3.2 Firm size and export status

The minimum export quality requirement breaks the sufficiency of $\eta$ for predicting firm total revenue (firm size). It also breaks the sufficiency of revenue for predicting export status. In Figure 5, we add three representative iso-revenue curves, $r_1$, $r_2$, and $r_3$, to the equilibrium configuration of firms displayed in Figure 4. $r_1$ and $r_2$ represent families of iso-revenue curves located, respectively, in region II and in the area below $r_x$ in region III. As in the unconstrained case, along those curves the value of $\eta$ is constant and all firms are domestic. 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 $\eta$. Since quality decreases along the curve, at point $A$ quality reaches the minimum level $\lambda$. From this point, $r_3$ goes straight down to point $B$, which is located on $\xi_x(\varphi)$. Since $\varphi$ is constant for firms on this segment and they all produce quality $\lambda$, their marginal costs, price, and revenues 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 (due to their higher $\eta$). The limit case of this set of iso-revenue curves is $r_x$, which is the minimum possible revenue for an exporter.

In contrast to the predictions of the unconstrained case and of single-attribute models of firm heterogeneity, the family of iso-revenue curves represented by $r_3$ includes both exporters and non-exporters. Therefore, rather than 0 or 1 as in Figure 3, 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.\footnote{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).}

Thus, revenue level is not sufficient to predict firm export status.

2.3.3 Testable predictions

While the model explains the existence of exporters and non-exporters with the same size, it also predicts that their quality and price will differ systematically. The following proposition establishes that, for firms on the same iso-revenue curve, exporters – either constrained or unconstrained – produce higher quality than non-exporters.

**Proposition 1.** Conditional on size (total revenue), quality is higher for exporters than for do-
For \( r < r_x \), this proposition is vacuous since none of the firms exports.

**Proof.** See Appendix 3.

This result can be verified by visual inspection of Figure 5. Exporters are either firms located between points A and B, in which case they produce quality \( \lambda \), or firms located above A, in which case they produce quality above \( \lambda \). Instead, non-exporters are located to the right of C, and thus produce quality below \( \lambda \). 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 1. 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

\[
\forall \tau, \ p_x(\varphi_x, \xi_x)|_{r_x=\tau} > p_d(\varphi_d, \xi_d)|_{r_d=\tau}, \quad x = \{u, c\}
\]  

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

Proposition 1 is the basis of our empirical investigation. Corollary 1 is the main testable prediction. These results are novel. While 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 the same export status for all firms. Here, in contrast, non-exporters can achieve the same revenue level as exporters by producing higher quantities, which they sell at lower prices due to 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 domestic size, they do not export.

So far we have assumed that fixed and variable costs of production increase with quality leaving the source of those costs unmodeled. An a priori appealing rationale is the presumption that producing higher quality goods requires more skilled-labor-intensive and more capital-intensive techniques. In that case, exporters, who produce higher quality than non-exporters – conditional on
size – will also pay higher average wages and have a higher capital-to-labor ratio. In Appendix 4, we provide a background model of the deeper fundamentals that might drive a positive relationship between quality and fixed and variable costs using an approach that partially draws on Verhoogen (2008). That relationship, combined with Proposition 1, delivers the following additional results:

**Corollary 2.** Conditional on size, exporters pay higher average wages than non-exporters

*Proof.* See Appendix 4.

**Corollary 3.** Conditional on size, exporters are more capital intensive than non exporters

*Proof.* See Appendix 4.

Finally, Proposition 1 and Corollaries 1, 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 India, US, Chile and Colombia. Because our theory hinges on a differentiated products demand structure, we expect our predictions to be more relevant to industries manufacturing those products. Accordingly, our baseline analysis is performed using data for establishments manufacturing differentiated products. We discuss the data sources briefly below; more specific discussion of the product level information for India and the U.S., and the steps we took to clean the data for all four datasets is provided in the Data Appendix.

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20 Exporters will also pay higher average wages if quality production requires paying efficiency wages.

21 Another potentially testable prediction, which differs from those of single-attribute models of firm heterogeneity, is that trade liberalization should induce a reshuffling of size rankings in favor of firms with high caliber. Thus, firm size in the closed economy does not perfectly predict size or export status in the open economy. For example, consider an iso-revenue curve in Figure 5 that crosses regions III, IV, and V in autarky. Following trade liberalization, firms lying in regions IV and V of the curve would choose to export and hence expand, whereas those in region III would remain domestic. We leave the empirical analysis of this prediction for further research.

22 To identify “differentiated” products, we use Rauch (1999) classification. Mapping product categories in our four datasets to the SITC classification used in Rauch (1999) required us to construct specific concordances, explained in detail in the Data Appendix.
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 registered under the Factories Act employing more than 20 persons.\textsuperscript{23} 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 “multipliers”). Further details about this data can be found in Sivadasan (2007).

For the US, we use data from the 1997 Census of Manufactures (CMF).\textsuperscript{24} 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. Data for a large proportion of (largely smaller sized) plants (“AR plants”) are collated by the census from administrative records. Because many variables for AR plants are imputed rather than directly collected, following the practice in the literature (e.g. Syverson 2004, Bernard, Redding and Schott, 2008) we exclude AR plants from our analysis. US Census data has been used extensively in microeconomic research (Bartelsman and Doms, 1999), and more specifically to examine differences between exporters and non-exporters (Bernard and Jensen, 1999). A detailed discussion of the Census of Manufactures data is available in the LRD technical documentation manual (Monahan 1992).

The novelty in this paper with regard to CMF data is the use of SIC seven-digit product-specific information to derive product-level unit values (or prices), defined as product revenue divided by product quantity.\textsuperscript{25} One drawback of our derived unit value measures is that product quantity

\textsuperscript{23} 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.

\textsuperscript{24} We checked robustness of our main results to using data from the 1992 CMF as well.

\textsuperscript{25} 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.
data is unavailable for many establishments and products. In particular, quantity information is often missing for certain products or industries where output units are “not meaningful” (Monahan, 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.

We use manufacturing data for Chile and Colombia to examine predictions relating to non-price variables, as the datasets for those countries do not include product level revenue and quantity information. For Chile, we use 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). For Colombia, we use 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, revenues, potential proxies for quality, output price, average wage, and capital intensity (capital to labor ratio).\footnote{In Section 5, as part of our robustness checks, we define and discuss a number of other variables.}

Ideally, we would like to have a measure of quality that is directly consistent with $\lambda$ 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 discuss in Section 4.3 why the ISO 9000 quality management certification could be a good proxy for quality ($\lambda$).

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 sales
value and quantity for the separate product lines of every establishment. This allows us to derive product-specific prices (unit values), which is critical for testing Corollary 1. While price information is available for each product line - so there are multiple price observations per establishment - data on export value (and all other data) are reported only at the establishment level. In our analysis, we check robustness to different assumptions about which product lines are exported and to restricting analysis to single-product establishments (see discussion in Section 4.2).

In the case of all other non-price variables (in particular, revenues, 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 establishments to the level of the firm. In Section 5.1, we discuss robustness of the results to defining size and other variables at the firm level.

To mitigate the 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 establishments producing differentiated products/industries in 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. Nominal variables (wages and capital) for India are reported in rupees, for the US in thousand dollars, for Chile in current Chilean pesos and for Colombia in current Colombian pesos.\textsuperscript{27} 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 fraction of exporters that can be inferred from the table is likely to overestimate the prevalence of exporting in the full sample. Subject to this caveat, we note that in our cleaned data samples, 26\% of product-year observations (1,681/6494) on price for India corresponds to exporters. For the wage and capital data, the exporter proportion for India is 20\%, and for the ISO data, the proportion is 18\%.\textsuperscript{28} For the US, the exporter proportion...
varies from 27% (for price) to 20% (for capital and wage). For Chile, about 21% establishment-year observations (6707/30,377) relate to exporters; this proportion is lower (13.2%) for Colombia. This lower prevalence in the US may be driven by greater coverage of small firms in the US data.\textsuperscript{29}

As noted earlier, price data are 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 49,203 price (establishment-product) observations, while there are 236,118 total (establishment) observations for all the other key variables. 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.\textsuperscript{30} The product, and hence price, data availability issue is also relevant for India; the proportion of exporter-related observations in the Indian price data is somewhat higher (26% relative to 20% for capital and wages).

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 is affected by differences in units across products. A more meaningful picture of the difference in prices between exporters and non-exporters is presented in Section 4.2 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 3%). 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 (Proposition 1 and Corollary 1) is that the expected value of quality and price is higher for exporters relative to non-exporters of the same size. This prediction contrasts with the results of single-attribute models (e.g. Kugler\textsuperscript{29})
and Verhoogen, 2008), which yield those predictions unconditionally. In those models, conditional on revenue there is no variation between exporters and non-exporters.

Because quality is not observed, directly testing Proposition 1 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 ancillary 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, $\varphi$ and $\xi$. Proposition 1 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 1 and the corollaries as

$$E [Y | r, D = 1] > E [Y | r, D = 0], \quad \forall r$$

where $Y = \{\lambda, p, \frac{V}{L}, wL\}$.

We adopt a regression approach to test the above predictions, allowing a flexible control for size. In particular, we assume that the conditional expectations take the linear separable form:

$$E [Y | r, D] = g_Y(r) + \delta_{Yx} D$$

where $g_Y(r)$ is a (product/industry specific) polynomial in revenue (including a constant), and $\delta_{Yx}$ is the coefficient on the export status dummy. The coefficient $\delta_{Yx}$ captures the gap between the left-hand-side and the right-hand side of (20), which our theory predicts to be positive. The linearity of the conditional expectation in (21) allows us to express a realization of the dependent variable as

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

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 $\varphi$ and $\xi$ that have the same revenue and export status. The coefficients of (22) 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 (22) do not capture a causal relationship. For example, it would be erroneous to interpret $\delta_{Y|x}$ 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, $\varphi$ and $\xi$, 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 $\delta_{Y|r}$ and $\delta_{Y|x}$ 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. Note that even for this non-causal interpretation the error term needs to be orthogonal to the independent variables.

While we allow the coefficients on the size (revenue) polynomial to vary across industries, we restrict the coefficient on the export dummy to be the same across products/industries in our baseline specification (22). We relax the restriction in Section 5, where we check if the coefficient on the exporter dummy varies systematically with different product characteristics.

One critical issue we need to address is comparability across industries. Our model and hence the predictions are essentially relevant to a single industry. Though we restrict attention to differentiated sectors, there is considerable heterogeneity across products/sectors within this group. Hence, 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 (21) to vary by product code or industry. 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 driven by particular products or industries. At the same time, 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 four key variables of interest – price, ISO 9000 adoption, 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

In this section, we use data for differentiated products in 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, prices should be higher for exporters relative to non-exporters of equal size. In contrast, under the null of single-attribute models, size perfectly predicts export status, so conditioning on revenue there should be no variation in export status in the first place to make such a comparison.

Our price measure is a unit value, 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. To allow for arbitrary correlation between error terms for a given establishment, we cluster standard errors at the establishment level.

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.

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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 the non-standardized price variable 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 industry 2, a better overall conclusion may be that exporters do not enjoy a large price premium.
Columns 3 and 4 are our baseline (preferred) 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 non-standardized log price.

In all specifications, exporters have a positive price premium. For India, all specifications with the standardized price variable yield a statistically significant premium for exporters. In the non-standardized case, the premium is below significance in columns 1 and 2, but larger and significant in the baseline specifications of columns 3 and 4, where size is flexibly controlled for. In those specifications, the standardized price premium is 17.7% and 16.9%, respectively. For the U.S., the estimated price premium is statistically significant in all specifications. In particular, the standardized price premium in the baseline specifications is 13.6% and 13.5%. These results confirm the main theoretical prediction of our model. We note that similar specifications have been estimated in the literature with similar results, though lacking a theoretical framework under which the results could be properly interpreted (e.g., Fajnzylber and Fernandes 2006, Iaccovone and Javorcik 2008, Kugler and Verhoogen 2008).

We perform several robustness checks. First, we redefine the export dummy as equal to one only for those firms with export sales above 2% of total revenue. For India, the magnitude and significance of the export premium in the baseline specifications is slightly lower. For the U.S., magnitude and significance are mostly unchanged. These results are displayed in Table A.1 of the Supplemental Appendix. Second, we replicate the analysis retaining only the largest product line for each establishment. While in our baseline specification we assume that all product lines for an exporter establishment are exported, establishments might export their main line of products and may not export subsidiary product lines. For India, the export premium has the same magnitude and is statistically significant when we control for a cubic function of size (column 3). It is positive but not significantly different from zero when we control for size with decile dummies. For the U.S. the results follow closely those of the baseline specification in all cases (Table A.1).

We also did a number of other robustness checks (not reported). 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”).

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32 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.
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 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). Finally, ISO 9000 certification as a proxy for quality has already been used in the international trade literature (e.g. Verhoogen, 2008). Results from estimating equation (22) with ISO certification as the dependent variable are presented in Table 3. 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. 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 log average wages and capital intensity (measured as the log of the capital to labor ratio), conditional on size. Note that these corollaries combine the main prediction of the model with ancillary assumptions about factor use of quality production. Results are presented in Table 4. For brevity, for each of the four countries, we only present the specifications with the cubic and size-decile controls for size. Note that here the size controls vary at the 4-digit industry level rather than at the product level. 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 establishment-year rather than an establishment-product-year. 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 13.6% of standard deviation wage premium for exporters in India, 9.7% in the U.S., 13.1% in Chile and 9.2% in Colombia. For all the countries, all specifications indicate statistically significant exporter wage premia. The results in row 2 using the non-transformed wage variable are similar.34

34A 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.

34We 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 in the total wage bill. We found the non-production share of the wage bill to be significantly
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 18.8% (of standard deviation) higher log capital to worker ratio, conditional on revenue. The corresponding premium is 25.0% for Chile and 14.7% for Colombia. The results for the U.S. are different. 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 negative premium changes to an insignificant positive premium.\footnote{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.}

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 checked 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 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. Results are reported in Table A.2\footnote{One potential explanation could be that quality upgrading requires increasing the intensity of capital in labor-abundant 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 address 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 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 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, like revenue, employment is also monotonically related to firm size in single-attribute models, employment can alternatively be used as a control for size to test the predictions of those models as the null hypothesis. The results (for our main price and ISO dummy variables) are presented in Table 5. As in the baseline case, there is a significant export premium across all specifications, which rejects the predictions of single-attribute models.

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 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

\[37\mathrm{Our\ predictions\ indicate\ that\ we\ should\ condition\ for\ size\ using\ revenue\ rather\ than\ employment.\ Thus,\ even\ though\ a\ specification\ that\ controls\ for\ employment\ is\ appropriate\ to\ test\ the\ null\ of\ single-attribute\ models,\ it\ could\ yield\ biased\ estimates\ under\ our\ framework\ as\ null.}\]
Database (LBD) on ownership links, we aggregate establishments up to the firm level (information on ownership links is unavailable in the other three datasets), and reestimate our baseline specification. The results are presented in panel 1 of Table A.3. These are similar to the baseline results, suggesting that conclusions are not sensitive to the use of establishment versus firm size controls. As an additional robustness check, in panel 2, we repeat the baseline analysis using only single-establishment firms. The baseline results are robust to this check as well.\(^\text{38}\)

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.\(^\text{39}\) We exclude firms that enter or exit export status during the period to avoid any transitional dynamics. The results, presented in Table A.4, confirm the baseline results, with magnitudes of the exporter premium being larger than the baseline case. 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 mechanisms we stress in the theory. We discuss those tests in the next section since they also check robustness against 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 and suggests that a model with more than one source of heterogeneity is necessary to provide a more complete characterization of firms’ exporting behavior. The model we propose in this paper is one particular multi-attribute model in which firms are heterogeneous in productivity and caliber. In this section, we provide additional evidence that supports the empirical relevance of this particular characterization of firms’ exporting behavior over potential alternatives. In particular, in Section 5.2.1 we identify industries where the economic mechanisms we emphasize are more likely to operate and evaluate whether the predictions of our model hold more strongly in those industries than in others. Also, since other multi-attribute models have been proposed in the literature, in Section 5.2.2 we evaluate the extent to which specific alternative multi-attribute models proposed in the

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\(^{38}\) As an additional robustness check, we restricted the sample to single-establishment single-product firms, and found the baseline results to be robust.

\(^{39}\) This approach can be interpreted as using firm dummies as instruments to address measurement error, as discussed in Angrist and Krueger (1999).
literature can explain the facts we document here.

5.2.1 Results by industry characteristics

Numerous alternative dimensions of heterogeneity other than “productivity” and “caliber” could introduce a wedge between firm size and export status. In this section, we delve deeper into the conditional (on size) price premium for exporters documented in earlier sections presenting a body of evidence that, as a whole, supports the empirical relevance of the specific characterization of firms’ exporting behavior that we propose. First, we apply our empirical strategy to non-differentiated products, where it is less obvious that our theory should apply. Then, we link the potential sources of the export quality constraint hypothesized in Section 2.3 – informational asymmetries, income per capita, and distance to destination country – to specific industries and check whether the conditional export premium is stronger in those industries.

Differentiated versus non-differentiated industries As a test that the mechanisms we describe in the paper are indeed those driving our empirical results, we estimate our baseline price regressions also for non-differentiated products. 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. Details of the concordances required to match the SITC Rev.2 based Rauch classification to 5-digit Indian product codes and the 5-digit SIC code for the US are discussed in the data appendix.

The results are presented in Table 6. Consistent with our previous discussion, the exporter price premium is higher for differentiated goods in both countries. In India, the premium is large and statistically significant for differentiated products, but insignificant (and negative) in the sample of homogenous products. In the US, even though there is still a price premium for homogeneous good exporters, the premium for exporters of differentiated goods is higher.

Industries classified according to source of export quality constraint Here we link industries to potential sources of the export quality constraint discussed in Section 2.3. First, as suggested in that section, minimum quality requirements for export might exist to solve informational asymmetry problems. To the extent that informational asymmetries are a relevant source of export quality constraints, the export premium should be higher for more differentiated products,
which tend to be more complex and more difficult to contract upon. We use estimates of elasticities of substitution from Broda and Weinstein (2006) to identify products with high degree of differentiation - those with low elasticity of substitution. In particular we construct a dummy variable that takes the value of 1 for products with elasticity of substitution above the median and interact it with our export dummy variable. In panel 1 of Table 7, we present the results. For India, we find that the dummy interaction is negative, as we would expect, and significant in the size-decile fixed-effect specification. In the US, the interaction is positive but statistically insignificant.

Second, 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. Unfortunately, our data sets do not provide information on firms’ exports by destination country. Thus, we use export destinations at the industry level as a coarser measure. Specifically, we use the concordances from product categories in the Indian and U.S. datasets (discussed in more detail in the appendix) to 4-digit SITC categories to construct trade-weighted means of destination GDP per capita and destination distance for each Indian and US product categories. These measures, standardized for ease of interpretation of the coefficients, are 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.

Panels 2 and 3 of Table 7 display the results. In the case of India, the coefficients on both interactions are positive as expected, but not statistically significant. For the U.S., the interaction terms are positive and strongly significant for both GDP and distance. We wish to note, however, that since the GDP per capita and distance measures we use are not ideal – they are defined at an aggregate level rather than at the establishment/firm level – these results are likely to be noisy.

The evidence we present here suggests that all three hypothesized sources of the export quality constraint are likely to play a role. However, further research using more detailed firm-level data including export destinations should be undertaken to pin down the relative importance of each of these sources. Taken together, the results of this section also support our characterization of

\footnote{The construction of the concordance between the Broda-Weinstein measures and the US and Indian product codes is discussed in detail in the data Appendix.}

\footnote{Data sources for GDP and distance are discussed in the Data Appendix. Note that unlike the dependence on external finance, dependence on government, Rauch, and Broda-Weinstein measures used earlier, the destination GDP per capita and destination measures are defined separately for India and the US using detailed export data for the individual countries.}

\footnote{The fact that it is not clear that one of these sources prevails over the others supports our choice of modeling
firms’ exporting behavior since they are consistent with the mechanisms that motivate the existence of export quality constraints.

5.2.2 Evaluation of alternate multi-attribute models in the literature

Alternate multi-attribute models have been proposed in the literature. Alessandria and Choi (2007) build a model with sunk costs and firm heterogeneity in productivity. Even though sunk costs are assumed common across 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. A similar reasoning can be applied to a model that combines Melitz (2003) with heterogeneous fixed costs (see Crozet et al, 2008). Under that framework, conditional on total sales, exporters would also be less productive and thus charge higher prices. However, they would not be expected to pay higher wages or be more capital intensive. In either case, firms with equal productivity should have equal sales volume in the domestic market. Thus, controlling for domestic sales rather than total sales, we should not observe systematic difference between prices charged by domestic firms and exporters. In Table 8, we can see that this is not the case. As our model also predicts, conditional on domestic sales, exporters charge higher prices than non-exporters.43

Ruhl (2008) and Das et al. (2007) add, respectively, firm heterogeneity in sunk export costs and in sunk and fixed export costs to the dynamic framework of Alessandria and Choi (2007). 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.

43Combining Kugler and Verhoogen’s (2008) framework with heterogeneous fixed costs yields the opposite prediction: exporters should charge lower prices than non-exporters, conditional on size.
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 \textit{a priori} obvious that such a model would be able to replicate our facts. Nevertheless, we undertake a crude check to address the potential impact of access to financing. Using the measure of dependence on external finance proposed by Rajan and Zingales (1996), we exclude products above the median for this measure and rerun the baseline price regressions. As the results in panel 1 of Table A.5 shows, the exporter premium is positive and significant even in the industries that are less dependent on external finance.

Finally, an alternative explanation for why there may be large purely domestic firms is that these firms are able to secure government contracts despite being less productive (e.g. due to an advantage in access to government officials). Then, if less productive firms produce lower quality and sell at lower prices as in Kugler and Verhoogen (2008), heterogenous access to government contracts might, in principle, explain our results. We check for the potential bias from government-related transactions in the following way. Using detailed input-output tables for the US (available from the website of the Bureau of Economic Analysis), we form a product level measure for the extent of dependence on government purchases (defined as fraction of output consumed by state and federal government). Then, we run the baseline price regressions excluding products above the median for this measure. Results presented in panel 2 of Table A.5 show that the baseline results hold for the sample of industries that are relatively less dependent on government purchases.

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.

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 findings 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.

Since the goal of this paper is to propose a more nuanced characterization of the determinants of firms’ export behavior, we restrict our analysis to providing evidence of its empirical relevance. However, this characterization 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 reducing the magnitude of the predicted export response to trade liberalization. Similarly, the lack of a one-to-one relationship between firm size and export status our model predicts 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 market can 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.
References


Appendix 1: Equilibrium existence and uniqueness in the closed and open economies

a. Existence and uniqueness in the closed economy. Since \( \Pi_d(\varphi, \xi, P) \) and \( \xi(\varphi, P) \) are continuous and differentiable in \( P \), \( \Pi(P) \) is also continuous and differentiable in \( P \). Because \( \Pi(P) \) 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 \( \lim_{P \to 0} \Pi(P) = \infty \) and \( \lim_{P \to \infty} \Pi(P) = 0 \). This implies that there exists at least one value of \( P \) such that \( \Pi(P) = f_e \).

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

b. Existence and uniqueness in the open economy. To save notation, rename \( \varphi = \tilde{\varphi}/c \) and \( \xi = \tilde{\xi}/f \), letting \( \tilde{\varphi} \) and \( \tilde{\xi} \) denote the original productivity and caliber draws. Hence, \( \varphi \) and \( \xi \) combine technology and input cost and can be interpreted as “cost-adjusted productivity and caliber”.

Ex-ante expected profits are given by

\[
\Pi(P, P^*) = \int_0^\varphi \int_0^\xi \Pi(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi, \quad P > 0, P^* > 0,
\]

\[
\Pi(\varphi, \xi, P, P^*) = \begin{cases} 
0 & \text{if } (\varphi, \xi) \in r(I) \\
\Pi_d(\varphi, \xi, P) & \text{if } (\varphi, \xi) \in \{r(II), r(III)\} \\
\Pi_c(\varphi, \xi, P, P^*) & \text{if } (\varphi, \xi) \in r(IV) \\
\Pi_u(\varphi, \xi, P, P^*) & \text{if } (\varphi, \xi) \in \{r(V.a), r(V.b)\}
\end{cases}
\]

where \( r(X) \) denotes region \( X = \{I, II, III, IV, Va, Vb\} \) as depicted in Figure 5. At the limits between regions, firms are indifferent. Thus, the function \( \Pi(\varphi, \xi, P, P^*) \) does not jump; it is continuous in \((\varphi, \xi)\), even though not differentiable at the limits of integration – of measure zero in \( R^2 \).

Expected profits can be written as:

\[
\Pi(P, P^*) = \int_0^\varphi \int_0^\xi \Pi(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi
\]

\[
= \int_0^\varphi \int_0^\xi \Pi_d(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi + \int_0^\varphi \int_{\varphi(P^*)}^\xi \Pi_d(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi + \int_0^\varphi \int_{\varphi(P^*)}^\xi \Pi_c(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi
\]

\[
+ \int_0^\varphi \int_{\varphi(P^*)}^\xi \Pi_u(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi
\]

\[
= \int_0^\varphi \int_0^\xi \Pi_d(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi + \int_0^\varphi \int_{\varphi(P^*)}^\xi \Pi_d(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi + \int_0^\varphi \int_{\varphi(P^*)}^\xi \Pi_c(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi + \int_0^\varphi \int_{\varphi(P^*)}^\xi \Pi_u(\varphi, \xi, P, P^*) \nu(\varphi, \xi) \, d\xi \, d\varphi
\]

\( (23) \)
where $\Pi_d$, $\Pi_u$, and $\Pi_c$ are respectively given by equations (8), (14), and (17). The functions $\Pi_d$, $\Pi_u$, and $\Pi_c$ are continuous and differentiable in $P$ and $P^*$, as are also the limits of integration. Therefore, the continuity and differentiability of the function $\Pi(P, P^*)$ in $P$ and $P^*$ follows directly.

Since $\Pi(\varphi, \xi, P, P^*)$ is continuous in $(\varphi, \xi)$, by application of Leibniz rule we can find the derivatives of $\Pi(P, P^*)$ with respect to $P$ and $P^*$. These derivatives result in expressions analogous to (23) except that they integrate over derivatives instead of function values (note that the derivatives of the limits of integration cancel out). Since $\Pi(\varphi, \xi, P, P^*)$ is continuous in $(\varphi, \xi)$, by application of Leibniz rule we can find the derivatives of $\Pi(P, P^*)$ with respect to $P$ and $P^*$. These derivatives result in expressions analogous to (23) except that they integrate over derivatives instead of function values (note that the derivatives of the limits of integration cancel out). Since $\Pi(\varphi, \xi, P, P^*)$ is continuous in $(\varphi, \xi)$, by application of Leibniz rule we can find the derivatives of $\Pi(P, P^*)$ with respect to $P$ and $P^*$. These derivatives result in expressions analogous to (23) except that they integrate over derivatives instead of function values (note that the derivatives of the limits of integration cancel out). Since $\Pi(\varphi, \xi, P, P^*)$ is continuous in $(\varphi, \xi)$, by application of Leibniz rule we can find the derivatives of $\Pi(P, P^*)$ with respect to $P$ and $P^*$. These derivatives result in expressions analogous to (23) except that they integrate over derivatives instead of function values (note that the derivatives of the limits of integration cancel out). Since $\Pi(\varphi, \xi, P, P^*)$ is continuous in $(\varphi, \xi)$, by application of Leibniz rule we can find the derivatives of $\Pi(P, P^*)$ with respect to $P$ and $P^*$. These derivatives result in expressions analogous to (23) except that they integrate over derivatives instead of function values (note that the derivatives of the limits of integration cancel out).

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

\[ \Pi(P, P^*) = f_e \]
\[ \Pi^*(P, P^*) = f^*_e \]

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

**Assumption 1:**

\[
\lim_{P \to -\infty} \Pi(P, P^*) < \lim_{P \to -\infty} \Pi^*(P, P^*)
\]
\[
\lim_{P^* \to -\infty} \Pi(P, P^*) > \lim_{P^* \to -\infty} \Pi^*(P, P^*)
\]

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 2.** Under Assumption 1, there exists a unique pair $(P, P^*)$ that solves the system of equations (24) and (25).

Since $\Pi(P, P^*)$ is strictly decreasing in $P^*$, for any given $P$ the value of $P^*$ that solves equation (24) is unique and implicitly defines a function $P^* = P^*^H(P)$. Similarly, since $\Pi(P, P^*)$ 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: $\frac{dP^*}{dP} \big|_H = -\frac{\partial \Pi(P, P^*)/\partial P}{\partial \Pi(P, P^*)/\partial P^*} < 0$. Analogously, equation (25) defines $P^* = P^*^F(P)$ and $P = P^F(P^*)$ with slope $\frac{dP^*}{dP} \big|_F = -\frac{\partial \Pi^*(P, P^*)/\partial P}{\partial \Pi^*(P, P^*)/\partial P^*} < 0$. 

43
The existence proof is represented in Figure A1. Assumption 1 implies that $f_e = \lim_{P \to \infty} \Pi^e (P, P^e (P)) < \lim_{P \to \infty} \Pi^* (P, P^* (P))$. Since $\Pi^* (P, P^*)$ is decreasing in $P^*$, this inequality also implies that

$$\lim_{P \to \infty} P^e (P) < \lim_{P \to \infty} P^* (P).$$

(26)

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

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

(27)

Since both $P^e (P)$ and $P^e^* (P)$ are decreasing, (26) and (27) 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: $\left| \frac{dP^*}{dP} \right|_H > \left| \frac{dP^*}{dP} \right|_F$. These derivatives are given by the following expressions:

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

where

$$A = J \frac{\alpha}{\alpha^*} \left( \frac{E}{P} \right)^{\frac{\alpha}{\alpha^*}} P^{-1} \left[ \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) v (\varphi, \xi) d\xi d\varphi + \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) \frac{\varphi}{\varphi (P, P^*)} d\xi d\varphi \right]$$

$$B = \frac{1}{\alpha} \left( \frac{\alpha - 1}{\alpha} \right)^{\alpha - 1} \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) v (\varphi, \xi) d\xi d\varphi$$

$$+ J \frac{\alpha}{\alpha^*} W^{\frac{\alpha - \alpha^*}{\alpha^*}} \left[ \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) v (\varphi, \xi) d\xi d\varphi + \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) \frac{\varphi}{\varphi (P, P^*)} d\xi d\varphi \right]$$

$$C = J \frac{\alpha}{\alpha^*} \left( \frac{E^*}{P^*} \right)^{\frac{\alpha}{\alpha^*}} P^{-1} \left[ \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) v^* (\varphi, \xi) d\xi d\varphi + \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) \frac{\varphi}{\varphi (P, P^*)} d\xi d\varphi \right]$$

$$D = \frac{1}{\alpha} \left( \frac{\alpha - 1}{\alpha} \right)^{\alpha - 1} \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) v^*(\varphi, \xi) d\xi d\varphi$$

$$+ J \frac{\alpha}{\alpha^*} W^{\frac{\alpha - \alpha^*}{\alpha^*}} \left[ \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) v^*(\varphi, \xi) d\xi d\varphi + \frac{\tau}{\xi_v (\varphi, P, P^*)} \int_0^{\tau_v (\varphi, P, P^*)} \eta (\varphi, \xi) \frac{\varphi}{\varphi (P, P^*)} d\xi d\varphi \right]$$

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: Formal characterization of the constrained equilibrium

The distinctive feature of the constrained equilibrium is the appearance of firms, in regions III and IV, that face a binding export quality constraint.

The curve $\xi_u(\varphi)$ is the solution to $\Delta_u \Pi(\varphi, \xi_u(\varphi)) = 0$. Along this curve, firms’ unconstrained choice of quality is monotonically decreasing in $\varphi$ (see equation for $\lambda_u$ in section 2.2). Thus, at some threshold productivity value ($\varphi_{\lambda}$), this choice is exactly $\lambda$. From equations (13) and (14), we can easily verify that both $\lambda_u$ and $\Delta_u \Pi$ are increasing in $\xi$ – conditional on $\varphi$. Hence, $\lambda_u > \lambda$ and $\Delta_u \Pi > 0$ for firms in region V.a. Since the export constraint does not bind for those firms, their export choice is determined by the sign of on $\Delta_u \Pi$. Thus, they prefer to export.

Equating (13) to $\lambda$, we obtain the expression for iso-quality curve $\xi_{\lambda}(\varphi)$ to the right of $\varphi_{\lambda}$:45

$$\xi_{\lambda}(\varphi) = \lambda^{2} \frac{\alpha}{1 - \beta} \left( \frac{\sigma - 1}{\sigma} \right)^{-\frac{1}{\sigma}} \left( \frac{\varphi}{c} \right)^{-\frac{1}{\sigma}} \left( \frac{\sigma - 1}{\sigma} \right)^{-\frac{1}{\sigma}} W^{-1}. \quad (28)$$

This curve is also monotonically decreasing in $\varphi$. Comparing (28) with (16), we can check that the two curves intersect at $\varphi_{\lambda}$ and $\forall \varphi > \varphi_{\lambda}: \xi_{\lambda}(\varphi) > \xi_u(\varphi)$. Firms located above $\xi_{\lambda}(\varphi)$ spontaneously satisfy the export quality requirement, so their export decisions are also governed by the sign of $\Delta_u \Pi$. Thus, firms in region V.b, where $\xi \geq \xi_{\lambda}(\varphi) > \xi_u(\varphi)$, also prefer to export.

Firms located between $\xi_u(\varphi)$ and $\xi_{\lambda}(\varphi)$ are forced to upgrade quality if they wish to export. Those that do it just attain quality $\lambda$. In section 2.3 we provide the expressions for marginal costs, price, revenue and profits for those constrained firms. We also define $\Delta \Pi_c \equiv \Pi_c(\varphi, \xi) - \Pi_d(\varphi, \xi)$, which is given by:

$$\Delta \Pi_c(\varphi, \xi) \equiv \frac{1}{\sigma} \left( \frac{\sigma - 1}{\sigma} \right)^{\sigma - 1} \lambda^{\alpha - \frac{\alpha'}{\alpha}} W - \frac{f}{\xi} \lambda^{\alpha} - f_x - J \left( \frac{\varphi}{c} \right)^{\sigma} \left( \frac{\varphi}{f} \right)^{\frac{\alpha - \alpha'}{\sigma}} \left( \frac{E}{P} \right)^{\frac{\alpha'}{\sigma}}. \quad \text{The export cut-off function } \xi_{\lambda}(\varphi) \text{ is implicitly defined by } \Delta \Pi_c(\varphi, \xi_{\lambda}(\varphi)) = 0. \quad \text{Since } \Delta \Pi_c(\varphi, \xi) \text{ is continuous and strictly increasing in its two arguments, by application of the implicit function theorem, } \xi_{\lambda}(\varphi) \text{ is continuous and decreasing in } \varphi. \quad \text{Its location is shown in the following lemma:}

Lemma A.1. The export cut-off function $\xi_{\lambda}(\varphi)$ is flanked by $\xi_u(\varphi)$ and $\xi_{\lambda}(\varphi)$:

$$\forall \varphi > \varphi_{\lambda}: \xi_{\lambda}(\varphi) > \xi_{\lambda}(\varphi) > \xi_u(\varphi)$$

Proof. As constrained firms are forced to deviate from their optimal (unconstrained) choice of quality, $\Pi_c(\varphi, \xi) \leq \Pi_u(\varphi, \xi)$. This implies that $\Delta \Pi_c(\varphi, \xi_u(\varphi)) < \Delta \Pi_u(\varphi, \xi_u(\varphi)) = 0$. Thus, firms

---

44 The expression for $\varphi_{\lambda}$ can be obtained using equations (13) and (16) to solve for $\varphi$ in $\lambda_u(\varphi, \xi_u(\varphi)) = \lambda$.

45 The iso-quality curve is discontinuous at $\varphi_{\lambda}$. Its expression to the left of $\varphi_{\lambda}$ is identical but for $\frac{\xi}{\sigma}$ replacing $W$.  

46
located on \(ξ_u(ϕ)\) strictly prefer not to export. On the other hand, since the export restriction is (just) not binding for firms located on \(ξ_u(ϕ)\), \(ΔΠ_e(ϕ, ξ_u(ϕ)) = ΔΠ_u(ϕ, ξ_u(ϕ)) > 0\). Therefore, firms located along \(ξ_u(ϕ)\) strictly prefer to export.

These two results, the continuity of \(ΔΠ_e(ϕ, ξ)\), and the fact that this function is strictly increasing in \(ξ\) then imply that \(∀ϕ > ϕ_u: ξ_u(ϕ) < ξ_x(ϕ) < ξ_u(ϕ)\). QED

**Appendix 3: Proof of Proposition 1**

Consider an exporter and a domestic firms located on the same iso-revenue curve. The exporter productivity and caliber draws are \((ϕ_x, ξ_x)\) while her optimal choice of quality is \(λ_x(ϕ_x, ξ_x)\). In the case this exporter is unconstrained, \(λ_x(ϕ_x, ξ_x) = λ_u(ϕ_x, ξ_x)\). In the case she is constrained, \(λ_x(ϕ_x, ξ_x) = λ_λ\). Similarly, the domestic firm on the same curve draws \((ϕ_d, ξ_d)\) and chooses quality \(λ_d(ϕ_d, ξ_d)\). As they are on the same curve, \(r_x(λ_x(ϕ_x, ξ_x)) = r_d(λ_d(ϕ_d, ξ_d))\).

Since the exporter has chosen to export, it has to be true that

\[
π_x(λ_x(ϕ_x, ξ_x)) ≥ π_d(λ_d(ϕ_x, ξ_x)),
\]

where \(λ_d(ϕ_x, ξ_x)\) indicates the quality level that the exporter would have chosen had she decided not to export. The optimality of \(λ_d(ϕ_x, ξ_x)\), conditional on not exporting, implies that any other quality level, in particular \(λ_x(ϕ_x, ξ_x)\), would have yielded lower profits. Therefore:

\[
π_d(λ_d(ϕ_x, ξ_x)) ≥ π_d(λ_x(ϕ_x, ξ_x)).
\]

Combining inequalities (29) and (30), and using \(π = \frac{1}{σ}r\), we obtain:

\[
\frac{1}{σ}(r_x(λ_x(ϕ_x, ξ_x)) − r_d(λ_x(ϕ_x, ξ_x))) − f_x ≥ 0.
\]

Since \(r_x(λ_x(ϕ_x, ξ_x)) = r_d(λ_d(ϕ_d, ξ_d))\) on the same iso-revenue curve, this expression can be written as

\[
- \frac{1}{σ}(r_d(λ_x(ϕ_x, ξ_x)) − r_d(λ_d(ϕ_d, ξ_d))) − f_x ≥ 0.
\]

Using \(r_d = p^{1−σ}λ^{α−1}\frac{E}{P}\) and the pricing equation, we obtain

\[
- \frac{1}{σ}\left(\frac{σ}{σ - 1}\right)\frac{1−σ}{E}\left[λ_x(ϕ, ξ_x)^α − (λ_d(ϕ_d, ξ_d))^{α−α'}\right] − f_x ≥ 0.
\]

Following analogous revealed preference argument for the case of a non-exporter, we obtain:

\[
\frac{1}{σ}\left(\frac{σ}{σ - 1}\right)\frac{1−σ}{W}\left[λ_d(ϕ_d, ξ_d)^α − (λ_x(ϕ, ξ_x))^{α−α'}\right] − f_x < 0
\]

46
Finally, multiplying (32) by \(-1\) and adding it to (31), we obtain:

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

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 4: Factor input requirements of quality production

Production requires the use of two primary factors, labor and capital. There are \(H_L\) types of labor, indexed by \(h = 1, \ldots, H\), which earn market-determined wages \(w^L_h\). There are also \(H_K\) types of capital, indexed by \(h = 1, \ldots, H_K\), and \(V\) vintages of each type of capital, indexed by \(v = 0, \ldots, V - 1\). 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 \(w^K_h\). The price of a unit of capital of type \(h\) and vintage \(v\) is \(p^v_h\) and equals the discounted future sum of rental rates: \(p^v_h = \sum_{t=0}^{V} \frac{w^K_h}{\rho^t}\), 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 \(K_h = \sum_{v=0}^{V-1} K^v_h\) 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 \(w^L = \frac{\sum_h w^L_h L_h}{L}\) and the average rental is \(w^K = \frac{\sum_h w^K_h K_h}{K}\). 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 \(\lambda\), a firm needs to pay average wage \(w^L = w^L \lambda^b_L\) and average rental rate \(w^K = w^K \lambda^b_K\), \(b_L > 0, b_K > 0\), where \(w^L\) and \(w^K\) are the least expensive types of labor and capital, respectively. This requirement applies to factor inputs associated both with fixed and with variable costs. Thus, producing higher quality requires hiring more skilled and higher-paid workers and more expensive types of capital.

The quantity of output only depends on the quantity of inputs used in production, not on their type. Output is produced using a constant returns to scale Cobb-Douglas production function: \(Y = \varphi L^{\alpha_L} K^{\alpha_K}\), where \(\alpha_L + \alpha_K = 1\). Combining this production function with the requirements of input quality described above yields the unit cost function postulated in equation (3):

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

where \(A = \frac{1}{\alpha_L^{\alpha_L} \alpha_K^{\alpha_K}}\), \(c = A \left( \frac{w^L}{\varphi} \right)^{\alpha_L} \left( \frac{w^K}{\varphi} \right)^{\alpha_K}\), and \(\beta = \alpha_L b_L + \alpha_K b_K\).
Analogously, we assume that the fixed cost part of quality production requires labor and capital combined in a Cobb-Douglas production function with the same exponents: $\lambda = [\xi L^{\alpha_L} K^{\alpha_K}]^{1/\kappa}$. These costs can be thought of as expenses related to the implementation of quality control systems, worker training, or product development. 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 $\lambda$, are as defined in equation (4):

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

where $f = A (w^L)^{\alpha_L} (w^K)^{\alpha_K}$ and $\alpha = \kappa + \alpha_L b_L + \alpha_K b_K$. These assumptions, together with the results of Proposition 1, yield Corollaries 2 and 3.

**Proof of Corollary 2.** The assumption that average wages are monotonically increasing in quality, combined with Proposition 1, implies that

$$\forall r, w^L(\lambda(x, \varphi_x, \xi_x))|_{r_x = r} > w^L(\lambda_d(\varphi_d, \xi_d))|_{r_d = r}. \quad QED$$

Firm-level statistics do not report firms’ capital as a simple count of “machine units”. Instead, capital in the plant is aggregated using their relative prices. Thus, rather than $K$ we observe $VK = \sum_{h=1}^{H} \sum_{v=1}^{V} p_{hv} K_{hv}$.

**Proof of Corollary 3.** To demonstrate Corollary 3, we first substitute the pricing equation for capital goods into the definition of $VK$ to obtain

$$VK = \sum_{h=1}^{H} \sum_{v=1}^{V} \sum_{t=0}^{v} \frac{w^t_{hv} K_{hv}}{\rho_t}. \quad (33)$$

We assume that relative prices of different types of capital do not change over time: $\forall h, \ w^t_{hv} = v_t w^K_h$. We also assume that, although firms’ composition of capital across types of capital goods differs, it does not differ across vintages within types, i.e., $\forall h, K_{hv} = a_v K_h, \ K_h = \sum_{v=1}^{V} K_{hv}$. Thus we can write equation (33) as

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

46Bernard et al. (2007) also assume that input shares associated with fixed and variable costs are equal.

47In 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.

48Note that $\alpha = \kappa + \beta$. The assumption that $\alpha > (1 - \beta)(\sigma - 1)$ then implies that $\kappa > \sigma(1 - \beta) - 1$. 48
where $\gamma = \sum_{v=1}^{V} \sum_{t=0}^{V_v} \frac{\nu_{vt}}{p_v}$. Variable costs are Cobb-Douglas, so cost shares are constant. Thus, 
\[
\frac{w^K K}{\alpha_K} = \frac{w^K L}{\alpha_L},
\]
which implies that 
\[
\frac{VK}{L} = \gamma \frac{w^K K}{\alpha_K} = \gamma \frac{w^K K}{\alpha_L} = \gamma \frac{w^L L}{\alpha_L} \lambda^{b_L}. \tag{34}
\]
Since fixed costs are also Cobb-Douglas with identical coefficients, equation (34) applies to those costs as well. Thus, it also characterizes the capital intensity of the plant, i.e. including capital and labor associated with both fixed and variable costs.

It is easy to check that 
\[
\frac{d\left(\frac{VK}{L}\right)}{d\lambda} > 0 \text{ if } b_L > 0.
\]
This result, combined with Proposition 1, immediately implies corollary 3.\footnote{Note that $b_L > 0$ implies that $\beta > 0$. Hence, while Proposition 1 and Corollary 1 hold even if quality does not drive up marginal costs, this assumption is needed for quality to imply higher wages and capital intensity.} 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 have missing data on our size proxies (revenue and employment) and key dependent variables (capital intensity and average wage rates). Also, because we control for size using industry-specific polynomials of order 3 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; overall there are about 5,456 distinct 5-digit codes. 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. Price is defined as the “ex-factory value” of goods manufactured divided by the quantity manufactured. The “ex-factory value” excludes all distribution and transportation costs associated with the sale of the manufactured products. In order to ensure comparability of price, we drop all observations where the product is measured in unspecified units (unit code 999). 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. 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. For various subsample and interaction tests, we merged in data on 6 different product level
characteristics. To do this, we first constructed a manual concordance between SITC (Rev 3) 4-digit codes and the 5-digit Indian product codes. The other steps involved in combining the data are described below.

- Rauch classification code: Rauch (1999) proposed a classification of SITC Rev 2 product codes into three categories – “homogenous”, “reference-priced” and “differentiated”. We used the concordance table available through the Center for International Data (CID) website \[^50\] to form a concordance between SITC (Rev 2) 4-digit codes and SITC (Rev 3) 4-digit code. In cases where there was multiple SITC (Rev 2) codes matched to a SITC (Rev 3) code, we chose the modal SITC (Rev 2) code as the match. We then combined the SITC (Rev 2) - SITC (Rev 3) concordance with our manual concordance between the SITC (Rev 3) 4-digit codes and the Indian product codes to merge in the Rauch SITC (Rev 2) classification scheme with the Indian data.

- Measure of external financial dependence: The Rajan-Zingales measure of dependence on external finance was available for the 2 digit SIC (1987) classification. We used the concordance from the CID website to form a concordance between the SIC 2-digit code and the SITC (Rev 3) 4-digit code. Again, the modal SIC 2 digit code was chosen as the unique match to the SITC (Rev 3) 4-digit code. We then used our manual concordance between the SITC (Rev 3) 4-digit codes and the Indian product codes to merge in the Rajan-Zingales measure with the Indian data.

- Measure of dependence on the government: Detailed Input-Output (I-O) tables for 1997 available at the Bureau of Economic Analysis website \[^51\] provide data based on a 5-digit IO classification code. For each IO code, we stored the amount of output consumed (for both intermediate and final use) by federal and state governments, as well as the total output. The BEA website provides a concordance of this code with the 10-digit HS classification code. We then combined this IO-HS concordance with a HS-SITC (Rev 3) 4-digit concordance from the CID website. We formed a measure of dependence on the government as the ratio of total output consumed by the government to the total output (summing across HS classifications) by each SITC (Rev 3) 4-digit code. We then used our manual concordance between the SITC (Rev 3) 4-digit codes and the Indian product codes to merge in the dependence on government measure with the Indian data. For a handful of itemcodes where the dependence measure was missing (because data for the corresponding 5-digit IO codes were missing), we imputed the fraction of output used by government for the corresponding 4-digit IO codes.

- Broda-Weinstein elasticity of substitution: These measures were available at the SITC (Rev 3) 4-digit

\[^50\] http://cid.econ.ucdavis.edu/data/sasstata/usxss.html
\[^51\] http://www.bea.gov/industry/io enchmark.htm
classification from Christian Broda’s website.\footnote{http://faculty.chicagogsb.edu/christian.broda/website/research/unrestricted/TradeElasticities/TradeElasticities.html} We merged this to Indian data using our manual concordance between the SITC (Rev 3) 4-digit codes and the Indian product codes.

- **Destination GDP per capita:** Data on Indian exports by SITC (Rev 2) 4-digit codes for 1997 was downloaded from the CID website. As described for the Rauch code, we formed a concordance between SITC (Rev 2) 4-digit and SITC (Rev 3) 4-digit using the concordance also available at the CID website. We then merged data on GDP per capita (in constant year 2000 $s) for 1997 from the World Bank’s World Development Indicators CD-ROM using the 3-digit country codes available in the trade and World Bank datasets. Next we formed export (CIF) value weighted GDP per capita and distance measures for each SITC (Rev 3) 4-digit code. This was then merged with the Indian data using our manual concordance between the SITC (Rev 3) 4-digit codes and the Indian product codes.

- **Destination distance:** We followed the same procedure as outlined for destination GDP per capita. We merged in bilateral distance date available from the CEPII website\footnote{http://www.cepii.fr/anglaisgraph/bdd/distances.htm} using the 3-digit country codes available in the trade and CEPII datasets.

**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). 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. Overall, we
found data on about 8,500 distinct 7-digit products in the 1997 CMF; while there is a total of about 13,000 distinct 7-digit product codes, data on many 7-digit codes are not collected in the CMF (Monahan, 1992). Price is defined as the product value of shipments to the total quantity. The quantity measure is not available for all product codes “they are not meaningful for some product lines” (Monahan, 1992). Product value of shipments is defined as net selling value, f.o.b. plant, of shipments, after discounts and allowances and exclusive of freight charges and excise taxes. 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. 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. Also, following the practice in the studies using census data, we drop all “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 adjustment for sampling probability is required. As in the case of the Indian data, for various subsample and interaction tests, we merged in data on 6 different product level characteristics. To do this, we first constructed a manual concordance between SITC Rev 2 (4-digit) and the 5-digit SIC (1987) code (obtained from http://www.census.gov/epcd/oei/view/appndxtd.txt). The other steps involved in combining the data are described below (refer discussion under Indian data above for more details including web addresses of data sources).

- Rauch classification code: Rauch (1999) proposed a classification of SITC Rev 2 product codes into three categories – “homogenous”, “reference-priced” and “differentiated”. The used our manual concordance between the SITC (Rev 2) 4-digit codes and the SIC 5-digit codes to merge in the Rauch SITC (Rev 2) classification scheme with the Indian data (defining the SIC 5 digit code as the first 5 digits of the 7-digit product code).

- Measure of external financial dependence: The Rajan-Zingales measure of dependence on external finance was available for the 2 digit SIC (1987) classification. This was directly merged into the US
data by using the first two digits of the 7-digit product code.

- Measure of dependence on the government: Detailed Input-Output (I-O) tables for 1997 available at the Bureau of Economic Analysis website provide data based on a 5-digit IO classification code. For each IO code, we stored the amount of output consumed (for both intermediate and final use) by federal and state governments, as well as the total output. The BEA website provides a concordance of this code with the 10-digit HS classification code. We then combined this IO-HS concordance with a HS-SITC (Rev 2) 4-digit concordance from the CID website. We formed a measure of dependence on the government as the ratio of total output consumed by the government to the total output (summing across HS classifications) by each SITC (Rev 2) 4-digit code. We then used our manual concordance between the SITC (Rev 2) 4-digit codes and the US SIC (1987) 5-digit codes to merge in the dependence on government measure with the US data. For a handful of SIC 5-digit codes where the dependence measure was missing (because data for the corresponding 5-digit IO codes were missing), we imputed the fraction of output used by government for the corresponding 4-digit IO codes.

- Broda-Weinstein elasticity of substitution: These measures were available at the SITC (Rev 3) 4-digit classification from Christian Broda’s website. We used the concordance table available through the Center for International Data (CID) website to form a concordance between SITC (Rev 2) 4-digit codes and SITC (Rev 3) 4-digit code. In cases where there was multiple SITC (Rev 3) codes matched to a SITC Rev 2 code, we chose the modal SITC (Rev 3) code as the match. We then combined the SITC (Rev 3) - SITC (Rev 2) concordance with our manual concordance between the SITC (Rev 2) 4-digit codes and the US SIC (1987) 5-digit codes to merge Broda-Weinstein measures with the US data.

- Destination GDP per capita: Data on US exports by SITC (Rev 2) 4 digit codes for 1997 was downloaded from the CID website. We then merged data on GDP per capita (in constant year 2000 $s) for 1997 from the World Bank’s World Development Indicators CD-ROM using the 3 digit country codes available in the trade and World Bank datasets. Next we formed export (CIF) value weighted GDP per capita and distance measures for each SITC (Rev 2) 4 digit code. This was then merged with the US data using our manual concordance between the SITC (Rev 2) 4-digit codes and the US SIC (1987) 5-digit codes.

- Destination distance: We followed the same procedure as outlined for destination GDP per capita. We merged in bilateral distance date available from the CEPII website using the 3 digit country codes.
available in the trade and CEPII datasets.

**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. As for the other datasets, for all the baseline analysis, we retain only industries classified as “differentiated sectors”. To undertake this classification, we merged the Rauch SITC (Rev 2) 4-digit data with a concordance between 3-digit ISIC code and SITC (Rev 2) code.\(^{54}\) We then defined as “differentiated” any ISIC 3 digit code where more than half of SITC (Rev 2) 4-digit codes that match to the ISIC code are categorized as “differentiated” per the Rauch classification.

\(^{54}\)From [http://www.macalester.edu/research/economics/page/haveman/Trade.Resources/Concordances/FromSITC/sitc2.isic2.txt](http://www.macalester.edu/research/economics/page/haveman/Trade.Resources/Concordances/FromSITC/sitc2.isic2.txt)
Figure 1: Percentage of establishments that are exporters, by size percentile

The Y axis is the fraction of firms that are exporters. Size percentiles are adjusted for industry mean size.
Figure 2: Unconstrained export quality equilibrium

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

$\xi_u(\varphi)$: export cut-off in the unconstrained regime
**Figure 3:** Fraction of exporters as a function of revenue in the unconstrained export quality equilibrium.
Region I: Non-survivors

Region III: Domestic firms

Region IV: Constrained exporters

Region V.a: Unconstrained exporters

Region V.b: Unconstrained exporters

Figure 4: Constrained export quality equilibrium

\( \xi(\varphi) \): cut-off between survivors and non-survivors

\( \xi_u(\varphi) \): export cut-off in the unconstrained regime

\( \xi_\lambda(\varphi) \): iso-quality curve for threshold quality \( \lambda \)

\( \xi_x(\varphi) \): export cut-off in the constrained regime
Figure 5: Iso-revenue and iso-quality curves in the constrained export quality equilibrium

- $\xi(\phi)$: cut-off between survivors and non-survivors
- $\xi_u(\phi)$: export cut-off in the unconstrained regime
- $\xi_\lambda(\phi)$: isoquality curve for threshold quality $\lambda$
- $\xi_x(\phi)$: export cut-off in the constrained regime
Figure A.1: Existence of equilibrium
Table 1: Summary statistics

The reported means and standard deviations are adjusted for sampling weights. The data cover the differentiated sectors (defined per the Rauch 1999 classification) for India, USA, Chile and Colombia. The nominal variables (wages and capital) for US in thousands of dollars, for India are measured in rupees, 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.

<table>
<thead>
<tr>
<th>Description</th>
<th>ALL ESTABLISHMENTS</th>
<th>NON-EXPORTERS</th>
<th>EXPORTERS</th>
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<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>SD</td>
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<td>Log per unit price</td>
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<td>7.40</td>
<td>2.97</td>
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<td>1.75</td>
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<td>ISO 9000 dummy</td>
<td>15,937</td>
<td>0.05</td>
<td>0.21</td>
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</table>

Panel 1: India (1998)

<table>
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<th>EXPORTERS</th>
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<tbody>
<tr>
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<td>N</td>
<td>Mean</td>
<td>SD</td>
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<td>Log(average wage rate)</td>
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<td>Capital intensity [Log (capital/labor)]</td>
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Panel 2: USA (1997)

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<td>SD</td>
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<tr>
<td>Log(per unit price)</td>
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<td>Capital intensity [Log (capital/labor)]</td>
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Panel 3: Chile (1991-96)

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</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>SD</td>
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<tr>
<td>Log(per unit price)</td>
<td>39,990</td>
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<td>Capital intensity [Log (capital/labor)]</td>
<td>39,990</td>
<td>5.44</td>
<td>1.42</td>
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Table 2: Log price: Baseline results

The dependent variable is log per unit price. The data cover the differentiated sectors (defined per the Rauch 1999 classification) for India and USA. 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. All regressions using Indian data are adjusted for sampling weights; the number of observations, plants and products do not adjust for sampling weights. Sampling weights are irrelevant for the US, as the 1997 Census of Manufacturing covers all establishments. Standard errors are clustered at plant level; * significant at 10%; ** significant at 5%; *** significant at 1%.

<table>
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<td>(3)</td>
<td>(4)</td>
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<tr>
<td>Dependent variable: Log price (standardized)</td>
<td>0.112**</td>
<td>0.130**</td>
<td>0.177***</td>
<td>0.169**</td>
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<tr>
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<td>[0.050]</td>
<td>[0.060]</td>
<td>[0.063]</td>
<td>[0.073]</td>
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<tr>
<td>Dependent variable: Log price</td>
<td>0.0534</td>
<td>0.0502</td>
<td>0.0872**</td>
<td>0.113***</td>
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<tr>
<td></td>
<td>[0.035]</td>
<td>[0.041]</td>
<td>[0.040]</td>
<td>[0.042]</td>
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<tr>
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<td>6,494</td>
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<td></td>
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<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Dependent variable: Log price (standardized)</td>
<td>0.082***</td>
<td>0.131***</td>
<td>0.136***</td>
<td>0.135***</td>
</tr>
<tr>
<td></td>
<td>[0.018]</td>
<td>[0.019]</td>
<td>[0.019]</td>
<td>[0.020]</td>
</tr>
<tr>
<td>Dependent variable: Log price</td>
<td>0.030**</td>
<td>0.062***</td>
<td>0.067***</td>
<td>0.066***</td>
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<tr>
<td></td>
<td>[0.012]</td>
<td>[0.013]</td>
<td>[0.013]</td>
<td>[0.014]</td>
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<tr>
<td>Number of observations</td>
<td>49,203</td>
<td>49,203</td>
<td>49,203</td>
<td>49,203</td>
</tr>
</tbody>
</table>

| 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: 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. The data covers entire manufacturing sector for the US, and the differentiated sectors only (defined per the Rauch 1999 classification) for India, Chile and Colombia. 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. All regressions are adjusted for sampling weights. Industry is defined using the 4-digit NIC code for India. Standard errors are clustered at the plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
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<tbody>
<tr>
<td>Coefficient on exporter dummy</td>
<td>0.142***</td>
<td>0.0771***</td>
<td>0.0751***</td>
<td>0.0854***</td>
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<td>[0.009]</td>
<td>[0.009]</td>
<td>[0.009]</td>
<td>[0.009]</td>
</tr>
<tr>
<td>Number observations/plants</td>
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<td>15,937</td>
<td>15,937</td>
<td>15,937</td>
</tr>
<tr>
<td>Industry fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Industry specific size polynomial (order 2)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Industry specific size polynomial (order 3)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<td>Industry-size decile fixed effects</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 4: Wage and capital 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. The data covers the differentiated sectors (defined per the Rauch 1999 classification) for India, USA, Chile and Colombia. All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. Columns 1, 3, 5 and 7 include industry fixed effects and an industry-year-specific polynomial of order three in size, and columns 2 and 4 include industry-year-size decile dummies. Size is defined as total sales of the establishment. All regressions using Indian data are adjusted for sampling weights. Industry is defined using the 4-digit SIC (1987) code for USA, the 4-digit NIC code for India, 4-digit ISIC code for Chile and Colombia. Standard errors are clustered at the plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
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<tr>
<th>Dependent variable</th>
<th>India</th>
<th>USA</th>
<th>Chile</th>
<th>Colombia</th>
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</thead>
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<tr>
<td></td>
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<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Standardized log average wage</td>
<td>0.138***</td>
<td>0.136***</td>
<td>0.082***</td>
<td>0.097***</td>
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<tr>
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<td>[0.032]</td>
<td>[0.035]</td>
<td>[0.014]</td>
<td>[0.014]</td>
</tr>
<tr>
<td>Log average wage</td>
<td>0.0743***</td>
<td>0.0748***</td>
<td>0.032***</td>
<td>0.039***</td>
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<tr>
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<td>[0.017]</td>
<td>[0.018]</td>
<td>[0.006]</td>
<td>[0.006]</td>
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<tr>
<td>Standardized capital intensity</td>
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<tr>
<td></td>
<td>[0.035]</td>
<td>[0.037]</td>
<td>[0.015]</td>
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<tr>
<td>Capital intensity</td>
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<td>-0.175***</td>
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<tr>
<td>Number of observations/plants</td>
<td>11,226</td>
<td>11,226</td>
<td>123,079</td>
<td>123,079</td>
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<tr>
<td>Industry-year fixed effects</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Industry-year specific revenue polynomial (order 3)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Industry-year-size decile fixed effects</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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</table>
Table 5: Robustness checks: conditioning on employment

The data covers the differentiated sectors (defined per the Rauch 1999 classification) for India, USA, Chile and Colombia. All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. In row 1 (for standardized price), columns 1 and 3 include product code fixed effects and a product specific polynomial of order three in size, and columns 2 and 4 include product-size decile dummies. For the other rows (non-price variables), columns 1, 3, 5 and 7 include industry fixed effects and an industry-year specific polynomial of order three in size, and columns 2 and 4 include industry-year-size decile dummies. Size is defined as domestic sales of the establishment. All regressions using Indian data are adjusted for sampling weights. Industry is defined using the 4-digit SIC (1987) code for USA, the 4-digit NIC code for India, 4-digit ISIC code for Chile and Colombia. Standard errors are clustered at plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th>India (1)</th>
<th>USA (2)</th>
<th>Chile (3)</th>
<th>Colombia (4)</th>
</tr>
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<td>Standardized log price</td>
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<td>0.170**</td>
<td>0.139***</td>
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<td>[0.0694]</td>
<td>[0.019]</td>
<td>[0.020]</td>
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<tr>
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<td>0.106***</td>
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<tr>
<td></td>
<td>[0.009]</td>
<td>[0.009]</td>
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<tr>
<td>Standardized log average wage</td>
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<td>0.223***</td>
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<td>Standardized capital intensity</td>
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<td>Industry-year fixed effects</td>
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<td>Yes</td>
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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Industry-year-size decile fixed effects</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>


### Table 6: Log price: Results for differentiated and homogenous goods sectors

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. All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. Products where the product code matches (as per our concordance) an SITC code that is categorized as differentiated as per the Rauch (1999) are classified as “differentiated “. All other products are classified as “homogenous”. 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 plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th>India (1997-98)</th>
<th></th>
<th></th>
<th>USA (1997)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Differentiated</td>
<td>Homogenous</td>
<td>Differentiated</td>
<td>Homogenous</td>
<td>Differentiated</td>
<td>Homogenous</td>
</tr>
<tr>
<td></td>
<td>products</td>
<td>products</td>
<td>products</td>
<td>products</td>
<td>products</td>
<td>products</td>
</tr>
<tr>
<td>Export dummy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.177***</td>
<td>0.169**</td>
<td>-0.0305</td>
<td>-0.0158</td>
<td>0.136***</td>
<td>0.135***</td>
</tr>
<tr>
<td></td>
<td>[0.063]</td>
<td>[0.073]</td>
<td>[0.0361]</td>
<td>[0.0549]</td>
<td>[0.019]</td>
<td>[0.020]</td>
</tr>
<tr>
<td>Number of observations</td>
<td>6,494</td>
<td>6,494</td>
<td>18,541</td>
<td>18,541</td>
<td>49,203</td>
<td>49,203</td>
</tr>
<tr>
<td>Product fixed effects</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Product specific revenue polynomial (order 3)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Product-size decile fixed effects</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 7: Log price: 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. The easlticity dummy . “Destination GDP per capita” is the export value weighted average GDP per capita of the destinations to which the product is exported in US $ million per person. “Destination distance” is the export value weighted average distance to the destinations to which the product is exported in million kilometers. 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 plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th>India (1997-98)</th>
<th>USA (1997)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>Panel 1: Interaction with elasticity of substitution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Export dummy</td>
<td>0.251***</td>
<td>0.296**</td>
</tr>
<tr>
<td></td>
<td>[0.0788]</td>
<td>[0.120]</td>
</tr>
<tr>
<td>Export dummy * High elasticity of substitution dummy</td>
<td>-0.206</td>
<td>-0.384**</td>
</tr>
<tr>
<td></td>
<td>[0.136]</td>
<td>[0.192]</td>
</tr>
<tr>
<td>Number of observations</td>
<td>6,494</td>
<td>6,494</td>
</tr>
</tbody>
</table>

**Panel 2: Interaction with destination per capita GDP**

|                              |                 |            |             |           |
| Export dummy                 | 0.277***        | 0.263***   | 0.113***    | 0.111***  |
|                             | [0.0678]        | [0.100]    | [0.019]     | [0.020]   |
| Export dummy X Standardized destination GDP per capita | 0.0248         | 0.0997     | 0.086***    | 0.087***  |
|                             | [0.0604]        | [0.0898]   | [0.021]     | [0.022]   |
| Number of observations       | 4,901           | 4,901      | 49,203      | 49,203    |

**Panel 3: Interaction with destination distance**

|                              |                 |            |             |           |
| Export dummy                 | 0.278***        | 0.278***   | 0.147***    | 0.143***  |
|                             | [0.0689]        | [0.102]    | [0.019]     | [0.021]   |
| Export dummy X Standardized destination distance | 0.0284         | 0.115      | 0.065***    | 0.048**   |
|                             | [0.0731]        | [0.111]    | [0.019]     | 0.021     |
| Number of observations       | 4,901           | 4,901      | 49,203      | 49,203    |

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 8: Robustness checks: conditioning on domestic sales

The data covers the differentiated sectors (defined per the Rauch 1999 classification) for India, USA, Chile and Colombia. All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. In row 1 (for standardized price), columns 1 and 3 include product code fixed effects and a product specific polynomial of order three in size, and columns 2 and 4 include product-size decile dummies. For the other rows (non-price variables), columns 1, 3, 5 and 7 include industry fixed effects and an industry-year specific polynomial of order three in size, and columns 2 and 4 include industry-year-size decile dummies. Size is defined as domestic sales of the establishment. All regressions using Indian data are adjusted for sampling weights. Industry is defined using the 4-digit SIC (1987) code for USA, the 4-digit NIC code for India, 4-digit ISIC code for Chile and Colombia. Standard errors are clustered at plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th>India</th>
<th>USA</th>
<th>Chile</th>
<th>Colombia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Standardized log price</td>
<td>0.202***</td>
<td>0.245***</td>
<td>0.138***</td>
<td>0.134***</td>
</tr>
<tr>
<td></td>
<td>[0.0589]</td>
<td>[0.0788]</td>
<td>[0.019]</td>
<td>[0.020]</td>
</tr>
<tr>
<td>ISO 9000 dummy</td>
<td>0.093***</td>
<td>0.101***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.008]</td>
<td>[0.009]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardized log average wage</td>
<td>0.349***</td>
<td>0.363***</td>
<td>0.133***</td>
<td>0.140***</td>
</tr>
<tr>
<td></td>
<td>[0.0318]</td>
<td>[0.0332]</td>
<td>[0.012]</td>
<td>[0.013]</td>
</tr>
<tr>
<td>Standardized capital intensity</td>
<td>0.323***</td>
<td>0.348***</td>
<td>-0.152***</td>
<td>-0.140***</td>
</tr>
<tr>
<td></td>
<td>[0.0348]</td>
<td>[0.0357]</td>
<td>[0.014]</td>
<td>[0.014]</td>
</tr>
</tbody>
</table>

Industry-year fixed effects: Yes/No
- Yes: Included, No: Not included

Industry-year specific domestic sales polynomial (order 3): YES/NO
- YES: Included, NO: Not included

Industry-year-size decile fixed effects: YES/NO
- YES: Included, NO: Not included
Table A.1: 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. 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 plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel 1: India (1997-98)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base case: Coefficient on exporter dummy from Panel 2 of Table 2</td>
<td>0.112**</td>
<td>0.130**</td>
<td>0.177***</td>
<td>0.169**</td>
</tr>
<tr>
<td></td>
<td>[0.050]</td>
<td>[0.060]</td>
<td>[0.063]</td>
<td>[0.073]</td>
</tr>
<tr>
<td>Coefficient on dummy for export share &gt;2%</td>
<td>0.151***</td>
<td>0.120*</td>
<td>0.161**</td>
<td>0.142*</td>
</tr>
<tr>
<td></td>
<td>[0.056]</td>
<td>[0.064]</td>
<td>[0.068]</td>
<td>[0.079]</td>
</tr>
<tr>
<td>Coefficient on exporter dummy, main product line only</td>
<td>0.171**</td>
<td>0.125</td>
<td>0.179**</td>
<td>0.126</td>
</tr>
<tr>
<td></td>
<td>[0.080]</td>
<td>[0.087]</td>
<td>[0.091]</td>
<td>[0.11]</td>
</tr>
<tr>
<td><strong>Panel 2: USA (1997)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base case: Coefficient on exporter dummy from Panel 1 of Table 2</td>
<td>0.082***</td>
<td>0.131***</td>
<td>0.136***</td>
<td>0.135***</td>
</tr>
<tr>
<td></td>
<td>[0.018]</td>
<td>[0.019]</td>
<td>[0.019]</td>
<td>[0.020]</td>
</tr>
<tr>
<td>Coefficient on dummy for export share &gt;2%</td>
<td>0.096***</td>
<td>0.133***</td>
<td>0.136***</td>
<td>0.130***</td>
</tr>
<tr>
<td></td>
<td>[0.021]</td>
<td>[0.021]</td>
<td>[0.022]</td>
<td>[0.024]</td>
</tr>
<tr>
<td>Coefficient on exporter dummy, main product line only</td>
<td>0.112***</td>
<td>0.122***</td>
<td>0.122***</td>
<td>0.121***</td>
</tr>
<tr>
<td></td>
<td>[0.020]</td>
<td>[0.021]</td>
<td>[0.021]</td>
<td>[0.025]</td>
</tr>
<tr>
<td>Product fixed effects</td>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Product specific size polynomial (order 2)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Product specific size polynomial (order 3)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Product-size decile fixed effects</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table A.2: Skill intensity measures
The skilled share of wage bill is the ratio of non-production worker wages to total wages. Skilled share of employment is the share of non-production workers in total employment. The dependent variable is log of the average wage rate. 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, 4-digit SIC for US, and 4-digit ISIC for Chile and Colombia. Standard errors are clustered at industry level; + significant at 15%; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th>India</th>
<th>USA</th>
<th>Chile</th>
<th>Colombia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skilled share of the wage bill</td>
<td>0.0166</td>
<td>-0.0147</td>
<td>0.244***</td>
<td>0.110***</td>
</tr>
<tr>
<td>(standardized)</td>
<td>[0.039]</td>
<td>[0.041]</td>
<td>[0.016]</td>
<td>[0.036]</td>
</tr>
<tr>
<td>Skilled share of employment</td>
<td>0.00961</td>
<td>-0.0149</td>
<td>0.192***</td>
<td>-0.0228</td>
</tr>
<tr>
<td>(standardized)</td>
<td>[0.0403]</td>
<td>[0.0464]</td>
<td>[0.016]</td>
<td>[0.0391]</td>
</tr>
<tr>
<td>Number of observations</td>
<td>11,226</td>
<td>11,226</td>
<td>123,079</td>
<td>17,053</td>
</tr>
<tr>
<td>Industry-year fixed effects</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry-year specific revenue</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>polynomial (order 2)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Industry-year specific revenue</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>polynomial (order 3)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry-year-size decile</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>fixed effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table A.3: Robustness checks: conditioning of firm sales and using single-establishment firms (USA 1997)

The data covers the differentiated products/industries (defined per the Rauch 1999 classification) of the manufacturing sector for the US. All reported figures are coefficients on an exporter dummy which equals one for firms where at least one establishment exports, and zero if none of the establishments of the firm exports. (In panel 2, establishment export status is the same as firm export status, because the sample includes only single establishment firms.) The first column reports results from regressions that include product (for log price) or 4-digit SIC industry code (for wage and capital intensity) fixed effects only. The second column includes product (industry) code fixed effects and a product (industry) specific polynomial of order two in size for dependent variable log price (for wage and capital intensity). The third column includes product (industry) code fixed effects and a product (industry) specific polynomial of order three in size for dependent variable log price (for wage and capital intensity). The fourth column includes product (industry)-size decile dummies for dependent variable log price (for wage and capital intensity). In all cases, size is defined as the log sales of the firm to which the establishment belongs. (In panel 2, firm size and establishment size are the same because the sample includes only single-establishment firms.) Standard errors are clustered at plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel 1: All variables (export dummy and size) defined at the firm level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log price (standardized)</td>
<td>-0.015</td>
<td>0.108***</td>
<td>0.121***</td>
<td>0.118***</td>
</tr>
<tr>
<td></td>
<td>[0.017]</td>
<td>[0.020]</td>
<td>[0.021]</td>
<td>[0.023]</td>
</tr>
<tr>
<td>Log average wage (standardized)</td>
<td>0.318***</td>
<td>0.054***</td>
<td>0.076***</td>
<td>0.072***</td>
</tr>
<tr>
<td></td>
<td>[0.022]</td>
<td>[0.018]</td>
<td>[0.016]</td>
<td>[0.017]</td>
</tr>
<tr>
<td>Capital intensity (standardized)</td>
<td>0.154***</td>
<td>-0.184***</td>
<td>-0.188***</td>
<td>-0.174***</td>
</tr>
<tr>
<td></td>
<td>[0.021]</td>
<td>[0.016]</td>
<td>[0.016]</td>
<td>[0.016]</td>
</tr>
<tr>
<td><strong>Panel 2: Sample restricted to single-establishment firms only</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log price (standardized)</td>
<td>0.113***</td>
<td>0.149***</td>
<td>0.151***</td>
<td>0.168***</td>
</tr>
<tr>
<td></td>
<td>[0.027]</td>
<td>[0.028]</td>
<td>[0.028]</td>
<td>[0.031]</td>
</tr>
<tr>
<td>Log average wage (standardized)</td>
<td>0.331***</td>
<td>0.068***</td>
<td>0.074***</td>
<td>0.090***</td>
</tr>
<tr>
<td></td>
<td>[0.016]</td>
<td>[0.016]</td>
<td>[0.017]</td>
<td>[0.017]</td>
</tr>
<tr>
<td>Capital intensity (standardized)</td>
<td>-0.128***</td>
<td>-0.266***</td>
<td>-0.262***</td>
<td>-0.252***</td>
</tr>
<tr>
<td></td>
<td>[0.023]</td>
<td>[0.019]</td>
<td>[0.019]</td>
<td>[0.019]</td>
</tr>
<tr>
<td>Product/industry fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Product/industry specific size polynomial (order 2)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Product/industry specific size polynomial (order 3)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Product/industry -size decile fixed effects</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table A.4: Robustness to using four-year means of variables

The data cover the differentiated sectors only (defined per the Rauch 1999 classification) for Chile and Colombia. 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, or have fewer than 3 observations in the four year period are excluded. Standard errors are clustered at plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Dependent variable: Standardized average wage</td>
<td>0.180***</td>
<td>0.219***</td>
</tr>
<tr>
<td></td>
<td>[0.0498]</td>
<td>[0.0531]</td>
</tr>
<tr>
<td>Dependent variable: Standardized capital intensity</td>
<td>0.311***</td>
<td>0.353***</td>
</tr>
<tr>
<td></td>
<td>[0.0618]</td>
<td>[0.0671]</td>
</tr>
<tr>
<td>Number of observations</td>
<td>1,978</td>
<td>1,978</td>
</tr>
<tr>
<td>Industry-year fixed effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry-year specific revenue polynomial (order 2)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry-year specific revenue polynomial (order 3)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Industry-year-size decile fixed effects</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Table A.5: Robustness to excluding sectors dependent on external finance and government purchases

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. 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 plant level; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
<th>Panel 1: Excluding products with above median dependence on Rajan-Zingales external finance measure</th>
<th>India</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable: Standardized price</td>
<td>0.217**</td>
<td>0.263**</td>
</tr>
<tr>
<td></td>
<td>[0.0874]</td>
<td>[0.121]</td>
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<tr>
<td>Panel 2: Excluding products with above median dependence on government purchases (based on US I-O table)</td>
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<tr>
<td>Dependent variable: Standardized price</td>
<td>0.390***</td>
<td>0.424***</td>
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<td></td>
<td>[0.0983]</td>
<td>[0.148]</td>
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<table>
<thead>
<tr>
<th>Product/industry fixed effects</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
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</thead>
<tbody>
<tr>
<td>Product/industry specific size polynomial (order 2)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Product/industry specific size polynomial (order 3)</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
<td>Product/industry-size decile fixed effects</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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</table>
Table A.6: Technology adoption dummies (India 1997-98)
All reported figures are coefficients on an exporter dummy defined equal to 1 for establishments that export >2% of the value of their output. The industry definition is 4-digit NIC for India. Standard errors are clustered at plant level; + significant at 15%; * significant at 10%; ** significant at 5%, *** significant at 1%.

<table>
<thead>
<tr>
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<th>(3)</th>
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<tbody>
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<td>0.221***</td>
<td>0.218***</td>
<td>0.223***</td>
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<td>[0.0155]</td>
<td>[0.0159]</td>
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<td>Robotics use dummy</td>
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<tr>
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<td>0.0428***</td>
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<td>[0.00609]</td>
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<td>0.117***</td>
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<td>[0.0101]</td>
<td>[0.0101]</td>
<td>[0.00998]</td>
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<td>Survey response on a floppy</td>
<td>0.121***</td>
<td>0.0786***</td>
<td>0.0776***</td>
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<td>[0.0107]</td>
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<td>[0.0108]</td>
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<td>Number of observations (plants)</td>
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<tr>
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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Industry specific size polynomial (order 2)</td>
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<td>Yes</td>
<td>No</td>
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<tr>
<td>Industry specific size polynomial (order 3)</td>
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<td>No</td>
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<tr>
<td>Industry-size decile fixed effects</td>
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<td>No</td>
<td>No</td>
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</table>