Product Quality, Firm Heterogeneity and International Trade*

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Abstract

I explore variation in price and export status in industries where I can estimate product quality and technical efficiency separately. The empirical results show that prices are increasing in quality and decreasing in efficiency and that selection into exporting is driven mainly by quality. Firms export because they generate more demand for their products, not because they can produce at lower cost. This result is consistent with a model that includes per unit transportation costs. In that case, changes in quality and efficiency have different impact on the firm's optimal strategy. On the one hand, firms with a cost advantage charge lower prices, are less likely to export and, when they do, sell a smaller fraction of their output in foreign markets. On the other hand, firms that can produce high quality products charge higher prices, are more likely to export and obtain a larger share of their revenue from foreign sales.

Keywords: Firm heterogeneity, microdata, quality, trade, unit value.

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1. Introduction

Recent empirical studies point to the importance of product quality differentiation in explaining features of international trade flows. Hallak and Sivadasan (2009) and Kugler and Verhoogen (2010) find that within narrowly defined product categories, exporters charge higher prices then non-exporting firms. Manova and Zhang (2009) show that exporting firms that charge higher prices earn greater revenue in each markets and export to more markets. Finally, Baldwin and Harrigan (2009) report that the average unit value of exported goods is positively related to foreign market distance. These patterns suggests product quality differentiation has important implication for export profitability and selection into exporting.

In this paper, I develop and estimate a model that separately identifies product quality and technical efficiency.[1] The empirical results show that firm-level prices are increasing in quality and decreasing in technical efficiency. However, while exporters produce higher quality products, they are *not* more technically efficient on average than firms that do not export.[2] This suggest that selection into exporting is driven mainly by product quality. Firms export because they generate more demand for their products, not because they can produce at lower cost. I show that this result is inconsistent with the standard iceberg trade costs assumption because, in that case, changes in quality and efficiency have similar impacts on export profitability and, as a result, selection. However, this is not the case in the presence of per unit transportation costs. In that case, the decomposition of productivity into quality and efficiency matters. While increases in efficiency and quality help the firm overcome advalorem tariff barriers in similar ways, a change in product quality provides an additional advantage to overcome transportation cost. This happens because per unit transport cost lead to a greater percentage change in price for low quality varieties. Therefore, an increase in product quality that leads to the same increase in (domestic) revenue than a given change in efficiency, is more likely to lead to entry in the foreign market. This result is related to the Alchian and Allen (1964) conjecture often described as "shipping the good apples out".

An important challenge I face is that direct information on product quality is generally unavailable. Many contemporaneous studies use average unit values, an estimate of price, to make inferences about the role of product quality in determining export patterns.[3] However, using price variation may be misleading because numerous factors other than quality can

[1]Technical efficiency refers to the firm's cost advantage. Conditional on quality, efficient firms will face lower production costs. As will be made clear later, in this paper, firm productivity is a mix of product quality and technical efficiency.

[2]Other works have found that exporters are not more productive than non-exporters (e.g. Rivers (2010) and Lu (2011))

[3]For instance Baldwin and Harrigan (2009), Hallak and Sivadasan (2009), Johnson (2010), Kugler and Verhoogen (2010), and Manova and Zhang (2009).

affect prices (e.g. technical efficiency). This makes it difficult to separately identify the impact of quality and efficiency on price and export status.[4] Instead, I use the theory as a guide to construct a plant-level measure of product quality from price and quantity information. I define product quality as the fraction of domestic demand unexplained by changes in price and aggregate conditions. Intuitively, firms that sell large quantities of physical output conditional on price are classified as high quality producers. Hummels and Klenow (2005), Hallak and Schott (2010), and Khandelwal (2010) use similar estimation procedures on bilateral trade flows to obtain country-level measures of product quality. The main difference with my work is that I use microdata to obtain producer-level measures of product quality and study within-industry variation in price and export status.

The empirical results show that, within an industry, prices are increasing in quality and decreasing in efficiency. Of course, because quality is a demand residual it could potentially capture other factors that increase demand but are unrelated to quality. As explained in Foster et al. (2008a), horizontal differentiation (e.g. firm specific history or location) can lead to variation in demand and higher prices. These factors will affect prices through variation in markups, but should not be related to production costs however. Therefore, to investigate the importance of this competing explanation, I estimate the effect or quality and efficiency on per unit production costs. As for prices, the model predicts that these costs should increase in quality and decrease in efficiency. The results supports that prediction and provide support for the quality interpretation of the demand residuals.[5]

Exporters in my sample charge prices on average 5 percent higher compared to non-exporters. The exporter price premium correctly suggests that exporters produce higher quality variety on average. However, it underestimated the actual exporter quality premium by one order of magnitude. This happens because prices are increasing in quality but decreasing in efficiency. Since prices reflect both of these characteristics, they can understate quality variation. I estimate that the quality of varieties sold by exporters is in fact more than 60 percent higher on average compared to varieties sold by non-exporters. Furthermore, the results show that export status does not explain price variation once I account for changes in efficiency and quality. A result consistent with the theoretical model.

Finally, I find that the probability of exporting is increasing in quality but that technical

[4]These studies often use producer size (e.g. revenue or employment) to control for efficiency. However, price and size both depends on quality and efficiency, making that interpretation of the estimated coefficient difficult.

[5]Kugler and Verhoogen (2010) find a positive association between input price and export status as well as between output price and export status. This suggest that firms that pay more for their input charge higher prices. But while the relation holds on average it is not clear that it will hold for each firm separately. Here, I take a closer look at the effect of quality on production costs by estimating the impact of changes in efficiency and quality on output price and input price at the producer level.

efficiency is not a good predictor for plant export status. This suggests that firms select into the export market because they are better able to generate demand for their product, not because they can produce at lower costs. At first, this result seems at odds with the empirical firm heterogeneity literature beginning with Bernard and Jensen (1995). However, it is important to emphasize that previous empirical studies used revenue-based measures of productivity which confound the separate effects of technical efficiency and product quality on producer revenue and export status. Instead, I estimate the separate impact of changes in efficiency and quality. The finding that exporters produce higher quality products but are not more efficient than non-exporters does not change the fundamental result that exporters are more *profitable* – it simply provides a more detailed view. Crucially, however, this implies that heterogeneity in efficiency and quality have different impact on the firm's outcome. This provides evidence against the standard iceberg trade cost formulation and points to the importance of studying the mechanisms by which firms generate demand for their product (e.g. Arkolakis (2010)).

The theoretical framework is a generalization of the Melitz (2003) model that includes product quality differentiation and per unit transport costs. As in the benchmark model, firms differ in their ability to produce varieties, so that high efficiency firms face lower marginal costs of production at any given quality level, and face a fixed export cost. In addition, as in Baldwin and Harrigan (2009), product quality increases demand conditional on price and increases cost conditional on efficiency. Since consumers care about quality-adjusted prices, firms that sell low priced varieties are not necessarily the most profitable. The model retains the predictions that larger firms tend to self-select into the export market. However, the increase in "productivity" can be decomposed into a quality and an efficiency margin. The model is similar to those developed by Johnson (2010), Kugler and Verhoogen (2010), and Hallak and Sivadasan (2009). The main difference is that I do not model the quality decision. Here, quality is a random draw like efficiency. Since I concentrate on cross-sectional variation and do not investigate the impact of trade liberalization this does not make any difference. My model share an important property with these other framework: when there is not per unit trade cost, these models are isomorphic to a Melitz model because changes in quality and efficiency have similar impacts on revenue and, as a result, selection. One of the contribution of this paper is to show how per unit transportation costs break that one-to-one mapping and make the decomposition of productivity into an efficiency and a quality component relevant.[6]

As explained by Alchian and Allen (1964) per unit transactions cost lowers the relative

[6]Hallak and Sivadasan (2009) suggests an alternative by including export quality requirements. While this framework generates selection on quality and breaks the firm size-export link, it cannot replicate the variation in the share of revenue from export across firms. Hence, introducing per unit transportation costs

price of high quality goods in foreign market. This implies that high quality producers are more likely to be profitable in the export market compared to lower quality producers. This effect is often described as shipping the good apples out and lead to relatively high prices for exported varieties. The importance of per unit transport cost was recently pointed out by Hummels and Skiba (2004). They confirm the Alchian-Allen conjecture using extensive bilateral trade data, thereby providing strong evidence against a widely used "iceberg" trade cost assumption standard in the trade literature. In this paper, I show that per unit trade cost help reconcile the model with the data on additional important dimensions. First, it implies that quality and efficiency do not have the same impact on firm selection. Second, firm size is not perfect predictor of export status. Third, the share of revenue from export varies across firm. This provides additional support for the per unit cost formulation.

The remainder of the paper is structured as follows. In the next section, I develop a model of international trade that includes heterogeneity in efficiency and quality. I use the model to show how per unit transport costs and quality differentiation interact to shape export patterns. In section 3, I describe the data set, define the main variables, and present summary statistics. In section 4, I confront the model with the data. I begin by estimating price elasticities of demand which I use to construct my measure of quality. I then explore the plant-level relationship between quality, efficiency, price, and export status. In section 5, I describe robustness checks of the empirical results. In section 6, I present some conclusions and ideas for future research. The appendix contains derivations of major results and a list of products included in the sample.

2. Theoretical Framework

In this section, I describe a straightforward extension of the Melitz (2003) framework that features per unit transportation costs and two dimensions of heterogeneity: technical efficiency and product quality.

2.1. Preferences

Consider an economy composed of a measure L of infinitely lived consumers each endowed with one unit of labor per period. Consumers have no taste for leisure and inelastically supply their labor to the market at the prevailing wage rate. Consumers derive utility from the consumption of a continuum of differentiated varieties. The aggregate preferences are

has the advantage of being more plausible in the current context (U.S.) and reconciles theory and data on additional dimensions.

given by the following utility function:

$$Q = \left\{ \int_{x \in X} [\omega(x) q(x)]^{\rho} dx \right\}^{1/\rho}, \quad \rho \in (0,1), \tag{1}$$

where $\omega(x) \geq 1$ is the quality and $q(x)$ the quantity consumed of variety x, while X is the measure of varieties available for consumption. Product quality is a demand shifter that captures every product characteristics that increases demand conditional on price.

The consumption of each variety is chosen to minimize the cost of acquiring the aggregate consumption bundle Q, so that the optimal aggregate expenditure on variety x is:

$$r(x) = RP^{\varepsilon-1} \left[\frac{p(x)}{\omega(x)} \right]^{1-\varepsilon} \text{with} \qquad \varepsilon = \frac{1}{1-\rho}, \tag{2}$$

where R is the total expenditure in the industry, P is the ideal price index given by $P = \left[\int_{x \in X} [p(x)/\omega(x)]^{1-\varepsilon} dx \right]^{\frac{1}{1-\varepsilon}}$, and $p(x)$ is the price of variety x. The preferences described in (1) are a version of the Dixit and Stiglitz (1977) aggregator extended to allow for substitution between quantity and product characteristics. This specification implies that the price elasticity of demand is the same for all varieties, independent of their characteristics, and is given by ε.

2.2. Production

Production uses only one input, labor, and entails both fixed and marginal costs. The total production costs depend on the quantity produced, the quality of the output and the firm's technical efficiency, denoted $\theta \in [1, \infty)$. I normalize the common wage rate to one without loss of generality and assume that the total cost function takes the specific form:

$$L(x) = \frac{\omega(x)^{\eta}}{\theta(x)} q(x). \tag{3}$$

The total cost function implies that the variable cost is increasing in quality and decreasing in efficiency.[7] This captures the idea that firms operated by high ability entrepreneurs are better able to exploit their resources to achieve lower marginal costs then firms managed by entrepreneurs of lesser ability.

[7]Production costs can increase in product quality because high quality units require more resources or higher quality inputs. Allowing for fixed production costs would not change the main results, even if they vary across product quality.

2.3. International Trade

I assume that the world is composed of two identical countries.[8] As discussed in Roberts and Tybout (1997), plants must build and maintain relations with foreign distributors in order to sell their products in foreign markets. In addition, plants generally face tariffs and pay freight costs to send their products to foreign markets. These trade impediments take the form of a fixed export cost (f_x) that must be paid *once* by firms to enter the foreign market, per unit transportation costs ($t > 0$) and iceberg costs ($\tau > 1$) – If τ units are shipped to the foreign country, only one unit arrives. These costs are assumed to be common to all firms and constant with respect to quality.

2.4. Profit Maximization

All potential entrants face a common production start up costs denoted f_e. The value of the investment opportunity is learned only once the fixed entry cost is sunk and the firm learns its quality and efficiency – a random draw from a common joint distribution with cumulative density function $G(\theta, \omega)$. After learning its quality and efficiency, the firm simultaneously chooses the domestic and export prices and whether or not to enter the foreign market. The firm's profit maximization problem can be written as follows:

$$\max_{p,\, p_x,\, I_x} \pi(\theta, \omega) = \left(p - \frac{\omega^\eta}{\theta}\right) q(p, \omega) + I_x \left[\left(p_x - t - \tau\,\frac{\omega^\eta}{\theta}\right) q(p_x, \omega) - f_x\right], \tag{4}$$

where p and p_x represent the price of a domestic variety sold in the domestic and foreign markets respectively, $q(p, \omega)$ is the optimal demand defined in (2). The first term represents profits from domestic sales (recall that there are no fixed production costs) and the second term represents the additional profit from exporting. Profit maximization implies that firms will set marginal cost equal to marginal revenue. This leads to the following pricing rules:

$$p(\theta, \omega) = \frac{\omega^\eta}{\rho\,\theta} \qquad \text{and} \qquad p_x(\theta, \omega) = \frac{1}{\rho}\left(t + \frac{\tau\,\omega^\eta}{\rho\,\theta}\right). \tag{5}$$

These equations show that the optimal prices are increasing in quality and decreasing in efficiency. Given the structure of preferences, the increase in marginal production costs associated with exporting is shifted to foreign consumers.

Given the assumptions on technologies and preferences, firms always make positive profits

[8]When countries are identical, they share the same aggregate variables, which greatly simplify the analysis. However, the main results do not depend on this assumption. Extending the model to include more than two countries is straightforward but keeping an eye on the empirical analysis provides no additional insights.

in their domestic market. However, firms will enter the foreign market only if the extra profits from exporting is greater than the fixed cost of exporting. Since profits are increasing in both quality and efficiency, the zero-profit efficiency threshold varies across quality and is given by:

$$\theta_x(\omega) = \frac{\tau}{\rho P} \left(\frac{\varepsilon f_x}{R} \right)^{\frac{1}{\varepsilon - 1}} \left[1 - \frac{t}{\rho P \omega} \left(\frac{\varepsilon f_x}{R} \right)^{\frac{1}{\varepsilon - 1}} \right]^{-1} \omega^{\eta - 1}. \tag{6}$$

Firms with quality ω will make non-negative profits in the foreign market and export if only if their efficiency is above $\theta_x(\omega)$; in that case $I_x = 1$ otherwise $I_x = 0$. Intuitively, the conditional threshold efficiency is increasing in trade costs.

2.5. Equilibrium

Each period, incumbents face a probability $\delta \in (0, 1)$ of being hit by an exogenous shock that will force them to exit the industry. Therefore, the expected value of staying in the market is equal to the stream of future profits discounted by the probability of exit: $V_e(\omega, \theta) = \sum_{t=0}^{\infty} (1 - \delta)^t [\pi_d(\omega, \theta) + I_x(\omega, \theta)\, \pi_x(\omega, \theta)]$. There exists an unbounded set of potential entrants in the industry. Firms will attempt entry in the industry as long as the expected value from entry is greater then the sunk entry cost. I assume that the characteristics of the ex-ante joint distribution of quality and efficiency is common knowledge, so that the ex-ante expected value of entry is the same for all potential entrant and equal to the average firm value. IN that case, the free entry condition is given by:

$$\overline{\pi} = \delta\, f_e, \qquad \text{with} \qquad \overline{\pi} = \int_{\omega} \int_{\theta} \pi_d(\omega, \theta) dG(\omega, \theta) + \int_{\omega} \int_{\theta(\omega)} \pi_x(\omega, \theta) dG(\omega, \theta). \tag{7}$$

Finally, in a stationary equilibrium, aggregate variables must remain constant over time. This requires a mass of new entrants (M_e) in each period, such that the mass of successful entrants exactly replaces the mass of incumbents hit by the exogenous shock and forced to exit. This aggregate stability condition requires that $M_e = \delta M$, where M is the equilibrium mass of producers. This completes the characterization of the unique costly trade open economy equilibrium.

2.6. Analysis of Equilibrium

An interesting property of the model is that, in the absence of per unit trade cost, it is isomorphic to a model in which there is a single dimension of heterogeneity – this is also true of models developed by Johnson (2010), Kugler and Verhoogen (2010), and Hallak and Sivadasan (2009). This can be shown by redefining quantity and efficiency in terms of quality-adjusted units. Let $\widehat{q} = \omega\, q$ denote the quality-adjusted physical output and $\widehat{p} = p/\omega$ the quality-adjusted price. Then, from (2), the optimal demand can be expressed has:

$$r = RP^{\varepsilon-1}\widehat{p}^{1-\varepsilon}. \tag{8}$$

To obtain the production function for quality-adjusted units, I define productivity as $\varphi(\omega,\theta) = \theta\,\omega^{1-\eta}$. This measure captures both the efficiency and the quality of the firm. I can then express total productions costs as:

$$L = \frac{1}{\varphi}\widehat{q}. \tag{9}$$

Finally, I can redefine the selection equation (6) as follows:

$$\varphi_x(\omega) = \frac{\tau}{\rho\, P}\left(\frac{\varepsilon\, f_x}{R}\right)^{\frac{1}{\varepsilon-1}}\left[1 - \frac{t}{\rho\, P\,\omega}\left(\frac{\varepsilon\, f_x}{R}\right)^{\frac{1}{\varepsilon-1}}\right]^{-1}. \tag{10}$$

In the absence of per unit transport cost ($t = 0$), the system of equations (8)-(10) is identical to the benchmark Melitz (2003) model – up to the fixed production costs. In that case, decomposing productivity into a quality and a productivity margin does not provide additional insights beyond matching price moments.

However, in the presence of per unit transport costs, changes in quality (ω) and efficiency (θ) that keep productivity (φ) constant will have different impact on export behavior. This happens because in that case, the ratio of export to domestic price depends on quality as follows:

$$\frac{p_x(\theta,\omega)}{p(\theta,\omega)} = \tau + t\,\frac{\varphi(\omega,\theta)}{\omega}. \tag{11}$$

As expected, the markup over domestic price is increasing in trade costs. Less obvious however is the fact that the markup is decreasing in quality but increasing in efficiency. This happens because an increase in quality raises domestic price thereby reducing the percentage increase in price associated with the per unit transport cost. Efficiency has the opposite impact. Further holding productivity fixed, an increase in quality will reduce the markup over domestic price. This implies that changes in quality and efficiency that leave productivity unchanged have different impacts on firm selection into exporting.

Consider two firms with the same productivity but different quality: $\varphi(\omega_1,\theta_1) = \varphi(\omega_2,\theta_2)$. Suppose that both firms export but that firm 1 produces a higher quality variety $\omega_1 > \omega_2$. Since domestic revenue depends only on productivity, these two firms will have the same domestic sales. However, the high quality firms will earn greater export profits. It is straightforward to show that the ratio of export revenues for these two firms is given by:

$$\left[\frac{r_x(\theta_1,\omega_1)}{r_x(\theta_2,\omega_2)}\right]_{\varphi} = \left(\frac{\omega_1}{\omega_2}\right)^{\varepsilon-1}. \tag{12}$$

Therefore, conditional on productivity, high quality firms will be larger because they sell more in the foreign market. Of course this also implies that the probability that a firm export is greater if they produce higher quality products because they are more likely to be able to recoup the fixed export cost.

Finally, the share of revenue from export is given by:

$$s_x = \frac{r_x(\theta,\omega)}{r_d(\theta,\omega)+r_x(\theta,\omega)} = \frac{1}{1+\left[\tau + t\,\frac{\varphi(\omega,\theta)}{\omega}\right]^{\varepsilon-1}} \tag{13}$$

This shows that the share of revenue from export if increasing in quality and decreasing in efficiency. Further, conditional on productivity an increase in quality will lead to an increase in the share of revenue from export. To summarize, the model delivers the following testable predictions:

1. Prices are increasing in quality and decreasing in efficiency.
2. Exporters charge higher prices on average.
3. The export status has no impact on price once efficiency and quality are controlled for.
4. When transportation costs are large relative to tariffs, selection into exporting will be driven mainly by quality.
5. In the presence of transportation costs, the share of revenue from export is increasing in quality and decreasing in efficiency.

Distinguishing efficiency and quality should not help beyond matching price moments. Of course this does not need to be the case in the data. The empirical analysis test those predictions.

3. Data and Measurement

The data set is derived from the Census of Manufactures (CM), a component of the U.S. Census Bureau's Economic Census. The CM is conducted every five years and covers the universe of manufacturing plants with one or more paid employees. Large- and medium-size firms, plus all firms known to operate more than one establishment, are sent questionnaires to be completed and returned to the Census Bureau by mail.[9] Firms that receive this questionnaire are required by law (Title 13, United States Code) to respond. The same law ensures the report is confidential and can only be used by Census Bureau employees for statistical purposes.

The CM contains plant-level data on payroll, employment, book values of equipment and structures, cost of materials and energy, and plant-by-product level data on the value of shipments. Starting in 1987, the CM also contains information on the value of export. In addition, for a subset of products, the CM collects plant-by-product information on shipments in physical units, which allows me to separate the value of shipments at the plant level into price and quantity. Only about 28 percent of plant-product-year observations in the CM have information on physical quantities. The information is not available when product data is being reported for the same period in surveys conducted by other Federal Government agencies. The selection occurs at the industry level, so that when physical output is recorded in the CM it is for all observations.

3.1. Sample

The unit of observation is a plant-product-year combination. For the empirical analysis, products are defined as five-digit standard industrial classification (SIC) product classes.[10] Because the CM does not collect information on factor inputs separately by product but rather at the plant level, the sample includes only the primary product of specialized plants. This reduces measurement problems in computing productivity measures. I consider a multi-product plant to be specialized if its primary product accounts for at least 50 percent of its total nominal value of shipments. In the CM, about 55 percent of plants are specialized. These plants account on average for about 70 percent of aggregate revenue in a given product class. About 20 percent of specialized plants export, compared to 25 percent for non-specialized

[9] For very small firms, which represent a small fraction of each industry's output, the reported data come from existing administrative records of other Federal agencies. Since product level information is not available for those plants, I remove them from the sample.

[10] Compared to four-digit industries, five-digit product classes removes a lot of horizontal differentiation from the analysis. For example, the four-digit SIC industry 2051, "Bread, Cake and Related Products" contains six five-digit products which are related in end use but differ in terms of material inputs and production technologies: Bread (20511); Rolls (20512); Sweet Yeast Goods (20513); Soft Cakes (20514); Pies (20515); Pastries (20518). Revisions to the SIC code system make it difficult to keep track of products over time while ensuring that the product's definition remains the same. Over the period 1987 to 1997, the CM contains 1,931 distinct five-digit product-classes. I remove the five-digit codes that do not appear in all three censuses from the sample. These observations represent about 4 percent of plant-product-year observations and 8 percent of the total value of shipments in the CM. Finally, because variation in units of measurement prevents an accurate comparison of physical output and unit value, I drop product classes with heterogeneous units of measurement for quantity.

plants. Finally, plants included in the sample receive on average 90 percent of their revenue from their primary product.

To ensure there is enough variation to estimate aggregate and plant fixed effects, I limit the sample to product classes with at least 10 observations in each year and at least 50 observations overall. Further, since plants that appear only once are dropped in fixed-effect estimation, the sample includes only products where more than half of the plant-year observations are related to plants that appear at least twice in the sample. Together, these rules lead to a sample of 52,263 observations distributed across 143 five-digit SIC product classes and three years, 1987, 1992 and 1997.[11] The sample includes about 6 percent of the plant-product-year observations recorded in the CM. The sample contains on average about half of a given product's plant-by-year observations, which together account for about 60 percent of the product's total shipment value. A list of five-digit SIC codes and descriptions for all products in the sample can be found in the appendix.

3.2. Measurement

The CM records domestic and foreign sales separately but only the total physical output of plants. This implies that I cannot compute domestic and foreign unit value separately. According to the model, however, these are the same. The pricing rule defined in equation (5) shows that total revenue exclusive of tariff and trade cost is given by the product of domestic price and total quantity – defined as the sum of domestic and foreign units sold. Therefore, I estimate price using the average unit value of output, defined as the ratio of the nominal product shipment value to physical quantity produced.[12]

The pricing rules are derived under the assumption that the domestic and foreign markets are identical, so that the markup is the same markup across country. Of course, this does not have to be the case in practice. From the model price and unit production costs are closely related. The important difference being that costs are independent of markup and will therefore be independent of any issues associated with market power (in the output market at least). I will therefore use per unit production costs as a robustness check. This provides a better sense of the ability of the model to match the empirical facts since it ignores important aspects of pricing decision. I define total variable costs has the sum of production

[11] I remove balancing codes, receipt for contract work, resale, and miscellaneous receipts from the sample because they are unrelated to production. In addition, I drop observations with missing information so that the sample remains the same in every estimation.

[12] In order to limit large reporting errors, I drop observations with an output price above 10 times or lower than one tenth of the product class's median price. These price outliers represent less than 2.5 percent of observations.

worker payroll, cost of material inputs and expenditure on energy. Per unit production costs are then computed by dividing total variable costs by total physical output.

I can use the model to derive a measure of efficiency. I define total factor productivity ($QTFP$) as physical output per inputs:

$$QTFP = \frac{q}{L} = \frac{1}{c} = \frac{\theta}{\omega^{\eta}}. \tag{14}$$

Note that $QTFP$ depends on the firm's efficiency and product quality. Holding efficiency fixed, $QTFP$ is decreasing in product quality. This implies that, in the presence of quality differentiation, $QTFP$ is a biased measure of the producer's "true" technical efficiency level, θ. I compute RTFP using the typical index form: $ln\, TFP = ln\, q - \psi_K ln\, K - \psi_L ln\, L - \psi_E ln\, E - \psi_M ln\, M$, where q, K, L, E and M represent establishment-level output quantities, capital stocks, labor hours, and energy and materials inputs, and where ψ_j for $j \in \{K, L, E, M\}$ are the factor elasticities for the corresponding inputs.[13] For simplicity I assume that the input elasticities, ψ, are constant across quality and I estimate them using five-digit SIC average cost shares over the sample.[14]

An important point to note is that $QTFP$ depends only on production costs and is not affected by demand-side effects that would affect prices. Therefore, in the current context, $QTFP$ is superior to the traditional revenue total factor productivity ($RTFP$) defined as: $RTFP = r/L = 1/\rho$. Hence, according to the model, $RTFP$ is constant across firms and

[13] I compute labor, materials, and energy cost shares from reported expenditures in the CM. The real capital stock is the sum of the plants' reported book values for their structures and equipment stocks deflated to 1987 levels using sector-specific deflators from the Bureau of Economic Analysis. Labor inputs are measured as plants' reported production-worker hours multiplied by the ratio of total payroll to production workers' payroll. I obtain the real cost of labor by multiplying the hours worked by the real wage. Real materials and energy inputs are plants' reported expenditures on each, deflated using the corresponding four-digit SIC input price indices from the NBER-CES Manufacturing Industry Database. For multi-product plants, I scale down all inputs using the primary product's share of the plant's nominal shipments. I construct the cost of capital by multiplying the real capital stock by the capital rental rate for the plant's respective two-digit industry. These rental rates are taken from unpublished data constructed and used by the Bureau of Labor Statistics in computing their Multi-factor Productivity series.

[14] This formulation implicitly assumes constant returns to scale. In general, each of the input elasticities ψ_j should be multiplied by the scale elasticity. As I report in the robustness section, the main results are robust to modest departures from unitary scale elasticities. In addition, there is empirical support for the constant returns to scale assumption see, Baily, Hulten and Campbell (1992) and Olley and Pakes (1996). Of course this is not the only method that can be used to estimate factor elasticities. Olley and Pakes (1996) and Levinsohn and Petrin (2003) suggests using either an instrumental variables procedure or proxy methods. These are not really appropriate in the current context. First, the sample is not an annual panel data. Second, the one-to-one mapping required between plant-level productivity breaks down if other unobservable plant-level factors besides productivity, such as the idiosyncratic demand shocks, drive changes in the observable proxy. Importantly, Van Biesebroeck (2004) finds high TFP correlations across various measurement alternatives. This suggests that alternative measures would not lead to first-order changes in the results.

depends only on the elasticity of substitution. In more general settings, such as the quadratic linear utility this will not be the case. Additional firm and market characteristics will also influence this measure (Foster et al. (2008a)). In that case, this measure will include price changes associated with random demand shocks unrelated to efficiency. This makes it an invalid instrument for price in a demand regression.[15]

Finally, since the CM does not collect information on export separately by product but rather at the plant level, I classify plants as exporter if they reports positive sales to foreign markets. Of course, this is an imperfect measure. However, my sample contains only specialized plants which derive on average 80 percent of their sales from a single product. It seems reasonable to assume that specialized plants that export will export some of their primary product.

3.3. Sample Characteristics

Table 1 shows summary statistics for the main variables. I remove product-year means from the variables before computing the statistics, so the results are not driven by product heterogeneity or aggregate shocks – I do the same for all regressions.

The top panel of the table shows correlation between the main variables. The first point to note is that total physical output is decreasing in price and increasing in efficiency. A finding consistent with the model. Second, the inverse correlation between efficiency and prices is in line with the prediction that more efficient firm will charge lower prices. Recall, however, that in the presence of quality differentiation this measure captures both the impact of changes in efficiency and quality. Therefore it underestimates the actual negtive impact of changes in efficiency on prices.

To give an idea of the variation in the data, I compute the standard deviations of plant log quantity, price, and physical total factor productivity ($QTFP$) for each product-year. Table 1 presents the mean and standard deviation for each measure. The most important message is that there is substantial variation in plant characteristics within each product class and heterogeneity across product classes in the extend of the cross-plant variation. The table also shows the average share of plant-by-year observations classified as exporters. On average about 27 percent of plant-by-year observations are classified as exporters, which is about the same as in the whole CM. The share of exporters varies substantially across product classes.

[15] In my sample the correlation between price and $RTFP$ is positive, even after controlling for quality. This suggests that $RTFP$ is capturing random demand shock unrelated to product quality.

Table 1: Sample Characteristics

	Plants Level Correlation Between Log			
	Quantity	Price	QTFP	Export Status
Quantity	1.00			
Price	-0.37	1.00		
QTFP	0.49	-0.81	1.00	
Export Status	0.20	0.04	0.01	1.00

	Standard Deviation Across Plants of Log			Share of
	Quantity	Price	QTFP	Exporters
Mean	1.39	0.52	0.60	0.27
Standard Deviation	0.31	0.22	0.22	0.18

Notes: The table shows the mean and the standard deviation of the within-product-year standard deviation across plants of quantity, price, and TFP. All variables are in logs and corresponding product-year means are removed from the variables before computing the statistics. The table also shows the mean and standard deviation across product classes of the fraction of exporters in each product-year categories. There are 143 different product classes. However, since three products appear in only two of the three sample years, the sample size is 423.

4. Empirical Analysis

In this section, I use the theoretical model to evaluate the plant-level relationship between quality, efficiency, price, and export status. The primary focus of the analysis is the link between quality, efficiency and selection into exporting. As explained in the theoretical section above, the impacts of quality and efficiency on export selection are not the same in the presence of per unit costs. I begin by estimating demand equations separately for each market using price and quantity information. From the results, I obtain product-level estimates for the price elasticity of demand and plant-level estimates for product quality. I then confront the model's main predictions with the data. In particular, I estimate the impact of changes in quality and efficiency on unit price and the probability of exporting.

4.1. Price Elasticity of Demand

In the theoretical model, the price and the quality of a producer's output are both determined by its productivity. However, from the point of view of the consumer, price and quality are two distinct product attributes. Equation (2) above shows how consumers combine them to determine their optimal demand for a particular variety. This equation suggests that product quality can be estimated from unobserved plant-level effects in regressions of quantity on price and additional controls. Adding a multiplicative error term to the optimal demand, defined in (2), and taking logs yields:

$$lnq_{it} = \beta_t - \varepsilon lnp_{it} + \nu_i + e_{it}, \tag{15}$$

where i and t index plants and year respectively. The first term is a time-varying effect common to all plants that captures variation in market characteristics over time. The second term controls for the increase in demand associated with entering the foreign market but unrelated to variations in price and quality.[16] The fourth term, $\nu_i = \varepsilon\, ln\, \omega_i$, is a plant unobserved effect equal to the product of the price elasticity of demand and the time-invariant product quality. If I don't control for quality in the demand equation, the estimates for the price elasticity of demand will be biased toward zero because of the positive correlation between price and quality. Therefore, a random effect estimator is not appropriate in this context, so I control for quality using plant-level fixed effects. Finally, the error term e_{it} represent idiosyncratic demand shocks.

Firms can respond to positive demand shocks by raising their prices. If this is the case, estimating (15) by OLS with fixed effects leads to biased estimates of the price elasticity of demand (ε) and, as a result, of the plant's output quality. Instead, I use the plant's physical total factor productivity ($QTFP$) as an instrument for price.[17] The two-stage least squares (2SLS) fixed effect procedure using QTFP as an instrument for price produces consistent estimates under two identifying assumptions. First, the instrument must be relevant. As explained above, $QTFP$ reflects idiosyncratic technologies, so they should have explanatory power over prices. As seen in Table 1, there is a strong negative correlation between price and $QTFP$. Second, the instrument must be exogenous. This requires that the plant-year residual (u_{it}) is uncorrelated with included regressors in *every* period. This condition is stronger than assuming zero contemporaneous correlation. However, it still allows for arbitrary correlation between the plant unobserved effect and the other explanatory variables. Therefore, the estimated price elasticity of demand are consistent despite the positive correlation between price, quality and the measure of efficiency $QTFP$.[18]

[16]The data does not contain separate information on quantity sold in the domestic and foreign market. I only observe total physical output. However, since f.o.b price is the same in both markets I can back out domestic physical output as $q_d = (r_x/r)q$. The advantage of using this formulation is that I allow for the domestic share of output to vary across firms. Unfortunately, however, those results did not yet go through the disclosure process. Instead I present the qualitatively similar results obtained under the assumption of constant within industry-year share of revenue from export.

[17]A potential problem with using $QTFP$ as an instrument is measurement error. Since I estimate prices by dividing revenue by physical output, measurement error in quantities will overstate the negative correlation between prices and $QTFP$. In that case measurement error provides biased estimates of the fitted prices used in the second stage and, as a result, biased price elasticities and quality measures. As explained in the robustness section below, the main results do not seem to be driven by measurement error.

[18]An important implicit condition is that random supply shocks do not generate within plant variation in

I estimate the demand equation (15) separately for each of the 143 five-digit products using both OLS and a 2SLS instrumenting price with $QTFP$. The results are summarized in Table 2. The IV estimates of demand elasticity have a mean of 1.18, which is about 30 percent lower on average than the corresponding OLS elasticity.[19] These results suggests that there is a positive correlation between exogenous random demand shocks (u) and prices (p), which biases OLS estimates of demand elasticities toward zero. The standard deviation for the estimated elasticities are generally small. About 95 percent of the IV and 91 percent of OLS elasticities are statistically significant at the 5 percent level. The mean within group R^2 is about 0.5, which implies that changes in price and aggregate factors explain about half of the variation in quantity demanded once quality is controlled for. Further, the IV estimates of demand elasticities are relatively well behaved compared to the OLS estimates. All point estimates for the IV elasticities are negative and, for about 95 percent of them, I cannot reject the hypothesis that they are smaller than minus one, compared to 80 percent for the estimated OLS elasticities. Finally, the first stage F statistics are larger than 10, the Staiger and Stock (1997) rule of thumb, for about 95 percent of product classes. This suggest that variation in $QTFP$ has sufficient explanatory power over price. Overall, these results support the use of the 2SLS estimation procedure.

4.2. Product Quality

By definition, the plant unobserved effects (ν_i) captures time-invariant changes in physical output across plants uncorrelated with movements along the demand curve. In other words, they capture long-run shifts in the plant's demand curve. From the model, I can obtain estimates for product quality from the firm unobserved effects and the estimated price elasticity as follows: $\widehat{\omega}_i = \exp(\hat{\nu}_i/\hat{\varepsilon})$. I report some characteristics of this plant-level proxy for product quality at the bottom of Table 2. The results for the OLS and IV estimates are almost identical, so I concentrate on the IV results.

First, I test the null hypothesis that the plant unobserved effects (ν_i) are all equal to 0 for each product class. On average test statistics is greater than 15 and I reject the null at the 5 percent level in all product classes. Second, the average within-product standard deviation

product quality. However, even if there is within-firm time-series variation in quality, the empirical evidence suggests that using the "average" quality is reasonable since it explains most of the time series variation in demand unexplained by price, export status, and aggregate factors in my sample.

[19] In the theoretical model, the markup over cost depends only on the price elasticity of demand. Precisely, the markup is equal to $1/\rho = \varepsilon/(\varepsilon - 1)$. In that case, the estimated elasticities imply very high markups. The average estimated elasticity of 1.18 translates into a markup of about 6.5. While this result is somewhat disappointing, it does not undermine the whole procedure. First, while the model predicts a very simple markup rule, this is unlikely to be the case in practice. Second, what matters for the empirical analysis is variation across industries not the levels.

Table 2: Price Elasticity of Demand and Quality

	OLS	IV
Mean Estimated Elasticity	−0.89	−1.18
Mean Standard Deviation	0.15	0.21
Mean within group R^2	0.48	0.46
Mean First Stage F	n/a	369
Share of $\varepsilon < 0$	0.99	1.00
Share of $\varepsilon < -1$	0.80	0.94
Mean F-statistic $H_0 : \nu_i = 0$	16.2	15.1
Standard Deviation of ν_i	1.26	1.31
Standard Deviation of e_{it}	0.41	0.43
Mean share of variance due to ν_i	0.90	0.90

Notes: This table summarizes the results from estimating the demand equation, defined in (15), separately for each of the 143 five-digit product classes. I control product quality using plant unobserved effects (ν_i). I present results from OLS and 2SLS using physical TFP as an instrument for price. The average sample contains 365 observations.

of the estimated plant fixed effect (ν_i) is 1.26. Therefore, there is abundant and statistically significant variation in the estimated long run demand shifts across plants. There is also a lot of dispersion in the time varying demand shocks. However, most of the variation in quantity demanded unexplained by price, export status, and aggregate factors is due to the plant unobserved effects. As reported in the table, an average of 90 percent of the variance in the overall error term ($\nu_i + e_{it}$) is due to the plant's fixed effects (ν_i).

4.3. Unit Value

In this section, I use the estimates for product quality to decompose price variation into a quality and a productivity margin. From the pricing rule defined in (5), the log of the optimal price can be expressed as follows:

$$ln\, p_{it} = \beta_t + \beta_\omega\, ln\, \hat{\omega}_i + \beta_\theta\, ln\, \hat{\theta}_{it} + e_{it}. \tag{16}$$

The first term on the right hand side of the equality, β_t, is constant common to all plants which captures the effect of markup on price. The second and third terms control for the impact of efficiency and quality on price and is measured using $QTFP_{it}$ while quality is derived from the estimated demand shift and price elasticity of demand, $\omega_i = \exp(\nu_i/\varepsilon)$. Finally, the error term includes other exogenous factors affecting price. A central prediction of the theoretical model is that the quality elasticity of price is positive ($\beta_\omega > 0$), and that an increase in productivity decreases price ($\beta_\theta < 0$).

Table 3: The Determinants of Price

Variables	Unit Value	Unit Cost	Homogeneous	Differentiated
Log Quality	0.232	0.167	0.060	0.351
	(0.047)	(0.047)	(0.009)	(0.060)
Log Efficiency	−0.786	−0.938	−0.825	−0.777
	(0.015)	(0.012)	(0.013)	(0.015)
Sample Size	52,263	52,263	21,439	30,824
R^2	0.604	0.848	0.675	0.592
SE of reg.	0.627	0.388	0.568	0.637

Notes: This table shows the OLS results from regressing plant-level prices (nominal value of shipments divided by the number of physical units of output) and, for the second column only, unit costs of production (sum of labor, energy, and material expenditures divided by the number of physical units of output) on the proxy for product quality (the plant fixed effect from the demand regression divided by the estimated elasticity of demand) and a measure of technical efficiency ($QTFP$). All variables are in logs and are standardized by removing the corresponding product-year mean and dividing by the product-year standard deviation. The sample is the pooled sample of 52,263 plant-year observations, except for the last two columns where I divide the observations into two categories, homogeneous (goods traded on an organized exchange and reference priced) and differentiated, according to the Rauch (1999) classification. Bootstrap standard errors are in parenthesis.

For the estimation, I normalize all variables by removing product-year mean and dividing by product-year standard deviation. Therefore aggregate factors and product class heterogeneity do not drive any of the results. The normalization does not affect the qualitative properties of the results but makes their interpretation more intuitive because coefficients represent the impact of a one standard deviation change in the independent variables. The results from estimating (16) are presented in Table 3. The benchmark results are presented in the first column. As predicted by the model, prices are increasing in quality and decreasing in productivity. According to the point estimates a one standard deviation increase in estimated quality leads to a 0.23 standard deviation increase in price, while a one standard deviation in estimated efficiency decreases price by 0.79 standard deviations. Both effects are statistically significant at conventional levels. According to the R^2 statistic, changes in quality and efficiency jointly explain about 60 percent of the within product-year variation in price in my sample.[20]

[20] In the presence of generated regressors estimated in a "first stage", such as quality or $QTFP$, inferences based on the usual OLS standard errors will be invalid since they ignore the sampling variation due to the estimation of these variables – see Wooldridge (2002). Instead, for the remainder of the analysis, I report bootstrap standard errors (Efron and Tibshirani (1986)). In the current context, the bootstrap is an appealing alternative to the use of asymptotic theory since it does not require a closed form solution for the variance-covariance matrix, which is difficult to obtain and evaluate. Another alternative is the use of the delta method. As it happens, the difference between the bootstrapped and the usual OLS estimated standard errors clustered by plant is small in the current analysis, and using clustered standard errors would not change the main results.

In the model, the markup does not depends on demand or any producer characteristics. This is due to the specific form of the utility function. However, variation in markup is potentially an important source of variation in price. For instance, firms could choose to reduce their markup in order to attract larger market shares. In that case, the estimated coefficients on quality and productivity are likely to be biased if I don't control for markup in the price regression. From the model, unit costs and price are closely related. The only difference between the two being the markup. So the impact of quality and productivity on unit costs should be the same as that on price. In the second column of Table 3, I use average unit production cost instead of price, so that markups are absent and do not drive the results. As in the benchmark regression, I find that prices are increasing in quality and decreasing in productivity in both regressions. The impact of productivity is statistically significantly larger when using per unit production cost than when using unit value. This suggests that high productivity firms tend to charge higher markup on average. Note that the R^2 is much higher when I use unit production costs instead of price. This suggests that the markup is influenced by many factors, other than quality and price, that do not impact unit costs.

While pooled regressions are instructive and provide useful benchmark results, it is likely that the relative importance of the effect of productivity on cost versus its effect on quality varies in response to changes in market and product characteristics. Therefore imposing the equality of the coefficients across products potentially masks important variation. I use the classification suggested by Rauch (1999) to separate product classes into two groups: homogeneous (includes reference price) and differentiated.[21] I report the results in that last two columns of Table 3. The results show that, as expected, changes in product quality have greater impact on prices in differentiated product classes. According to the point estimates, a one standard deviation increase in product quality raises price by less than a tenth of a standard deviation in product classes classified as homogeneous. However, the same change results in an increase of more than a third of a standard deviation in differentiated product classes. Hence, while quality differentiation is important in most markets, the results suggest that it has a more pronounced effect in differentiated product categories. Meanwhile, the impact of productivity on price is negative, statistically significant, and of similar magnitude in both categories of product classes.

[21] I could separate products based on the standard deviation of the quality estimates but it seems more compelling to use outside information to test whether or not the results line up with my priors. The sample contains about a dozen product classes not included in Rauch's classification. I classify those based on the product descriptions. Removing them from the sample does not affect the main results.

Table 4: The Exporter Price Premium

Variables	Premium	Unit Value	Unit Cost	Homogeneous	Differentiated
Export Status	0.099	0.017	0.004	0.032	0.002
	(0.018)	(0.020)	(0.019)	(0.009)	(0.029)
Log Quality		0.230	0.166	0.057	0.350
		(0.044)	(0.048)	(0.011)	(0.057)
Log Efficiency		−0.786	−0.938	−0.825	−0.777
		(0.014)	(0.011)	(0.014)	(0.014)
Sample Size	52,263	52,263	52,263	21,439	30,824
R^2	0.002	0.604	0.848	0.675	0.592
SE of reg.	0.995	0.627	0.388	0.568	0.637

Notes: This table shows the OLS results from regressing plant-level prices (nominal value of shipments divided by the number of physical units of output) and, for the second column only, unit costs of production (sum of labor, energy, and material expenditures divided by the number of physical units of output) on the export indicator variable (equal to 1 if the plant export and zero otherwise), the proxy for product quality (the plant fixed effect from the demand regression divided by the estimated elasticity of demand) and a measure of technical efficiency (physical TFP). All variables are in logs and are standardized by removing the corresponding product-year mean and dividing by the product-year standard deviation. The sample is the pooled sample of 52,263 plant-year observations, except for the last two columns where I divide the observations into two categories, homogeneous (goods traded on an organized exchange and reference priced) and differentiated, according to the Rauch (1999) classification. Bootstrap standard errors are in parenthesis.

4.4. Exporter Price Premium

The model predicts that the export status of the plant should have no effect on the optimal price once quality and productivity are controlled for. This happens because the impact of a change in market size on price operates exclusively through quality. To see if this prediction holds, I re-estimate the price regression (16) including the export status dummy:

$$ln\, p_{it} = \beta_t + \beta_x\, I^x_{it} + \beta_\omega\, ln\, \hat{\omega}_i + \beta_\varphi\, ln\, \hat{\varphi}_{it} + e_{it}, \tag{17}$$

where I^x_{it} is the export indicator equal to one if the plant exports and zero otherwise, $\hat{\omega}_i$ is the estimated demand residual which serves as a proxy for log product quality, $\hat{\varphi}_{it}$ is the estimated plant productivity, and e_{it} represents exogenous idiosyncratic shocks that affects price.

I report the results from estimating (17) in Table 4. In the first column, I regress price on the export dummy alone. I find that exporters charge prices on average about a tenth of a standard deviation higher than domestic plants. A plausible explanation is that exporters produce varieties of higher quality than domestic plants. In column (2), I estimate a richer specification that includes quality and productivity. The export dummy is still positive but much smaller and no longer statistically significant. The estimated coefficient on quality and productivity have the expected sign and are statistically significant. Consistent with the model's prediction, these results imply that plant export status does not explain price variation after controlling for changes in quality and productivity. I control for variation in markup in the third column by using unit production costs instead of price. This change does not affect the main finding that export status does not explain variation in price once quality and productivity are controlled for.

Finally, in the last two columns, I estimate the price equation separately for product classes classified as homogeneous and those classified as heterogeneous. For differentiated products the results are the same as in the benchmark. Prices are increasing in quality and decreasing in productivity and plant export status has no impact on prices. However, I find that for homogeneous goods, the export status is positive and statistically significant even after controlling for quality and productivity. As the appendix shows, when marginal costs depend on output, prices will still vary across export status even after quality is controlled for. This happens because, in addition to its indirect impact on price through its effect on the optimal quality choice, entry in the foreign market will affect prices through returns to scale. The positive coefficient on export status suggests that there are decreasing returns to scale in the production of homogeneous goods.

4.5. Export Status

There is a vast literature that documents systematic differences across plants that export and plants that produce only for the domestic market - See Bernard et al. (2007) for a review of that literature. I also find that exporters are different than non-exporters in my sample. They produce more output, generate more revenue and employ more workers. In addition, as reported in Table 5, I find that exporters charge higher prices and produce higher quality goods on average compared to non-exporters. However, price variation does not capture the full extent of quality variation because of the opposite impacts of productivity on price. In my sample exporters charge prices 5% higher on average compared to non-exporters. Using my proxy for product quality, I estimate that the average quality of exporter's output is about 58 percent higher than that of non-exporter. In other words, exporters sale on average more units than non-exporters conditional on price and market size – recall that the demand regression includes exporter dummy variables to control for the increase in demand associated with entry in the foreign market but uncorrelated with variation in quality. This estimate, the first of its kind, shows that the exporter quality premium is one order of magnitude larger than the exporter price premium.

According to the Welch's t tests for equality of means across groups reported at the bottom of the table, the differences in price and quality are statistically significant. However,

Table 5: Exporters vs. Non-exporters Characteristics

Variables	Unit Value	Quality	QTFP	Productivity	N
Non-exporters	-0.01	-0.12	-0.001	-0.02	41,602
	(0.45)	(1.09)	(0.54)	(0.64)	
Exporters	0.04	0.46	0.005	0.07	10,661
	(0.57)	(1.24)	(0.62)	(0.60)	
t-stat for equal mean	-7.99	-43.47	-1.01	-12.67	

Notes: This table shows within group means and standard deviations (in parenthesis) across-plants of unit value, product quality, physical TFP and labor productivity (total value of shipment over labor hours) for exporters and non-exporters. All variables are in logs and I remove corresponding product-year mean such that aggregate factors and product heterogeneity do not drive the results. The table also shows the Welch's t statistics for equality of means across groups.

I find that domestic plants are just as technically efficient as exporters.[22] This result seems at odds with the important firm heterogeneity literature. As a check, I also calculated the mean labor productivity, defined as revenue over total hours worked. In line with previous studies, I find that exporters have statistically higher labor productivity. This implies that differences in productivity measures and not sample characteristics drive the result. Revenue-based measures of productivity confound the impact of demand and supply effects on profitability. They basically capture the effects of both TFP and quality.

In the model, firms enter the export market only if the extra profit from exporting is positive. Using the pricing rule, it is possible to express the ratio of foreign variable profits to fixed export costs as:

$$T = \frac{R(\rho\, P)^{\varepsilon-1}}{\varepsilon\, f_x} \left(\frac{t}{\omega} + \frac{\tau}{\varphi(\omega,\theta)}\right)^{1-\varepsilon}$$

The variable T is the product of two main components. The first depends exclusively on market characteristics and is common to all plants. The second is plant specific and depends on product quality and productivity. I estimate the probability that plant i exports at time t conditional on the observed variables from the following Probit equation:

$$\text{prob}\,\{I_{it}^x = 1|\text{Observed Variables}\} = \Phi(\beta_t + \beta_\omega\, ln\, \hat{\omega}_i + \beta_\varphi\, ln\, \hat{\varphi}_{it}), \qquad (18)$$

where Φ is the cumulative density function of the unit-normal distribution. As before, I_{it}^x is an export indicator variable equal to 1 when the plant exports, and 0 when it does not. I

[22] It is important to note that, as explain in detail in the appendix, TFP measures are generally downward biased when quality is not directly control for. Further, this bias is more important for exporters. This can explain, at least in part, that there is only a very small difference in TFP across exporters and non-exporters.

Table 6: The Determinants of Export Status

Variables	(1)	(2)	(3)	(4)	(5)
Log Quality	0.078			0.081	0.084
	(0.002)			(0.002)	(0.002)
Log TFP		0.001		-0.013	
		(0.002)		(0.002)	
Log Productivity			0.022		-0.014
			(0.002)		(0.002)
Pseudo R^2	0.036	0.000	0.003	0.037	0.037
Log Pseudo Likelihood	-25,481	-26,438	-26,365	-25,454	-25,456

Notes: This table shows the results from Probit regressions. The dependent variable is a dummy variable equal to 1 if the plant reports positive exports in the period and 0 otherwise. The proxy for product quality is the estimates plant time-invariant demand shift divided by the estimated price elasticity of demand. There are two measures of productivity. TFP denotes physical TFP, while productivity refers to labor productivity, defined as revenue divided by hours worked. The measures of quality and productivity are in logs and are standardized by removing the corresponding product-year means and dividing by product-year standard deviation. The sample is the pooled sample of 52,263 plant-year observations. Bootstrap standard errors are in parenthesis.

allow the constant β_t to vary over time to account for possible changes in trade costs over time.

I present the results from estimating Probit equation (18) in Table 6. As predicted quality has a positive, and significant impact on the probability of exporting. However, while the coefficient on $QTFP$ on the probability of export is positive, it is very small and not statistically significant. This result is not surprising given that, as reported in Table 5, non-exporters are on average just as technically efficient as exporters. However, as shown in the third column, I find that an increase in labor productivity increases the probability of export. This difference in results arise because the revenue-based measures of productivity confound the impact of demand and technical efficiency on profitability and the decision to export. As can be seen from the last two columns, once quality is controlled for, I find that using labor productivity instead of physical TFP yields similar results. According to the point estimates a one deviation increase in quality increases the probability of export by about 8 percent. Meanwhile, an increase in productivity as a negative, but small and arguably economically insignificant, impact on the probability of export.

The finding that productivity plays no role in determining the plant's export status runs against the model's prediction that more productive firm self-select in the export market. It is important to emphasis, however, that this does not invalidate the model's main prediction that productivity influences product characteristics. In the model, product quality is completely determined by the plant's physical productivity. This is not the case in practice.

In my sample, the correlation between productivity and quality is about 0.19 in the sample. Therefore, plant specific factors other than physical productivity contribute significantly to the plant's long run demand shift. The results from Table 6 suggest that selection into exporting is driven by the fraction of demand uncorrelated with physical productivity. Firms become exporters because they are better able to generate demand for their products, not because they face lower marginal production costs. I briefly explore additional factors that determines demand in the next section. However, the identification and study of these factors is beyond the scope of this paper and left for future research.

4.6. Share of Revenue from Export

In the benchmark model without transportation costs, the share of revenue from exporting is constant. However, when per unit cost are included, the share of revenue from exporting varies across firms. Firms that produce higher quality product tend to obtain a larger fraction of their income from foreign markets. I can test this prediction using estimated quality and productivity. I do not present the results in this version of the paper because they have not gone through the U.S. Census disclosure process. I can, however, report that the qualitative properties of the estimated coefficients are consistent with the model.

5. Robustness

In this section, I provide details on the robustness of the results to the maintained assumptions. First, as explained in the appendix, quality-adjusted measures of inputs and outputs are required in order to obtain accurate measures of physical TFP in the presence of vertical product differentiation. Physical TFP is still exogenous to demand shocks even when it is biased, so that the estimated price elasticity of demand obtained by 2SLS are consistent. However, since the measurement error is systematically related to quality, the estimated impacts of productivity and quality on price are biased and inconsistent. To address this issue, I re-estimate the price equation (17) using 2SLS instrumenting for productivity. The estimated productivity contains information on the plant physical efficiency even in the presence of measurement error. However, as explained in the appendix, the ranking of plants across productivity and the dispersion of productivity across plants will not be correct in general. In an effort to reduce ranking error, I group plants in productivity quintile and instrument for plant productivity using the within-quintile mean productivity. The results are presented in the second column of Table 7. For convenience, the first column reproduces the benchmark results from the second column of Table 4. The estimated impact of quality on price is about the same but the impact of productivity on price is slightly larger in absolute value

Table 7: Robustness Checks

	Benchmark	TFP1	TFP2	Sample	Selection	Geo
Export Status	0.017	0.014	0.029	-0.001	0.046	0.022
	(0.021)	(0.021)	(0.001)	(0.025)	(0.015)	(0.021)
Log Quality	0.230	0.239	0.069	0.224	0.206	0.223
	(0.048)	(0.044)	(0.014)	(0.056)	(0.031)	(0.047)
Log TFP	-0.786	-0.831	-0.761	-0.825	-0.779	-0.786
	(0.015)	(0.027)	(0.024)	(0.016)	(0.018)	(0.015)
Sample Size	52,263	52,263	52,263	34,831	52,263	52,263
R^2	0.604	–	0.581	0.622	0.595	0.601
SE of reg.	0.627	0.629	0.645	0.599	0.634	0.631

Notes: This table summarizes the results of exercises designed to test the robustness of the benchmark results to the maintained assumptions. The dependent variable is the plant log average unit value. The first column reproduces the benchmark results from the second column of Table 4. In the second column, I control for measurement error in physical productivity by instrumenting with mean quintile productivity. In the third column, I use a measure of productivity robust to cyclical changes in factor utilization. In the fourth column, I restrict the sample to observations for which I can separately identify the plant unobserved effect and residual term. In the fifth column, I control for sample selection bias by estimating a type II Tobit model. In the final column, I control for regional factor and plant age. Bootstrap standard errors are in parenthesis. The sample is the pooled sample of 52,263 plant-year observations.

than in the benchmark regression. The export status is still close to zero and statistically insignificant.

Second, Burnside et al. (1996) and Basu et al. (2006) present empirical evidence that factor utilization is procyclal. If this is the case, the capital stock is not an accurate measure of capital utilization and its use leads to biased estimates of productivity. The authors suggest using energy usage to proxy for capital utilization. Therefore, I re-estimate (17) using a corrected measure of physical TFP that uses energy consumption as a proxy for capital stock. As can be seen from the third column of Table 7, the estimated coefficient on quality is now smaller, but still positive and statistically significant.

Third, in the model I associate quality with long run shifts in demand. Therefore, I estimate quality using plant-level fixed effect. This requires that plants appears at least twice in my sample. This is not always the case. As explained in the data section above, I restrict my sample to product classes for which more than half of the plant-year observations are related to plants that appear more than once. However, I include all the plants in the price, export price premium and export status regressions. For plants that appear only once, the estimated quality therefore contains both the long run demand shift and the idiosyncratic demand shock. Since the expected value of the random shocks is zero, the estimated quality is accurate on average. However, it is still important to evaluate the separate impact of each component. In the fourth column, I restrict the sample to plant-year observations for which

I can partial out the impact of demand shocks (u) and compute quality (ω). The results are similar to the benchmark. Price is increasing in quality and decreasing in productivity but the export status does not affect price.

Fourth, my sample is unbalanced. This happens for many reasons, such as changes in the relative importance of the primary product, or plant entry and exit. The estimates will be biased if sample selection is not random. Since in the model, selection is completely exogenous and uncorrelated with any plant characteristics, I cannot use the theory to derive a selection equation. Therefore, I simply assume that plants that made larger capital investment are, other things equal, less likely to exit the industry. I control for selection using a two stage type II Tobit model. In the first stage, I estimate the impact of productivity, export status, and capital stock on the probability of exit. I use the results to construct the inverse Mills ratio which serves as a control in the demand equation. I find that the coefficient on the inverse Mills ratio is large, positive, and significant in about 70 percent of the demand regressions. I report the results from regressing price on the proxy for quality obtained from those demand regressions in column (5) of Table 7. The coefficients on quality and productivity have the expected signs and are statistically significant. An important difference with the benchmark results is that the estimated impact of exporting on price is now positive and statistically significant. As explained in the appendix, this is consistent with the model when there are returns to scale.

Finally, as explained in last section, the proxy for quality includes information on factors uncorrelated with productivity that also influence the demand for a particular variety. In the theory, firms compete face common aggregate conditions. However, in reality, many industries are segmented into multiple regional markets. Syverson (2004) shows that differences in regional demand and competition are important sources of price heterogeneity. Further, because it takes time for consumers to learn about new products, older vintage varieties may have an advantage over newly introduced ones. Foster et al. (2008b) find empirical support for this conjecture using U.S Census micro data on manufacturing plants.[23] My theoretical model does not account for the accumulation of quality capital such as brand recognition or consumer habits, but rather concentrates on the contemporaneous relationship between production costs and demand. I re-estimate the demand equation (15) including regional indicators and plant age to partial out the fraction of demand explained by regional difference

[23]The authors suggest a dynamic explanation for demand shifts that emphasizes the role of learning. An important difference with the current study is that consumers' knowledge accumulation process is exogenous to the producer, such that all firms benefit from the same growth rate of demand over time. Since the current paper emphasizes the endogenous nature of quality and the contemporaneous relationship between quality and production costs, but is silent on the intertemporal accumulation of brand capital, the two studies are complementary.

in demand and learning from the estimated plant unobserved effects.[24] I estimate the impact of quality on price using this new proxy and present the results in the last column of Table 7. The main results of interest are not affected by this change: prices are increasing in quality and decreasing in productivity, and the export status is not significant.

6. Conclusion

The firm heterogeneity literature argues that more productive firms self-select into the export market. However, selection is based on profitability, not productivity. In this paper I take a closer look at firm profitability. I develop and estimate a model of international trade that separately identifies product quality and technical efficiency. I use this model to show that in the presence of per unit transport costs, distinguishing between quality and efficiency matters because they have different effects on selection into exporting. This happens because per unit transport cost lead to a greater percentage change in price for low quality varieties. Therefore, an increase in product quality that leads to the same increase in (domestic) revenue than a given change in efficiency, is more likely to lead to entry in the foreign market.

The framework provides a tractable tool for studying the firm's price and export decisions. First, I use the theory as a guide to construct a new proxy for product quality from price and quantity information. Intuitively, quality is defined as the ability to sell large quantities of output conditional on price. Then, I use this plant-level measure of quality to study the determinants of variation in price and export status. Overall, the empirical results provide support for the main predictions model. In particular, I find that prices are increasing in product quality and decreasing in plant efficiency. I also find that exporters produce goods of higher quality and that selection into exporting is driven by the firm's ability to generate demand for its product, not by increases in efficiency. This provides evidence against the standard "iceberg" trade cost formulation standard in the literature.

Looking at the broader picture, it is important to emphasize the importance of some of the results presented in this study. First, export status and aggregate factors explain about half of the variation in demand across manufacturing plants in my sample. Since it is difficult to argue that the other half is random, this implies that our current models are missing crucial

[24] Regions are defined according to the Bureau of Economic Analysis' definition of Labor Market Areas. Labor market areas are collections of counties that are usually, but not always, centered on Metropolitan Statistical Areas. See U.S. Bureau of Economic Analysis (1995) for detailed information. This measure of economic geography is superior to political divisions such as states or counties since it is based on commuting patterns. It therefore better captures the economic interactions between groups of producers and consumers. Since plant age cannot be measured accurately in the sample, observations are divided into categories according to the number of Censuses in which they appear. The age is determined using information from Census years 1963, 1967, 1972, 1977, 1982, 1987, 1992, and 1997.

components of producer behavior. Second, the estimated demand shifts, however they are interpreted, contribute significantly in explaining variation in price and unit costs and this link is stronger in more differentiated product categories. Further, these demand shifts are positively related to the plant's physical total factor productivity and export status. These results bring to the fore the importance of those plant-specific demand shifts and call for additional study of their determinants.

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List of Products

The following table lists the codes and description of the 143 five-digit product classes include in the sample - more details are available in Census (1996).

Five Digit SIC Product Codes and Descriptions

SIC	Name	SIC	Name
20111	Beef, not Canned or made into Sausage	23230	Men's and Boy's Neckwear
20114	Pork, not Canned or made into Sausage	23532	Cloth Hats and Caps
20136	Pork, Processed or Cured	23871	Leather Belts
20137	Sausage and Similar Products, not Canned	23872	Belts other than Leather
2013B	Other Processed Meats	24211	Hardwood Lumber
20151	Young Chickens	24212	Softwood Lumber
20153	Turkeys	24217	Softwood Cut Stock
20159	Liquid, Dried, and Frozen Eggs	24261	Hardwood Flooring
20223	Natural Cheese	24262	Hardwood Dimension Stock
20235	Dry Milk Products	24311	Wood Window Units
20352	Pickles and other Pickled Products	24364	Softwood Veneer
20353	Prepared Sauces	24365	Softwood Plywood
20354	Mayonnaise and Salad Dressings	24390	Fabricated Structural Wood Products
20372	Frozen Vegetables	24511	Manufactured Mobile Homes
20382	Frozen Dinners	24931	Particleboard
20384	Frozen Specialties	24937	Prefinished Particleboard
20224	Process Cheese and Related Products	24266	Wood Furniture Frames
20411	Wheat Flour	25113	Wood Dining Room and Kitchen Furniture
20440	Milled Rice	25115	Wood Bedroom Furniture
20473	Dog Food	25120	Upholstered Wood Household Furniture
20481	Chicken and Turkey Feed	25147	Other Metal Household Furniture
20482	Dairy Cattle Feed	25151	Innerspring Mattresses
20483	Dairy Cattle Feed Supplements	26214	Uncoated Free sheet
20485	Swine Feed Supplements	26314	Recycled Paperboard
20487	Beef Cattle Feed Supplements	26530	Corrugated and Solid Fiber Boxes
20511	Bread	26552	Fiber Cans
20512	Rolls, Bread-Type	26570	Folding Paperboard Boxes
20514	Soft Cakes	26732	Specialty Bags and Liners
20521	Crackers, Pretzels, and Biscuits	26741	Grocers Bags and Sacks
20530	Frozen Bakery Products	26742	Shipping Sacks and Multiwall Bags
20610	Sugarcane Mill Products	26753	Surface-Coated Paperboard
20680	Nuts and Seeds	28430	Surfactants and Finishing Agents
20771	Grease and inedible Tallow	28750	Mixed Fertilizers

Five Digit SIC Product Codes and Descriptions – cont.

SIC	Name	SIC	Name
20772	Feed and Fertilizer Byproducts	28917	Nonstructural Caulking Compounds
20791	Shortening and Cooking Oils	28932	Lithographic and offset Inks
20871	Flavoring Extracts	28934	Flexographic Inks
20910	Canned and Cured Fish and Seafoods	29111	Gasoline
20922	Prepared Fresh Fish and Fresh Seafood	29920	Lubricating Oils and Greases
20923	Frozen Fish	31430	Men's Footwear (except Athletic)
20925	Frozen Shellfish	31440	Women's Footwear (except Athletic)
20951	Roasted Coffee	31490	Footwear (except Rubber)
20961	Potato Chips and Sticks	31610	Suitcases
20962	Corn Chips and Related Products	31710	Handbags and Purses
20970	Manufactured Ice	31720	Personal Leather Goods
20980	Macaroni, Spaghetti, and Egg Noodle	32410	Cement, Hydraulic
2099E	Spices	32730	Ready-Mixed Concrete
2099G	Food Preparations	32740	Lime
2221C	85% or more Filament Fabrics	32751	Gypsum Building Materials
2221D	85% or more Spun Yarn Fabrics	33212	Other Ductile Iron Castings
22411	Woven Narrow Fabrics	33219	Other Gray Iron Castings
22516	Women's Finished Panty Hose	33240	Steel Investment Castings
22522	Men's Finished Seamless Hosiery	33417	Aluminum ingot
22571	Weft Knit Fabrics Greige Goods	33532	Aluminum Sheet and Strip
22573	Finished Weft Knit Fabrics	33541	Extruded Aluminum Rod
22581	Warp Knit Fabrics Greige Goods	33630	Aluminum Die-Castings
22584	Finished Warp Knit Fabrics	33640	Nonferrous Die-Castings
22617	Finished Cotton Broadwoven Fabrics	34481	Prefabricated Metal Building Systems
22619	Finishing of Cotton Broadwoven Fabrics	34494	Fabricated Bar Joists
22628	Finished Manmade Fiber and Silk Fabrics	34625	Hot Impression Die Impact
22629	Finishing of Manmade Fabrics	34996	Powder Metallurgy Parts
22690	Finished Yarn	35853	Commercial Refrigerators
22732	Tufted Carpets and Rugs	37322	Outboard Motorboats
22811	Carded Cotton Yarns	37323	Inboard Motorboats
22814	Spun Noncellulosic Fiber and Silk Yarns	37324	Inboard-Outdrive Boats
22825	Filament Yarns	37327	Other Boats
22971	Nonwoven Fabrics	37921	Travel Trailers
22982	Soft Fiber Cordage and Twine	39951	Metal Caskets and Coffins
22995	Paddings and Upholstery Filling		