Multi-Product Firms and Product Quality[*]

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Abstract

This paper argues that quality differentiation is an important feature of the operations of multi-product firms. Manufacturers vary product quality across their product range by using inputs of different quality levels. Firms' core competency is in varieties of superior quality that bring higher sales despite being more expensive. We base these conclusions on four stylized facts that we establish using detailed customs data for China. First, firms earn more bilateral and global revenues from their more expensive products. Second, exporters focus on their top expensive goods, drop cheaper articles and earn lower revenues in markets where they sell fewer varieties. Third, companies' sales are more skewed towards their core expensive goods in destinations where they offer less items. Finally, export prices are positively correlated with input prices across products within a firm. We rationalize these stylized facts with a model of international trade with multi-product, multi-quality firms. Our results have important implications for the effects of trade reforms and the design of trade-promoting policies.

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1 Introduction

An overwhelming share of international trade is conducted by large firms that manufacture a broad variety of products instead of specializing in a limited set of goods. These multi-product firms typically concentrate sales in a few core products that generate the majority of cross-border flows and firm export profits (Bernard et al. 2009, Arkolakis and Muendler 2010). Companies also frequently modify their product mix in response to changes in the economic environment. Such reallocations play an important role in the adjustment to trade reforms and exchange rate movements, thereby shaping firm- and aggregate productivity (Bernard et al. 2010a,b, Gopinath and Neiman 2011, Campos 2010, Chatterjee et al. 2011). While these regularities have been well documented, little is known about the determinants and attributes of firms' core competencies. Identifying these factors is important for understanding the success of multi-product exporters, designing trade-promoting policies, and ultimately aggregate trade outcomes.

This paper argues that quality differentiation is an important feature of the operations of multi-product firms. Manufacturers vary product quality across their product range by using intermediate inputs of different quality levels. Firms' core goods are varieties of superior quality that bring higher sales despite being more expensive. We base these conclusions on four stylized facts that we establish using detailed customs data for China. First, firms earn more bilateral and global revenues from their more expensive products. Second, exporters focus on their top expensive goods, drop cheaper articles and earn lower revenues in markets where they sell fewer varieties. Third, companies' sales are more skewed towards their core expensive goods in destinations where they offer less items. Finally, export prices are positively correlated with input prices across products within a firm.

To discipline the empirical analysis, we develop a model of international trade with quality differentiation across firms and across products within multi-product firms. In the model, manufacturers draw ability levels and product-specific expertise. Better quality guarantees bigger sales but entails higher marginal costs. Abler companies offer a higher quality of any given good, export more varieties, and earn higher revenues. Within each firm, more expensive products generate greater sales. Exporters thus observe a product hierarchy and expand their product range by adding goods in decreasing order of quality. We derive theoretical predictions that allow us to test for the presence of quality differentiation in the data. We also consider two versions of the model that distinguish between constant and variable mark-ups.

Our study relies on the key insight that prices contain information about product quality because manufacturing higher quality requires the use of sophisticated intermediates, skilled workers and specialized equipment. Such inputs are relatively expensive and increase production costs. When quality rises sufficiently quickly with marginal costs, so do good prices and revenues. Conversely, in the absence of vertical differentiation across inputs and outputs, more efficient production techniques are associated with lower marginal costs, lower prices, and higher sales. The prior literature has in fact used the sign of the correlation between prices and revenues across the makers of a product as a litmus test for quality heterogeneity across firms.[1] Similarly, the positive correlation we document between unit values and sales across products within Chinese exporters points to firms varying quality across goods and generating most of their profit stream from high-quality items.

An important component of firms' prices is the mark-up they charge above marginal cost. Alternative demand systems can have very different implications for the optimal mark-ups of single- and multi-product firms. For example, with CES preferences, all manufacturers set the same constant mark-up across all of their goods (Melitz 2003, Bernard et al. 2010a). With linear demand on the other hand, more efficient suppliers impose higher mark-ups, especially on their best-selling commodities (Melitz and Ottaviano 2008, Mayer et al. 2011, Eckel and Neary 2010). Nevertheless, these variable mark-ups do not overturn the sign of the correlation between prices and revenues: In the absence of quality differentiation across firms and products, more productive exporters still command lower prices and earn higher revenues, while firms' leading goods by sales remain their cheapest varieties. The opposite patterns we find in the data can therefore not be easily attributed to variable mark-ups.

Two additional features of our empirical analysis help validate our quality interpretation. First, our results are more pronounced in sectors with greater scope for quality differentiation. The patterns we document are stronger for differentiated goods (relative to homogeneous products) and for R&D- and advertising- intensive industries. Second, input prices are positively correlated with output prices across products within a firm. In the absence of detailed information on domestic input usage or direct measures of product quality, we use the prices producers pay for their imported intermediates as an imperfect signal for the quality of all of their inputs.[2] Since we study multi-product firms that source multiple inputs, we do so by employing detailed input-output tables for China. This allows us to allocate inputs to the production of different export goods and to obtain an average input price for each output.

Although we do not observe mark-ups directly, we are nevertheless able to distinguish between different demand structures. With CES, the distribution of sales across a firm's products is independent of product scope and determined only by products' attributes (such as quality and marginal cost). This is no longer the case with linear demand, because product scope then affects mark-ups across varieties within a firm. In the data, we indeed find that the ratio of export sales of the top to the second-best product within a firm decreases with the number of goods offered. In other words, when firms contract their product range, they shift activity towards their core high-quality goods both along the extensive and the intensive margin: They sell fewer varieties by dropping cheaper, lower-quality products and move market share towards their top, high-quality products. These results are consistent with variable mark-ups and with findings in Mayer et

[1] See for example Verhoogen (2008), Kugler and Verhoogen (2012), Hallak and Sivadasan (2008), Kneller and Yu (2008), Iacovone and Javorcik (2010), and Manova and Zhang (2012).

[2] This is consistent with Kugler and Verhoogen (2009) who find a positive correlation between the prices Colombian plants pay for imported and domestic inputs.

al. (2011) for France. While they consider only firms' product ranking by sales, we also study product hierarchies based on prices.[3]

Most directly, we contribute to two recent literatures that have evolved indepently of each other: the literature on multi-product firms and the literature on firm heterogeneity in efficiency and output quality (see references above). We are one of the first to examine questions at the intersection of these two lines of research. In concurrent work, Eckel et al. (2011) offer the only other study of multi-product, multi-quality companies using data for Mexico. They find that manufacturers' more expensive varieties generate higher domestic revenues and bigger export sales worldwide. We corroborate the latter pattern for the case of China, and offer additional results for the variation in exporters' product scope, product quality, and sales concentration across destinations. We also employ information on firms' input prices to proxy product quality. These additional results prove important for understanding the behavior of multi-product exporters, especially with regards to how they optimize over quality and mark-ups.

On the theoretical side, our model is the first to formally introduce product quality in extensions of Melitz (2003) and Melitz and Ottaviano (2008) to multi-product firms. Nevertheless, it can be seen as a quality interpretation of existing treatments of multi-product firms that abstract away from vertical differentiation, namely Bernard et al. (2010a) and Mayer et al. (2011). We therefore emphasize our empirical contribution and the new stylized facts we document. We view the theoretical framework as an illustration of the economic mechanisms at play and as validation that our interpretation of the empirical results is internally consistent.

More broadly, our findings shed light on the determinants of firms' export success and the design of export-promoting policies in developing countries. While improving production efficiency enables firms to manufacture goods more cheaply, our analysis indicates that quality upgrading is equally if not more important for competing in global markets, especially in industries with greater scope for quality differentiation. This suggests how policy makers may want to target investment– and trade stimulating interventions, especially in developing economies where producers face restricted access to capital and skilled labor necessary for quality upgrading.

In the same vein, the patterns we uncover imply that facilitating access to high-quality inputs can allow manufacturers to increase output quality and thereby improve export performance. Given the limited availability of specialized parts in less advanced countries, import liberalization might therefore be an important policy option for emerging markets that rely on export activity for economic growth. This is consistent with prior evidence that foreign materials are of superior quality than domestic inputs and that importing a wider range of intermediates allows firms to expand their product scope (Kugler and Verhoogen 2009, Goldberg et al. 2010).

Our results also have implications for the welfare and distributional consequences of globalization. Firm heterogeneity has been shown to increase the ex-ante welfare gains from trade, even if not ex-post welfare conditional on reaching a certain share of expenditure on foreign

[3] See De Loecker et al. (2012) for related work on how multi-product firms adjust mark-ups after trade reforms.

goods (Arkolakis et al. 2012, Melitz and Redding 2013). It seems intuitive and likely that the same arguments would apply to the role of multi-product firms. Endogenous productivity growth appears to matter as well (Burstein and Melitz 2011). Separately, there is growing evidence that financial and labor market frictions significantly distort cross-border trade (c.f. Manova 2013, Helpman et al. 2010, Cosar et al. 2010). Since producers can choose to upgrade quality just as productivity, and since resources are arguably easier to reallocate across products within a firm than across firms, the operations of multi-product exporters could thus importantly affect welfare. To the extent that sophisticated inputs and skilled labor are complementary in the production of quality goods (Verhoogen 2008), trade liberalization might also shift employment and wages differentially across the skill distribution.

Finally, the stylized facts we uncover indirectly inform studies of exchange rate pass-through to producer and consumer prices (c.f. Gopinath et al. 2011). Given the significance of multi-product firms in international trade, it is important to understand their pricing strategies. This requires knowledge of how product quality and the use of imported inputs affect marginal costs.

The remainder of the paper is organized as follows. The next two sections introduce the model and its testable predictions. Section 4 provides an overview of the data, while Section 5 presents the empirical results. The last section concludes.

2 Theoretical Framework

We incorporate quality variation across firms and across products within firms in two existing models of multi-product firms: Bernard, Redding and Schott (2010a) (henceforth BRS) and Mayer, Melitz and Ottaviano (2011) (henceforth MMO). We consider both in order to compare environments with constant and with variable mark-ups. To highlight the novel results, the exposition moves quickly and describes the economy in partial equilibrium.[4] We focus on how firms choose which products to manufacture, which markets to enter, and which products to sell in each market. The theory retains most features of BRS and MMO but inverts the relationships between firm prices and various export outcomes as higher prices are associated with better quality and superior performance.

2.1 Quality production technology

Consider a world with $J+1$ countries. In each country, a continuum of heterogeneous firms produce horizontally and vertically differentiated goods. In order to begin production, firms have to incur sunk entry costs associated with research and product development. Firms face uncertainty about their production costs and product quality, and observe them only after completing this irreversible investment. At that point, firms decide whether to exit immediately, sell at home or export. To economize on notation, we do not include subscripts indicating the exporting country.

[4] In general equilibrium, the sunk entry costs would pin down a free entry condition and the labor market would clear. The predictions of the model tested in the empirical section would not change qualitatively.

Manufacturing goods of higher quality is associated with higher marginal costs because it requires the use of more sophisticated - and thus more expenive - inputs and assembly technologies. This assumption is motivated by evidence in the prior literature of a positive correlation between product quality, input prices and output prices (Verhoogen 2008, Kugler and Verhoogen 2012, Manova and Zhang 2012, Crozet et al. 2009, Iacovone and Javorcik 2010). For expositional simplicity, we do not explicitly model firms' input choice but follow Baldwin and Harrigan (2011) in assuming that product quality is fixed by a marginal cost draw.[5] There is a unique input factor, labor, whose wage is normalized to 1 to serve as the numeraire.

The quality of a firm's product is determined by two components: firm-wide ability $\varphi \epsilon (0, \infty)$ drawn from a distribution $g(\varphi)$, and firm-product specific expertise $\lambda_i \epsilon (0, \infty)$ drawn from a distribution $z(\lambda)$. At a marginal cost of $\varphi\lambda_i$ workers, the firm can produce one unit of product i with quality $q_i(\varphi, \lambda_i) = (\varphi\lambda_i)^{1+\theta}$, $\theta > -1$.[6] This parameterization captures the idea that abler firms can offer higher quality across the full range of their product space for given expertise draws, for example because they have better management, equipment or marketing. At the same time, the success of research and product development may differ across products within a firm, resulting in varying degrees of expertise and product quality. $g(\varphi)$ and $z(\lambda)$ are assumed independent of each other and common across firms with continuous cumulative distribution functions $G(\varphi)$ and $Z(\lambda)$ respectively, while λ is i.i.d. across products and firms.

2.2 Firm behavior under CES demand

Set up

We first study firm behavior when consumers exhibit love of variety such that the representative consumer in country j has a CES utility function:

$$U_j = \left[\int_{i \in \Omega_j} (q_{ji} x_{ji})^{\alpha} \, di \right]^{\frac{1}{\alpha}}. \tag{1}$$

Here q_{ji} and x_{ji} represent the quality and quantity consumed by country j of variety i, and Ω_j is the set of goods available to j. The elasticity of substitution across products is $\sigma \equiv 1/(1-\alpha) > 1$ with $0 < \alpha < 1$. If total expenditure in country j is R_j, j's demand for variety i is

$$x_{ji} = R_j P_j^{\sigma-1} q_{ji}^{\sigma-1} p_{ji}^{-\sigma}, \text{ where } P_j = \left[\int_{i \in \Omega_j} \left(\frac{p_{ji}}{q_{ji}} \right)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}} \tag{2}$$

is a quality-adjusted ideal price index and p_{ji} is the price of that variety in country j. In this set up, quality is defined as any intrinsic characteristic, taste preference or other demand shock

[5] See Verhoogen (2008) and Johnson (2012) for models in which more productive firms optimally choose to use higher quality inputs or adopt a more expensive technology to produce higher-quality goods. Endogenizing product quality in this way would not change the qualitative predictions of the model.

[6] An alternative interpretation of this cost structure is that workers have heterogeneous skills, and that more skilled workers earn a higher wage and are able to produce goods of better quality.

that increases the consumer appeal of a product given its price. Our empirical analysis will emphasize the first of these interpretations as we will examine evidence on input prices as a proxy for inherent product quality.

As standard with CES demand, a number of additional assumptions about firms' cost structure are required in order to match important patterns in the data. Aside from the sunk entry cost, firms also face a fixed operation cost of headquarter services f_h and a fixed management cost f_p for each active product line, in units of labor. This will imply that companies with different ability draws will choose to produce a different number of products. Entering each foreign market j is associated with additional headquarter services f_{hj} necessary for complying with customs and other regulations, as well as for the maintenance of distribution networks. Because of this fixed cost, some low-ability sellers in the domestic market will not become exporters or will supply some but not all countries. Finally, exporting entails additional destination-product specific fixed costs f_{pj} (constant across products within j, but varying across countries), which reflect market research, advertising, product customization and standardization. There are also variable transportation costs of the iceberg kind such that τ_j units of a good need to be shipped for 1 unit to arrive. These trade costs will ensure that firms might not offer every product they sell at home in every market they enter.

Production and exporting

With monopolistic competition and a continuum of varieties, firms take all price indices P_j as given. Moreover, a firm's price for product i does not affect demand for its other products.[7] Manufacturers thus separately maximize profits in each country-product market. In particular, a firm with ability φ will choose the price and output level of a product with expertise draw λ_i in country j by solving

$$\begin{aligned} \max_{p,x} \pi_{ji}(\varphi,\lambda_i) &= p_{ji}(\varphi,\lambda_i)\, x_{ji}(\varphi,\lambda_i) - \tau_j x_{ji}(\varphi,\lambda_i)\,\varphi\lambda_i - f_{pj} \\ \text{s.t. } x_{ji}(\varphi,\lambda_i) &= R_j P_j^{\sigma-1} q_{ji}(\varphi,\lambda_i)^{\sigma-1}\, p_{ji}(\varphi,\lambda_i)^{-\sigma}. \end{aligned} \quad (3)$$

Producers will therefore charge a constant mark-up $\frac{1}{\alpha}$ over marginal cost and earn the following revenues and profits:

$$p_{ji}(\varphi,\lambda_i) = \frac{\tau_j\varphi\lambda_i}{\alpha}, \qquad r_{ji}(\varphi,\lambda_i) = R_j\left(\frac{P_j\alpha}{\tau_j}\right)^{\sigma-1}(\varphi\lambda_i)^{\theta(\sigma-1)}, \qquad \pi_{ji}(\varphi,\lambda_i) = \frac{r_{ji}(\varphi,\lambda_i)}{\sigma} - f_{pj}. \quad (4)$$

When j corresponds to the firm's home market, there are no iceberg costs ($\tau_j = 1$) and the destination-product fixed cost f_{pj} is replaced by the product-specific overhead cost f_p. Note that the empirical analysis examines free-on-board export prices and revenues, that is $p_{ji}^{fob}(\varphi,\lambda_i) = \frac{\varphi\lambda_i}{\alpha}$ and $r_{ji}^{fob}(\varphi,\lambda_i) = R_j (P_j\alpha)^{\sigma-1}(\varphi\lambda_i)^{\theta(\sigma-1)}$.

If $\theta = -1$, the model would reduce to the original BRS framework in which firms (firm-products) with lower marginal costs $\varphi\lambda_i$ set lower prices and earn higher revenues and profits.

[7] See Eckel et al. (2011) for an alternative model which incorporates product cannibalization effects.

While there would be quality differentiation across firms and products if $\theta\epsilon\left(-1,0\right)$, quality would not increase sufficiently quickly with marginal costs to overturn these predictions. When $\theta > 0$, however, quality does rise sufficiently quickly with marginal costs to matter: Within a given product category, more successful firms now enjoy bigger revenues and profits despite charging higher prices because they offer products of better quality. Across products within a firm, more expensive varieties are of higher quality and generate higher revenues and profits. To emphasize our novel results, we focus on $\theta > 0$ below.

Consumer love of variety and the presence of product specific overhead costs f_p imply that no firm will export a product without also selling it at home. In turn, firms optimally manufacture only goods for which they can earn non-negative profits domestically. Since profits increase in expertise, for each ability draw φ, there is a zero-profit expertise level $\lambda^*\left(\varphi\right)$ below which the firm will not make i. This value is defined by:

$$r_d\left(\varphi,\lambda^*\left(\varphi\right)\right)=\sigma f_p, \tag{5}$$

where d indicates that revenues are calculated for the domestic market.

Recall that product expertise is independently and identically distributed across goods. By the law of large numbers, the measure of varieties that a firm with ability φ will produce equals the probability of an expertise draw above $\lambda^*\left(\varphi\right)$, or $\left[1-Z\left(\lambda^*\left(\varphi\right)\right)\right]$. Since $d\lambda^*\left(\varphi\right)/d\varphi < 0$, higher-ability firms will have a lower zero-profit expertise cut-off and offer more products. One interpretation of this result is that abler firms bring superior managerial, equipment or marketing quality to any product. This can partially offset using less skilled workers or inputs of lower quality such that output quality and consumer appeal remain high.

Turning to exporting, firms will only introduce a product in a given market if they expect to make positive profits. Since profits rise with product expertise, a firm with ability φ will export product i to country j only if its expertise draw is no lower than $\lambda_j^*\left(\varphi\right)$ given by:

$$r_j\left(\varphi,\lambda_j^*\left(\varphi\right)\right)=\sigma f_{pj}. \tag{6}$$

The measure of products that firm φ exports to j will thus equal $\left[1-Z\left(\lambda_{xj}^*\left(\varphi\right)\right)\right]$. Since $d\lambda_j^*\left(\varphi\right)/d\varphi < 0$, abler firms export more products than less able firms to any given destination.

When the exporting expertise cut-off lies above the zero-profit expertise cut-off, $\lambda_j^*\left(\varphi\right) > \lambda^*\left(\varphi\right)$, there will be selection into exporting. Across products within a firm, not all goods sold at home will be shipped to j. Similarly, across firms supplying a product domestically, not all will be able to market it abroad. Given the prevalence of both patterns in the empirical literature, we assume that $\lambda_j^*\left(\varphi\right) > \lambda^*\left(\varphi\right)$ holds for all j.

For every ability φ, the expertise cut-off for exporting will vary across destinations because the market size R_j, price index P_j, variable τ_j and fixed f_{pj} trade costs are country specific. Firms therefore adjust their product range across markets. In particular, each exporter follows a unique hierarchy of products in every destination and adds goods in decreasing order of product quality (and marginal cost) until it reaches the marginal product which brings zero profits. Within a supplier, higher-quality goods will be shipped to more countries, earn higher revenues in any given market, and generate higher worldwide sales. A firm's core, top-selling variety in every market will be its most expensive, highest-quality item.

The nature of this product ladder is the main dimension along which the model with multi-product, multi-quality firms differs from BRS. In the absence of quality differentiation across goods, firms' core competencies lie in their cheapest varieties. This means that when $\theta < 0$, firms expand their product range by adding products in increasing order of marginal cost.

CES preferences imply that within a firm, the ratio of two goods' revenues in a given market does not depend on product scope. It is instead pinned down by the ratio of the supplier's expertise in manufacturing these varieties: $r_{j1}(\varphi, \lambda_1) / r_{j2}(\varphi, \lambda_2) = (\lambda_1/\lambda_2)^{\theta(\sigma-1)}$. In other words, when firms enlarge or contract their product range, this affects their product mix (extensive margin) but not the sales distribution across inframarginal products (intensive margin).

Observe that product hierarchies will generally vary among producers because the expertise draws are i.i.d across firms and goods. In practice, the product ranking might also vary across countries within a manufacturer if there are idiosyncractic taste or cost shocks at the firm-destination-product level. For simplicity, we abstract away from such idiosyncracies in the model and note that these would only work against us finding empirical support in the data.

2.3 Firm behavior under linear demand

Set up

We next examine the decisions of multi-product firms when consumer preferences take a different form:

$$U_j = x_{j0} + \beta \int_{i\in\Omega_j} q_{ji} x_{ji} di - \frac{1}{2}\gamma \int_{i\in\Omega_j} (q_{ji}x_{ji})^2 di - \frac{1}{2}\eta \left[\int_{i\in\Omega_j} q_{ji}x_{ji} di\right]^2, \tag{7}$$

where x_{j0} is the consumption level of a homogeneous numeraire good in country j. As before, q_{ji} and x_{ji} represent the quality and quantity consumed of variety i, and Ω_j is the set of differentiated goods available to j. The parameters $\beta > 0$ and $\eta > 0$ govern the elasticity of substitution between the numeraire and the differentiated products, while $\gamma > 0$ captures the degree of product differentiation across varieties i. Denoting total expenditure in country j as R_j, this utility function gives rise to linear demand for item i:

$$x_{ji} = \frac{R_j}{\gamma q_{ji}} \left(\widehat{P}_j - \frac{p_{ji}}{q_{ji}}\right), \text{ where } \widehat{P}_j = \frac{\eta M_j P_j + \beta\gamma}{\eta M_j + \gamma} \text{ and } P_j = \frac{1}{M_j} \int_{i\in\Omega_j} \frac{p_{ji}}{q_{ji}} di. \tag{8}$$

Here M_j is the measure of varieties consumed in j, and P_j their average quality-adjusted price. Notably, $\widehat{P}_j$ is a quality-adjusted price ceiling, above which demand is 0. Combined with an iceberg transportation cost τ_j, this choke price will be sufficient to generate selection of firms into exporting, as well as selection of products within firms into specific foreign markets. For expositional simplicity, we therefore follow standard practice in the literature and assume away all fixed production and trade costs that entered the CES case above.

Production and exporting

As before, firms are atomistic, take all price indices as given, and there are no cannibalization effects across a manufacturer's goods. To maximize profits, producers therefore choose their price and output level separately in each destination-product market:

$$\begin{aligned} \max_{p,x} \pi_{ji}(\varphi,\lambda_i) &= p_{ji}(\varphi,\lambda_i)\, x_{ji}(\varphi,\lambda_i) - \tau_j x_{ji}(\varphi,\lambda_i)\,\varphi\lambda_i \\ \text{s.t. } x_{ji}(\varphi,\lambda_i) &= \frac{R_j}{\gamma q_{ji}(\varphi,\lambda_i)}\left[\widehat{P}_j - \frac{p_{ji}(\varphi,\lambda_i)}{q_{ji}(\varphi,\lambda_i)}\right]. \end{aligned} \tag{9}$$

Firms' optimal price, mark-up v, revenues and profits for product i in country j are now given by:

$$\begin{aligned} p_{ji}(\varphi,\lambda_i) &= \frac{1}{2}\left[\widehat{P}_j (\varphi\lambda_i)^{1+\theta} + \tau_j\varphi\lambda_i\right], \qquad v_{ji}(\varphi,\lambda_i) = \frac{1}{2}\left[\widehat{P}_j (\varphi\lambda_i)^{1+\theta} - \tau_j\varphi\lambda_i\right], \\ r_{ji}(\varphi,\lambda_i) &= \frac{R_j}{4\gamma}\left[\widehat{P}_j^2 - \tau_j^2 (\varphi\lambda_i)^{-2\theta}\right], \qquad \pi_{ji}(\varphi,\lambda_i) = \frac{R_j}{4\gamma}\left[\widehat{P}_j - \tau_j (\varphi\lambda_i)^{-\theta}\right]^2. \end{aligned} \tag{10}$$

The case of $\theta = -1$ corresponds to the MMO model, in which firms (firm-products) with lower marginal costs $\varphi\lambda_i$ have lower prices, higher revenues and bigger profits. The same is true if $\theta \epsilon (-1, 0)$ and quality increases only slowly with marginal costs. When $\theta > 0$, however, these patterns are reversed: Now firms earn greater revenues and profits from their more expensive varieties because they offer consumers superior quality. This is the case we study below.

Reasoning as before, firms will observe a strict hierarchy of products based on their quality level. In each market they enter, they will start with the same core variety and add more goods in decreasing order of expertise. Since profits rise monotonically with quality, firm φ's optimal product range in market j will be determined by an expertise threshold $\lambda_j^*(\varphi)$ for which profits are 0. Similarly, the producer will make only goods above a zero-profit expertise level $\lambda^*(\varphi)$ determined in its domestic market d (where $\tau_j = 1$). These cut-offs are defined by:

$$\widehat{P}_d = (\varphi\lambda^*(\varphi))^{-\theta} \qquad \text{and} \qquad \widehat{P}_j = \tau_j \left(\varphi\lambda_j^*(\varphi)\right)^{-\theta}. \tag{11}$$

When $\lambda_j^*(\varphi) > \lambda^*(\varphi)$, there will be selection into exporting and not all goods φ sells at home will be shipped to j. Once again, abler firms export more products than less able firms to any given destination because $d\lambda_j^*(\varphi)/d\varphi < 0$. Moreover, a given supplier will vary its product scope across countries in response to differences in market conditions as summarized by $\widehat{P}_j$ and τ_j. In particular, firms export fewer goods to tougher markets where the choke price $\widehat{P}_j$ is lower.

These results are all qualitatively the same as with CES preferences. An important distinguishing feature of linear demand, however, is its implication for mark-ups. While constant under CES, mark-ups now vary across firms, products and destinations in systematic ways. All else constant, abler producers extract higher mark-ups than less able competitors. Across goods within a firm, core varieties of higher quality receive higher mark-ups than peripheral varieties of lower quality. A firm's high-quality products thus sell at steeper prices both because they entail higher marginal costs and because they secure bigger mark-ups. Finally, while marginal cost and quality are constant across destinations within a firm-product pair, mark-ups and prices are lower in more competitive markets where the price ceiling $\widehat{P}_j$ is lower.

Recall that the distribution of sales across a firm's goods is independent of its product scope under CES. This is no longer the case with variable mark-ups and linear demand. Within a firm, the sales ratio of two goods in country j is now $r_{j1}(\varphi,\lambda_1)/r_{j2}(\varphi,\lambda_2) = 1 + \frac{\tau_j^2(\varphi\lambda_2)^{-2\theta} - \tau_j^2(\varphi\lambda_1)^{-2\theta}}{\widehat{P}_j^2 - \tau_j^2(\varphi\lambda_2)^{-2\theta}}$. If $\lambda_1 > \lambda_2$, this ratio is decreasing in $\widehat{P}_j$ because both its numerator and denominator are positive. In other words, in tougher markets with lower choke prices $\widehat{P}_j$, firms shift activity towards their core high-quality goods both along the extensive and the intensive margin: They sell fewer varieties by dropping cheaper, lower-quality products and skew sales towards their top, high-quality products.

2.4 Firm profits

Whether firms operate under CES or linear demand, they enter a given market only if total expected revenues there exceed all associated costs. The export profits in country j of a firm with ability φ are:

$$\pi_j(\varphi) = \int_{\lambda_j^*(\varphi)}^{\infty} \pi_j(\varphi,\lambda)\, z(\lambda)\, d\lambda - f_{hj}. \tag{12}$$

Recall that the destination-specific overhead headquarters costs f_{hj} have been normalized to 0 for the case of linear demand.

Abler firms have a lower exporting expertise cut-off $\lambda_j^*(\varphi)$ and sell more products in j. They also earn higher revenues from each good than firms with the same product expertise draw but lower ability. Since export profits $\pi_j(\varphi)$ increase with ability, only firms with ability above a cut-off level φ_j^* will service destination j, where φ_j^* satisfies:

$$\pi_j\left(\varphi_j^*\right) = 0. \tag{13}$$

With asymmetric countries, φ_j^* varies across destinations and abler firms enter more markets because they are above the exporting ability cut-off for more countries. Abler exporters thus outperform less able producers along all three export margins: number of export destinations, product range in each country, and sales in each destination-product market.

Finally, not all firms that incur the sunk cost of entry survive. Once they observe their ability and expertise draws, firms begin production only if their expected profits from all domestic and foreign operations are non-negative. Firm φ's total profits are given by:

$$\pi(\varphi) = \int_{\lambda^*(\varphi)}^{\infty} \pi_d(\varphi,\lambda)\, z(\lambda)\, d\lambda + \sum\nolimits_j \left(\int_{\lambda_j^*(\varphi)}^{\infty} \pi_j(\varphi,\lambda)\, z(\lambda)\, d\lambda - f_{hj} \right) - f_h, \tag{14}$$

where we have assumed that the fixed cost of headquarter services $f_h = 0$ under linear demand. The first integral in this expression captures the firm's domestic profits from all products above its expertise cut-off for production $\lambda^*(\varphi)$, while the summation represents worldwide export profits from all traded products and destinations.

Total profits increase in φ because abler firms sell more products domestically, earn higher domestic revenues for each product, and have superior export performance as described above. Companies below a minimum ability level φ^* are therefore unable to break even and exit immediately upon learning their attributes. This cut-off is defined by the zero-profit condition:

$$\pi(\varphi^*) = 0. \tag{15}$$

3 Empirical Predictions

Section 2 delivers a number of testable predictions that make it possible to empirically distinguish between models of multi-product firms with and without quality differentiation, as well as between models with constant and with variable mark-ups. These key predictions are summarized in this section and provide the backbone for our empirical analysis. For clarity, we state all results in terms of $\theta > 0$ and $\theta < 0$, since quality differentiation affects observed firm outcomes in the data only in the former case. We discuss CES vs. linear demand only when there are material differences between the two.

3.1 Variation across firms within a product

Within a given product category, the correlation between price and revenue across firms depends on the extent of quality differentiation. This is a central result in the prior literature and not novel to our framework. We restate it here for completeness but do not examine it empirically given the prior evidence consistent with quality sorting across firms.

Proposition 1 *If $\theta > 0$, product prices and revenues are positively correlated across firms within a destination-product market. If $\theta < 0$, this correlation is negative.*

3.2 Variation across products within a firm

In the absence of vertical differentiation across products, firms' core products have low marginal costs and prices. By contrast, when there is scope for quality upgrading, firms' best-selling varieties are associated with better quality, higher marginal costs and higher prices.

Proposition 2 *If $\theta > 0$, product prices are positively correlated with worldwide revenues across products within a firm, and positively correlated with bilateral revenues across products within a firm-destination. If $\theta < 0$, these correlations are negative.*

3.3 Variation across destinations within a firm

Product scope and product hierarchies

Multi-product firms observe a hierarchy of products. Each firm focuses on its core competencies and drops its peripheral goods in destinations where it sells fewer products This has implications for a firm's average price $\overline{p}_j(\varphi)$ across the products it offers in market j:

$$\text{CES:} \quad \overline{p}_j(\varphi) = \frac{\tau_j \varphi}{\alpha} \int_{\lambda_j^*(\varphi)}^{\infty} \lambda z(\lambda)\, d\lambda, \qquad \text{LD:} \quad \overline{p}_j(\varphi) = \frac{1}{2} \int_{\lambda_j^*(\varphi)}^{\infty} \left[\widehat{P}_j(\varphi\lambda)^{1+\theta} + \tau_j \varphi \lambda \right] z(\lambda)\, d\lambda. \tag{16}$$

Consider first the case of CES preferences and constant mark-ups. Under quality sorting, exporters add varieties in decreasing order of marginal cost and quality. Firm φ will thus offer lower average quality at a lower average price in countries where it exports more products, i.e. $\lambda_j^*(\varphi)$ is lower. In the absence of quality differentiation, product scope and $\overline{p}_j(\varphi)$ are instead positively correlated across destinations within firms, because exporters add products in increasing order of marginal cost.

Note that $\overline{p}_j(\varphi)$ is an arithmetic mean. One could alternatively consider a sales-weighted average price, $\widetilde{p}_j(\varphi) = \frac{\tau_j \varphi}{\alpha} \int_{\lambda_j^*(\varphi)}^{\infty} \frac{r_j(\varphi,\lambda)}{r_j(\varphi)} \lambda z(\lambda)\, d\lambda$ where $r_j(\varphi) = \int_{\lambda_j^*(\varphi)}^{\infty} r_j(\varphi,\lambda) z(\lambda)\, d\lambda$ are total firm revenues in j. The correlation of product scope with $\widetilde{p}_j(\varphi)$ is, however, thereotically ambiguous. With quality sorting for example, when firms expand their product range they add low-quality cheap products, but these goods generate limited revenues. If the former effect is sufficiently strong, $\widetilde{p}_j(\varphi)$ will fall with product scope, but less quickly than the simple average.

Consider next the case of linear demand. Under quality differentiation, the relationship between product range and the average price across markets within firms is thereotically ambiguous because of two opposing forces. In less competitive markets, firms sell more low-quality varieties which tends to lower $\overline{p}_j(\varphi)$, but they also set higher mark-ups which tends to increase $\overline{p}_j(\varphi)$. The net effect is thus indeterminate. Without quality variation, both mechanisms go in the same direction such that product scope and $\overline{p}_j(\varphi)$ are unambiguously positively correlated.

Proposition 3 *Firms observe a hierarchy of products in all markets. If $\theta > 0$, product scope is positively or negatively correlated with average price across destinations within a firm. If $\theta < 0$, this correlation is unambiguously positive.*

Note that according to this proposition, finding a negative correlation in the data conclusively indicates quality sorting, while a positive correlation does not rule it out.

Product scope and firm sales

All else constant, firms earn higher revenues in destinations where they ship more goods. Depending on the structure of demand, the distribution of sales across products may or may not change with the number of varieties sold. These relationships hold regardless of the presence and extent of quality differentiation in the market.

Proposition 4 *All else constant, product scope is positively correlated with total bilateral revenues across destinations within a firm. With CES preferences, the distribution of sales across products is unaffected by product scope. With linear demand, the distribution of sales is more skewed towards firms' core products in markets where they sell fewer goods.*

4 Data

Our analysis exploits proprietary data from the Chinese Customs Office on the universe of Chinese firms that participated in international trade over the 2003-2005 period.[8] These data report the free-on-board value of firm exports and imports in U.S. dollars by product and trade partner for 243 destination/source countries and 7,526 different products in the 8-digit Harmonized System.[9] They also record the quantities traded in one of 12 different units of measurement (such as kilograms, square meters, etc.), which makes it possible to construct unit values. Trade volumes for each product are consistently documented in a unique unit of measurement.

In principle, unit values should precisely reflect producer prices. Since trade datasets rarely contain direct information on prices, the prior literature has typically relied on unit values as we do. The level of detail in our data is an important advantage as the unit prices we observe are not polluted by aggregation across firms or across markets and products within firms. We have confirmed that all of our results are robust to excluding potential outliers with price levels below the 1^{st} percentile of above the 99^{th} percentile.

While we observe all trade transactions at the monthly frequency, we focus on annual exports in the most recent year in the panel (2005) for three reasons. First, we are interested in documenting stylized facts about the cross-sectional variation among firms and do not study export dynamics. Second, there is a lot of seasonality and lumpiness in the monthly data, and most companies do not sell a given product to a given market in every month. By focusing on annual data, we abstract from these issues and related concerns with sticky prices. Finally, outliers are likely to be of greater concern in the monthly data.

Some state-owned enterprises in China are pure export-import businesses that do not engage in manufacturing but serve exclusively as intermediaries between domestic producers (buyers) and foreign buyers (suppliers). Following standard practice in the literature, we identify such wholesalers using keywords in firms' names and exclude them from our sample.[10] We do so in order to focus on the operations of companies that both make and trade goods since we are interested in how production efficiency and product quality affect export activity. Showing direct evidence on the prices firms pay for imported inputs is thus an important part of our analysis as they proxy for input quality. We cannot apply this approach to intermediaries because we do

[8] Manova and Zhang (2008) describe these data and provide an overview of Chinese trade patterns.

[9] Product classification is consistent across countries at the 6-digit HS level. The number of distinct product codes in the Chinese 8-digit HS classification is comparable to that in the 10-digit HS trade data for the U.S..

[10] We drop 23,073 wholesalers who mediate a quarter of China's trade. Using the same data, Ahn et al. (2011) identify intermediaries in the same way in order to study wholesale activity.

not observe their suppliers and cannot interpret their import transactions as input purchases.

We study the variation in the scope for quality differentiation across products using three relatively standard proxies in the literature. These measures are meant to capture technological characteristics of the manufacturing process that are exogenous from the perspective of an individual firm. The first indicator is the Rauch (1999) dummy for differentiated goods that are not traded on an organized exchange or listed in reference manuals. It is available for SITC-4 digit categories, which we concord to the Chinese HS-8 digit classification. We also employ continuous measures of R&D intensity or combined advertising and R&D intensity from Klingebiel et al. (2007) and Kugler and Verhoogen (2008), respectively. These are based on U.S. data for 3-digit ISIC sectors, which we match to the HS-8 products in our sample. The imperfect correlation among these three indices of quality differentiation makes it unlikely that our results are driven by some other unobserved product characteristic.

4.1 Comparing prices across products

Our empirical strategy rests critically on the comparison of prices across a firms' product range. Conceptually, we are interested in how quality differs across products, where quality is interpreted as the utility consumers derive from a single physical unit of a product. This poses an obvious challenge: While it is easy to conclude that a rotten apple is of worse quality than a shiny apple, and that a moldy orange is inferior to a fresh orange, it is difficult to rank the appeal of an apple and an orange in absolute terms (Figure 1). We can however rate them in relative terms, by noting how they measure up to the average apple and orange offered on the market. This is precisely what we do. It is consistent with the idea that quality is in the eye of a discerning beholder who uses market-wide average quality as a benchmark.

Figure 2 illustrates the logic behind this idea. Consider two firms, each of which produces apples and oranges. Compared to the average fruit in this market, Firm 1 sells much more delicious-looking apples but its oranges are covered in mold. By contrast, Firm 2 offers half-rotten apples and perfectly juicy oranges. To describe this environment, we will say that Firm 1's apples are of higher quality than its oranges, while Firm 2's apples are of lower quality than its oranges. Through the lens of the model, this would imply that apples are Firm 1's core product and oranges its peripheral good. Conversely, Firm 2's core competency lies in growing oranges, and apples are its peripheral good.

We implement this approach by demeaning every export (import) unit value by the average observed across all firms exporting (importing) that product. For example, if firm f charges $\log price_{fp}$ for product p, and the average log export price across all Chinese firms selling p is $\overline{\log price_p}$, then we use $\log price_{fp} - \overline{\log price_p}$ as a standardized price that we can compare across f's different goods. When we examine f's operations in a particular destination d, we are careful to demean its export prices by the relevant averages across Chinese exporters to that specific market. In other words, if f ships products p and p' to country d, we will compare

$\log price_{fpd} - \overline{\log price_{pd}}$ to $\log price_{fp'd} - \overline{\log price_{p'd}}$. Our results for bilateral exports are however not sensitive to this choice of demeaning, and also obtain if we subtract the global $\overline{\log price_{p}}$ and $\overline{\log price_{p'}}$ averages instead.

Working with log prices instead of prices is motivated by two reasons. First, it is what the model calls for, given that we will estimate theoretically-derived equations in their log-linear form with Ordinary Least Squares. Second, by demeaning log prices we obtain the distance between a firm's price from the market average in percentage terms instead of in absolute levels. This facilitates the comparison of prices across goods by accounting for differences across products in both the first and second moments of the price distribution.

4.2 A first glance at the data

Table 1 illustrates the substantial variation in export prices across the 96,522 Chinese manufacturers, 6,908 products, and 231 importing countries in our data. Consider first the average price for each firm-product pair, constructed as the ratio of worldwide revenues and quantities shipped to all destinations d, $price_{fp} = \frac{\sum_d revenue_{fpd}}{\sum_d quantity_{fpd}}$. After removing product fixed effects, the mean log price in the data is 0.00, with a standard deviation of 1.33 across goods and manufacturers. There is comparable dispersion at the firm-product-destination level, with an average log price of 0.00 and standard deviation of 1.24.

Prices vary considerably across Chinese producers selling a particular good to a given country: The standard deviation of firm prices in the average destination-product market is 0.90. This highlights the extent of firm heterogeneity in the data.

There is also a lot of variation in unit values across products within a given exporter. The standard deviation of demeaned log prices across goods for the average supplier is 0.85 when we consider worldwide exports. This number is 0.74 when we instead look at the spread of bilateral prices across products for the average firm-destination pair. This demonstrates the heterogeneity in product attributes across exporters' merchandise.

A growing body of work has established that export prices and revenues are positively correlated across firms within narrow product categories. This pattern holds in our data as well. Appendix Table 1 reproduces results from Manova and Zhang (2012). Using the same data, they regress log export unit values on log export sales by firm, product and destination. Controlling for destination-product fixed effects, they find a positive and significant coefficient. This association is moreover stronger among differentiated goods and sectors intensive in R&D or advertising. This evidence is consistent with quality differentiation across firms, with more successful exporters offering higher-quality goods at steeper prices.

The main contribution of our paper is in describing the variation in outcomes across goods within a firm. We therefore move away from studying the variation across firms within products explored in Manova and Zhang (2012), and instead include firm or firm-destination fixed effects in all of our regressions. As a first pass at the data, we document summary statistics indicative of a positive correlation between export prices and revenues across products within a manufacturer. We rank each firm's products twice, based on either worldwide export revenues or export prices. The best selling or most expensive good is ranked first, the second most receives second rank, etc. We thus obtain every firm's *global* product rank by sales or price.

Table 2 shows that firms' top-selling varieties tend to be their most expensive articles. Each cell in the table indicates what fraction of all firm-product pairs receive a certain rank by price (rows) and sales (columns). A firm's leading product by export revenues is often also its most or second-most expensive product (41%=4.39/10.75 and 19%=2.02/10.75 of the time, respectively). Similarly, a firm's most expensive product is also usually ranked first or second by export revenues (41% and 18% of the time, respectively). Moreover, the entries along the diagonal contain the biggest fraction of firm-product pairs in any row or column. We view these patterns as suggestive of quality differentiation across products within a firm. In particular, exporters' core expertise appears to lie in expensive (high-quality) goods that generate the biggest share of revenues, whereas peripheral products are cheap (of low quality) and contribute little to sales.

5 Empirical Results

Our empirical analysis proceeds in two steps. We first test the central prediction of the model that firms' high-quality goods command high prices and generate high revenues. This will allow us to conclude that multi-product firms use inputs of different quality levels to produce goods of different quality levels. We then examine the relationship between product scope, export revenues, average price and sales skewness across destinations within a firm. This will lead us to believe that firms concentrate activity towards their core, high-quality goods in markets where they offer fewer products and earn less.

5.1 Variation across products within a firm

Export prices and export revenues

We first consider the cross-product variation in manufacturers' worldwide sales and prices. We aggregate the data to the firm-product level by summing trade revenues and quantities across markets. We then take their ratio and construct firm f's average export price for product p across all destinations d it serves as $price_{fp} = \frac{\sum_d revenue_{fpd}}{\sum_d quantity_{fpd}}$. In order to make these prices comparable across goods, we demean them by their product-specific average across firms as described above. For notational simplicity, $\log price_{fp}$ below always refers to these demeaned log prices.

Using this measure, we estimate the following specification:

$$\log price_{fp} = \alpha + \beta \log revenue_{fp} + \delta_f + \varepsilon_{fp}, \tag{17}$$

where $revenue_{fp} = \sum_d revenue_{fpd}$. In the spirit of the model, we include firm fixed effects δ_f to account for systematic differences across exporters in ability. In practice, these fixed effects also control for other unobserved firm characteristics that might affect trade outcomes across the product range, including productivity, managerial competence, fixed capital equipment, overall quality of the labor force, maintained distribution networks, and general experience with foreign markets. At this level of aggregation, the sample comprises 898,247 observations spanning 96,522 firms and 6,908 products. For consistency, we report Huber-White heteroskedasticity-consistent robust standard errors throughout the paper. Our results are robust to alternative treatments of the error terms, such as clustering by firm, product or - where relevant - by destination.

We are primarily interested in β, which reflects the sign of the conditional correlation between export price and revenues across goods within a firm. The sign of this correlation allows us to evaluate the importance of product quality for the operations of multi-product exporters. In particular, finding that $\beta > 0$ would be consistent with the case of $\theta > 0$ in the model. We emphasize that we cannot and do not want to give β a causal interpretation since unit values and sales are the joint outcome of producers' profit maximization and are both determined by firm ability and product expertise.

The results in Table 3 lend strong support to quality differentiation among products within suppliers. Across a firms' merchandise, more expensive goods generate systematically higher global sales. The point estimates in Column 1 indicate that a one-standard-deviation increase in exports is associated with a 11% higher price. Column 2 confirms that this result is unrelated to the variation in market power across a company's products, which could influence its pricing strategy for reasons outside our model. For each product p, we proxy firm f's market power with its share of total Chinese exports of p, $\frac{revenue_{fp}}{\sum_f revenue_{fp}}$, where the summation in the denominator is taken over all firms exporting p.

We also conduct two sensitivity analyses to ensure that our findings are not driven by measurement error (ME) in export values or quantities that could bias β.[11] First, we explore the variation in the scope for quality differentiation across products (θ in the model) using three common proxies from the prior literature. In Column 3, we regress prices on foreign sales, the Rauch (1999) indicator for differentiated goods, and the interaction of the two. The positive correlation between export prices and revenues is 60% higher among non-homogeneous products. Similar results obtain in Columns 4 and 5 when we instead measure the potential for quality upgrading with sectors' R&D intensity or combined advertising and R&D intensity. If an industry's R&D intensity is 20 percentage points higher than another's, its β would be 6 percentage points bigger. All of these patterns are significant at 1%. The rational for this diff-in-diff approach is that while ME might be present, it arguably does not vary systematically across industries. In other words, ME is more likely to affect the coefficients on the main effects in these regressions than on the interaction terms.

As a second specification check, we study the *ranking* of firms' export price and revenues instead of their *levels*. This allows us to rely much less directly on the construction of unit

[11] See Manova and Zhang (2012) for a discussion of why the direction of such bias (upward vs. downward) is ex-ante ambiguous and depends on the nature of ME in revenues and/or quantities. They also show that the correlation of price and revenue is not mechanically positive by construction.

prices. We order each manufacturer's products based on worldwide sales such that the top-selling good is ranked first, the second-most receives rank 2, etc. We also array firms' products by their (demeaned) unit value. As Column 6 illustrates, there is a strong positive correlation between products' global ranks by price and revenue across goods within exporters. In unreported regressions, we have confirmed that this correlation increases with sectors' scope for quality differentiation. These results reinforce our conclusion that $\beta > 0$ is not driven by ME bias, since such bias would have to be quite severe to distort product rankings in a systematic way.

We next perform a more stringent test of the model and examine the variation across exporters' goods within specific destination markets. We estimate an expanded version of equation (17) with the firm-product-country triplet as the unit of observation:

$$\log price_{fpd} = \alpha + \beta \log revenue_{fpd} + \delta_{fd} + \varepsilon_{fpd}. \tag{18}$$

Here $\log price_{fpd}$ is firm f's log price for product p in destination d, after it has been demeaned by the product-country specific average price. Similarly, bilateral instead of global trade flows enter on the right-hand side. We include firm-destination pair fixed effects δ_{fd}, which implicitly account for the variation in total expenditure, consumer price indices and market toughness across countries as directed by the theory. It additionally controls for cross-country differences in consumer preferences, trade costs and other institutional frictions outside our model. For simplicity, we use the same parameter notation in all estimating equations, although they of course differ across specifications conceptually.

As evidenced in Table 4, exporters earn higher revenues from their more expensive products not only in terms of worldwide sales, but also within each destination. This correlation is not driven by differences in market power across firms' product lines, which we now proxy with bilateral market shares $\frac{revenue_{fpd}}{\sum_f revenue_{fpd}}$. The relationship is also significantly stronger for goods with greater scope for quality differentiation. It is furthermore robust to using products' price and revenue ranks instead of levels, where these ranks have been constructed separately for each firm and importing country based on bilateral sales. Overall, the point estimates and their statistical significance are very similar to those for worldwide exports in Table 3.

Export prices and imported-input prices

The results in Tables 3 and 4 strongly suggest that firms' best-selling products are their most expensive varieties. In our model, this outcome obtains only with quality variation across goods within a firm, i.e. when $\theta > 0$. However, other theoretical frameworks might generate the same relationship without it. The systematic patterns we document across sectors with different potential for quality upgrading go a long way towards establishing our interpretation. Nevertheless, we would ideally like to show corroborative evidence using direct measures of product quality.

In the absence of such information, we exploit the rich nature of our data to construct proxies for the quality of firms' products. A large number of Chinese exporters (61%) use foreign components in their production process. The customs files record all such purchases. While we do not observe manufacturers' domestic materials and labor, we can use the prices they pay for imported parts as an indicator for the quality of all their inputs. A positive correlation between this indicator and export prices across a firm's products would then signal that producers vary the quality of their merchandise by using materials of different quality levels.[12]

While this technique has been used in the prior literature, its application poses some challenges in our context. We are interested in exporters that make multiple products using multiple intermediates. In principle, for each firm f and product p, we would like to calculate $\log input\ price_{fp}$, the average input price across all imported inputs f uses to manufacture p. We therefore need to carefully match inputs to outputs in order to develop quality proxies that vary across products within a firm. We pursue two different matching strategies and find very similar results that are consistent with quality differentiation among exporters' goods.

We first focus on foreign inputs in the same broad industry classification as the output product. For example, if a firm buys tires and steering wheels and sells cars, both its exports and imports would be recorded in the automobile industry. The average price across the tires and wheels it uses would then proxy the quality of the cars it makes. If the company also manufactures cell phones, the prices it pays for SIM cards and displays would enter the measure of the quality of its cell phones but not that of its cars.

Recall that we observe trade flows by HS-8 digit product. For every producer f, we construct a weighted average log input price across all materials f imports (e.g. tires, steering wheels) in a given HS-3 digit category (e.g. vehicles), which we label $\log input\ price_{f,HS3}$. We use import values as weights, but our results are robust to taking an unweighted average instead.[13] We assign this average input price to all HS-8 digit products f exports in the same 3-digit industry (e.g. cars and trucks). This allows us to obtain input quality proxies for 26% of the firm-product pairs in our export data, for a sample of 232,966 observations.

Our second approach to matching firms' imported materials to exported products relies on detailed input-output tables for China. These tables report the total value of inputs used from one sector for production in another sector, in a matrix of 139 industries. The relative contribution of two inputs varies significantly across output sectors. For example, manufacturing a car might require tires, multiple displays and some cloth for upholstering; assembling a cell phone might demand only 1 display, no tires and no cloth; and sewing a dress might need only cloth but no tires or displays.

For each firm, we can therefore apply the input-output tables to allocate some part of its every imported input to each of its exported products. Let u_{ij} be the value of input i used in the production of sector j in the IO tables. Let the set of sectors j exported by firm f be J. We will

[12] Note that if such a positive correlation instead reflected producers passing on cost shocks to consumers for reasons outside our model, we would have observed a negative correlation between export prices and revenues, as higher export prices would have signaled less efficient production rather than higher quality.

[13] Before this manipulation, we demean all import prices by their product-specific average import price across firms. This makes import prices comparable across goods and parallels our standardization of export prices.

assume that a share $\frac{u_{ij}}{\sum_{j\epsilon J} u_{ij}}$ of f's total imports of i are employed in manufacturing j. Using these inferred input values as weights, we construct the weighted average input price for firm f's output j across its inputs i.[14] We refer to this measure as $\log input\ price_{f,IO}$, and assign it to all HS-8 digit products f exports in IO sector j. This generates input quality proxies for 62% of the firm-product pairs in our export data, for a sample of 553,070 observations.

We believe parsing out inputs to outputs in this way is informative if imperfect. It gauges the variation in marginal costs across a firm's products in a more comprehensive way than focusing only on inputs within the same narrow sector as the output, as we did for $\log input\ price_{f,HS3}$. At the same time, companies need not necessarily combine intermediates in the same proportion as the IO tables suggest. To the extent that individual firms' sourcing deviates from the aggregate patterns reflected in the IO tables, this would introduce classical measurement error and bias our results downwards. For robustness, in unreported regressions available on request, we have considered a slightly different formula for $\log input\ price_{f,IO}$ and reassuringly obtained very similar results.[15]

We examine the relationship between producers' output and input prices by estimating:

$$\log price_{fp} = \alpha + \beta \log input\ price_{fp} + \delta_f + \varepsilon_{fp}, \tag{19}$$

where $\log price_{fp}$ is firm f's demeaned export price for product p based on worldwide sales. We measure $\log input\ price_{fp}$ with either $\log input\ price_{f,HS3}$ (Panel A of Table 5) or $\log input\ price_{f,IO}$ (Panel B); the two deliver point estimates of comparable magnitude and significance. As before, we exploit purely the variation across output goods within a manufacturer by including firm fixed effects δ_f. We are once again interested in β as a conditional correlation without a causal interpretation: The choices of input and output quality would be intimately related in exporters' profit maximization problem in a fuller model with endogenous quality choice.

Consistently with our theoretical predictions for $\theta > 0$, we find a highly statistically and economically significant positive association between input and output prices across products within a firm. Our baseline in Column 1 indicates an elasticity of 0.11 to 0.14. Compared to the correlations between export prices and revenues in Tables 3 and 4, the results here are much less subject to concerns with measurement error since input and output prices are independently constructed from different data series. Our findings are also robust to explicitly controlling for manufacturers' market power both in the output market for their export goods and in the input market for their imported parts (Column 2). As earlier, we capture the former with f's share of total Chinese exports of the output product p, $\frac{revenue_{fp}}{\sum_f revenue_{fp}}$. To measure the latter symmetrically,

[14] As before, we use import prices demeaned by their product-specific average import price across firms.

[15] In particular, we constructed the weighted average input price using the ratios $\frac{u_{ij}}{\sum_{i\epsilon I} u_{ij}}$ as weights without exploiting information on firms' import values. These weights implicitly assume that all firms use different inputs i in the same proportion when making a given product j. This is the counterpart to the assumption behind $\log input\ price_{f,IO}$ in the text: that all firms allocate a given input i in the same proportion across different outputs j.

we average f's share of total Chinese imports across all of its inputs that are matched to its output product p and used in the calculation of its log $input\ price_{fp}$.[16]

Through the lens of our model, we interpret this as strong evidence that Chinese exporters use inputs of different quality levels to produce goods of different quality levels. To shed more light on this mechanism, we re-estimate equation (19) separately for homogeneous and differentiated export products in Columns 3 and 4. Firms' export prices rise substantially more quickly with their input prices when the output product is differentiated. This is in line with the model's prediction that output price and quality increase faster with marginal cost and input quality in sectors with greater scope for quality differentiation (i.e. higher θ).

Our results survive two further robustness checks motivated by the specifics of our data. All Chinese customs transactions are recorded as occurring under one of two main trade regimes: processing and ordinary trade.[17] Processing firms import inputs specifically for further processing, assembly and re-exporting. Ordinary exporters may or may not use imported materials in their production process. Since we have removed all trade intermediaries from our sample, we can interpret the import transactions we observe for both ordinary and processing exporters as purchases of inputs from abroad. We have nevertheless confirmed that all patterns in Table 5 hold when we focus specifically on processing imports only. Column 5 replicates our baseline regression for this subsample, and all other findings are available upon request.

Finally, we verify that our results are not driven by potential aggregation bias in the matching of inputs to outputs. By design, the two algorithms we use can map multiple HS-8 digit export products to the same imported-input price (at the HS-3 digit or IO-sector level). In Column 6, we collapse the data such that output prices on the left-hand side are at the same level of aggregation as input prices on the right-hand side. Our results continue to hold, with the point estimate for β increasing. All findings in Columns 2-5 also obtain at this level of aggregation.

To summarize the analysis so far, there is a robust positive correlation between export prices, export revenues and input prices across goods within manufacturers. These results are consistent with quality differentiation across products within a firm, whereby exporters earn higher revenues from their core expensive goods of superior quality (Proposition 2).

5.2 Variation across destinations within a firm

Extensive margin: product scope and product hierarchies

We next examine how exporters adjust their product scope across destinations. Our interest here is not in the underlying differences across markets that trigger such adjustments, but in the attributes of the goods firms choose to sell when they contract or expand their product range.

[16] It is not obvious ex ante whether and how market power would enter. Manufacturing more of a certain product requires bigger input quantities. A bigger export market share might thus allow firms to charge higher mark-ups and to negotiate lower input prices. This would tend to bias β downwards. On the other hand, input scarcity or convexity in production costs might bias β upwards.

[17] See Manova and Yu (2011) among others for more details on these regimes.

We first study the variation in product scope, average price and export revenues across destinations within a company. For each firm f and country d, we obtain total bilateral exports, $revenue_{fd} = \sum_p revenue_{fpd}$, and record the number of products shipped, $Nproducts_{fd}$. We construct two proxies for suppliers' average product quality in d based on free-on-board prices. The first measure is the arithmetic average of f's log prices across the goods it sells in d, after these prices have been demeaned by their product-destination specific average. The second measure takes the weighted average of these demeaned prices, using the firm's bilateral exports as weights.

We take Propositions 3 and 4 to the data by estimating:

$$\begin{aligned} \log revenue_{fd} &= \alpha + \beta \log Nproducts_{fd} + \delta_f + \varepsilon_{fd} \quad \text{and} \\ \log avg\ price_{fd} &= \alpha + \beta \log Nproducts_{fd} + \delta_f + \varepsilon_{fd}. \end{aligned} \tag{20}$$

Given the firm fixed effects δ_f in these regressions, β is identified purely from the variation across countries within manufacturers. As before, it reflects conditional correlations of interest and does not have a causal interpretation: In the model, product scope, export revenues and average prices are jointly pinned down by producers' ability draw and characteristics of the destination market.

In line with our theoretical predictions for quality sorting ($\theta > 0$), exporters earn systematically higher revenues in countries where they sell more products (Column 1 of of Table 6). At the same time, product scope is negatively correlated with the average price across a supplier's merchandise (Column 2). This pattern is not driven by cross-country differences in the market power the firm enjoys, as proxied by the average market share across its products in a destination (Column 3). Moreover, it holds in the sample of differentiated goods with potential for quality upgrading, but is absent among homogeneous commodities (Columns 4 and 5). Finally, the theoretically ambiguous relationship between product scope and the revenue-weighted average price is also negative (Column 6). As expected, however, it is markedly weaker in absolute terms than that for the arithmetic average.

These relationships are economically significant. The typical firm experiences an 85% rise in bilateral revenues and a 1.3% drop in average f.o.b. prices when it exports 50% more products to a given country. The latter correlation is 36% higher among differentiated varieties.

These results indicate that exporters expand (restrict) their product offerings across markets by adding (dropping) cheaper goods of inferior quality. However, they do not directly establish whether firms follow a global hierarchy of products that is preserved across destinations. We next present evidence consistent with manufacturers focusing on their core competencies - high-quality varieties - when they sell fewer products. This analysis illustrates how multi-product exporters adjust their bilateral sales along the extensive margin.

To operationalize this, we use the unique ranking of each firm f's products based on its global sales, as in Table 2. For each company, the good that generates the highest revenues worldwide receives rank 1, the second-best seller - rank 2, etc. We record the average, 10^{th} percentile and 90^{th} percentile rank observed across the products f sells in destination d. If the exporter strictly follows the product quality ladder in all countries, then his minimum product rank would be 1 in every market. The maximum rank, on the other hand, would equal the number of products shipped, $Nproducts_{fd}$. Thus, there should be no systematic variation in the minimum product rank across destinations within a firm, while product scope should be positively correlated with the maximum and with the average product rank. Deviations from these patterns would signal that firms do not adhere to a particular product hierarchy, but instead routinely re-order products across markets. In practice, we work with the 10^{th} and 90^{th} percentiles instead of the minimum and the maximum ranks to guard against idiosyncratic outliers.[18]

We evaluate these predictions in Table 7 by regressing each of the three relevant rank measures (jointly referred to as $rank_{fd}$) on the number of bilaterally traded products:

$$rank_{fd} = \alpha + \beta Nproducts_{fd} + \delta_f + \varepsilon_{fd}. \tag{21}$$

The unit of observation in this specification remains the producer-destination pair. Firm fixed effects ensure that the conditional correlation β is estimated from the variation across markets within an exporter.

As Panel A shows, the average product rank indeed rises significantly with product scope. This pattern is more pronounced among differentiated goods, although it is also present among homogeneous varieties. Importantly, the 90^{th} percentile increases about twice as fast with the number of goods shipped, whereas the 10^{th} percentile is essentially unaffected.

In Panel B, we re-estimate equation (21) using the global rank of firms' products by *price* instead of by sales. Now exporters' most expensive product receives rank 1, their second-most expensive variety - rank 2, etc. We obtain qualitatively similar results with two exceptions. Average rank becomes independent of product scope for non-differentiated products, which strengthens our conclusions. While the 10^{th} percentile now falls with $Nproducts_{fd}$, the important observation for our purposes is that the 90^{th} percentile rises faster than that in absolute terms.

Together, Tables 6 and 7 suggest that exporters' core competency lies with their expensive products, which correspond to their highest-quality goods. In destinations where firms choose to offer fewer varieties, they focus on their leading quality items. At the same time, product hierarchies might not be perfectly observed across destinations as postulated in our stylized model. This can for example be attributed to unobserved taste (demand) shocks at the product-destination or firm-product-destination level, as in BRS.[19]

Intensive margin: product scope and sales distribution

Finally, we study the distribution of export sales across goods within a firm. In particular, we consider how exporters' product scope is correlated with the concentration of activity towards

[18] Qualitatively similar results obtain if we instead use these extreme values.

[19] For completeness, we have checked that the results for the variation across destinations within firms in Tables 6 and 7 also apply to the variation across firms within a destination. We do so by re-estimating the relevant equations with destination dummies instead of the firm fixed effects. This implies that within a market, firms exporting more products have higher revenues and focus on their core expensive goods. These findings are consistent with the model and further corroborate our interpretaion.

their core competencies. This relationship reflects producers' adjustments along the intensive margin of trade.

As a measure of concentration, we record the log ratio of export revenues for the top and second-best product of firm f in destination d, $\log(revenue_{fd1}/revenue_{fd2})$.[20] We identify these top two products based on either bilateral sales or price. We then regress this ratio on the exporter's log number of products sold in that market. Since we are interested in the variation across importing countries within a manufacturer, we include firm fixed effects δ_f:

$$\log(revenue_{fd1}/revenue_{fd2}) = \alpha + \beta \log Nproducts_{fd} + \delta_f + \varepsilon_{fd}. \quad (22)$$

As Table 8 shows, firms skew their exports more towards their top-selling (Column 1) and most expensive (Column 4) product in countries where they sell fewer varieties. Halving the merchandise range is associated with a 20% rise in revenues from the most profitable good relative to the second-best, and a 9% increase in sales of the most expensive to the second most expensive item. In unreported regressions, we have confirmed that similar results obtain when we use an alternative measure of sales concentration across products: a Herfindahl index for the distribution of bilateral exports across all products f ships to destination d. This constitutes a consistency check for Column 1, but unlike Column 4 does not shed light on the attributes of the products that generate high revenues (i.e. expensive or cheap).

These patterns suggests that the constant mark-up assumption in the CES version of the model is not validated in the data. Instead, variable mark-ups appear important in accounting for the decisions of multi-product exporters. Moreover, the relationship we identify is considerably stronger among homogeneous articles than differentiated varieties (Columns 2-3 and 5-6). Through the lens of the model, this suggests that in tougher markets, shifting activity towards core goods is more attractive to firms if they sell products with high elasticity of substitution.[21]

6 Conclusion

This paper establishes that quality differentiation is an important feature of the operations of multi-product firms. We develop a model in which manufacturers vary product quality across their product range by using inputs of different quality levels. Firms' core competency is in varieties of superior quality that bring higher sales despite being more expensive. This theoretical framework delivers predictions that allow us to test for the presence of quality differentiation in the data. We also consider two versions of the model that distinguish between constant and variable mark-ups.

Using detailed customs data for China, we establish four new stylized facts consistent with this model. First, firms earn more bilateral and global revenues from their more expensive products. Second, exporters focus on their top expensive goods, drop cheaper articles and earn

[20] As MMO, we take logs to consider the relative contribution of these products in percentage terms.

[21] This result would also be consistent with the cross-product cannibalization effects in Eckel and Neary (2010).

lower revenues in markets where they sell fewer varieties. Third, companies' sales are more skewed towards their core expensive goods in destinations where they offer less items. Finally, export prices are positively correlated with input prices across products within a firm.

Overall, these empirical findings paint a coherent picture in line with our characterization of multi-product, multi-quality firms. They are consistent with the idea that when exporters expand activity in a given market, they introduce peripheral goods of lower quality. While this reduces the observed average price across products, it boosts total foreign sales. Conversely, when firms contract their operations abroad, they focus on their core competencies. More specifically, manufacturers adjust along the extensive margin by retaining their high-quality products and dropping marginal goods of lower quality. Suppliers also respond along the intensive margin by concentrating sales even more towards their top varieties.

Our results shed light on the determinants of firms' export success and the design of export-promoting policies in developing economies. They also have implications for exporters' response to trade reforms and exchange rate fluctuations. An important avenue for future research is understanding how quality differentiation across firms and across products within firms affects the welfare and distributional consequences of international trade. Two key considerations in this context would be the complementarity between input quality and workers' skill, and frictions in the allocation of resources across firms and across product lines within firms.

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Table 1. The Variation in Export Prices across Firms, Products and Destinations

This table summarizes the variation in f.o.b. export prices across firms, products, and destinations in 2005. Line 1 (Line 2): summary statistics for firm-product (firm-product-destination) log prices, after taking out product fixed effects. Line 3: for each destination-product market with multiple Chinese exporters, we record the standard deviation of log prices across firms. Line 3 shows how this standard deviation varies across destination-product pairs. Line 4 (Line 5): for each multi-product firm, we record the standard deviation of log prices across products (by destination). Line 4 (Line 5) shows how this standard deviation varies across firms (firm-destination pairs).

	# Obs	Average	St Dev	Min	5th Percentile	95th Percentile	Max
Variation across firms within products							
1. firm-product prices (product FE)	898,247	0.00	1.33	-12.03	-2.02	2.18	13.61
2. firm-product-destination prices (product FE)	2,179,923	0.00	1.24	-12.12	-1.93	2.02	13.65
3. st dev of prices across firms within dest-product pairs (dest-product FE)	159,778	0.90	0.74	0.00	0.08	2.30	8.36
Variation across products within firms							
4. st dev of prices across products within firms (firm FE, product FE)	74,034	0.85	0.63	0.00	0.13	2.05	8.21
5. st dev of prices across products within firm-dest pairs (firm-dest FE, product FE)	330,805	0.74	0.63	0.00	0.07	1.94	9.07

Table 2. Ranking Firms' Products by Export Prices and Revenues

This table ranks products within multi-product firms based on either worldwide export revenues (columns) or export price (rows). The top selling or most expensive product within each firm is ranked first, the second most receives rank 2, etc. For each firm-product pair, we construct the export price as the ratio of worldwide export revenues and quantities, demeaned by its product-specific average across firms. Each cell in the table shows what percent of all firm-product pairs receive a certain rank by price and revenue.

Product Rank by Sales	1	2	3	4	5	>5	Total
Product Rank by Price							
1	**4.39%**	1.91%	1.09%	0.69%	0.50%	2.16%	10.75%
2	2.02%	**2.03%**	1.05%	0.66%	0.46%	2.02%	8.24%
3	1.13%	1.14%	**1.16%**	0.68%	0.45%	1.93%	6.50%
4	0.73%	0.71%	0.72%	**0.77%**	0.46%	1.91%	5.30%
5	0.50%	0.49%	0.50%	0.50%	**0.53%**	1.89%	4.40%
>5	1.98%	1.96%	1.98%	1.99%	2.00%	**54.90%**	64.82%
Total	10.75%	8.25%	6.50%	5.30%	4.40%	64.81%	100.00%

Table 3. Worldwide Export Prices and Revenues across Products within a Firm

This table examines the relationship between worldwide export prices and revenues across products within firms. For each firm-product pair, we construct the (log) export price as the ratio of worldwide export revenues and quantities, demeaned by its product-specific average across firms. Market power is proxied by the firm's share of total Chinese exports by product. Products' scope for quality differentiation is proxied by the Rauch dummy for differentiated goods (Column 3), sectors' R&D intensity (Column 4), or sectors' combined advertising and R&D intensity (Column 5). Column 6 uses products' rank by price and revenue across products within each firm instead of (log) price and revenue. All regressions include a constant term and firm fixed effects. Robust T-statistics in parentheses. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Dependent variable: (log) export price by firm and product

	Baseline	Market Power	Rauch Dummy	R&D Intensity	Adv. + R&D Intensity	Product Rank
	(1)	(2)	(3)	(4)	(5)	(6)
(log) Revenue	0.039 (68.94)***	0.040 (70.37)***	0.028 (17.21)***	0.034 (47.48)***	0.036 (37.83)***	0.076 (17.50)***
Market Share		-0.361 (-12.12)***				
(log) Revenue x Quality Differentiation			0.017 (9.49)***	0.298 (9.66)***	0.144 (4.33)***	
Quality Differentiation			-0.170 (-9.53)***	-4.776 (-15.54)***	-0.011 (-0.04)	
Firm FE	Y	Y	Y	Y	Y	Y
R-squared	0.41	0.41	0.44	0.42	0.42	0.69
# observations	898,247	898,247	619,357	871,596	875,097	898,247
# firms	96,522	96,522	84,464	93,514	94,005	96,522

Table 4. Bilateral Export Prices and Revenues across Products within a Firm-Destination

This table examines the relationship between bilateral export prices and revenues across products within firm-destination pairs. For each firm, product and destination, we demean the (log) price by the product-destination specific average across firms. Market power is proxied by the firm's share of total Chinese exports by product-destination. Products' scope for quality differentiation is measured as in Table 3. Column 6 uses products' rank by price and revenue across products within each firm-destination pair instead of (log) price and revenue. All regressions include a constant term and firm-destination pair fixed effects. Robust T-statistics in parentheses. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Dependent variable: (log) export price by firm, product and destination

	Baseline	Market Power	Rauch Dummy	R&D Intensity	Adv. + R&D Intensity	Product Rank
	(1)	(2)	(3)	(4)	(5)	(6)
(log) Revenue	0.040 (84.92)***	0.042 (87.33)***	0.033 (21.87)***	0.032 (52.65)***	0.035 (43.35)***	0.101 (16.85)***
Market Share		-0.077 (-18.34)***				
(log) Revenue x Quality Differentiation			0.012 (7.37)***	0.413 (17.94)***	0.216 (7.99)***	
Quality Differentiation			-0.170 (-10.94)***	-6.416 (-29.22)***	-1.512 (-6.34)***	
Firm-Destination FE	Y	Y	Y	Y	Y	Y
R-squared	0.53	0.53	0.57	0.53	0.53	0.73
# observations	2,179,923	2,179,923	1,494,839	2,130,413	2,139,735	2,179,923
# dest-firm pairs	724,622	724,622	564,012	706,738	711,036	724,622

Table 5. Export Prices and Imported-Input Prices

This table examines the relationship between firms' export prices and imported input prices. The outcome variable is firms' (log) export price by HS-8 digit product, except in Column 6 where it is the weighted average (log) export price by HS-3 digit product or IO sector using export revenues as weights. The input price is the weighted average of (log) import prices for inputs matched to the output product, using import values as weights. It is based on imports in the same HS-3 digit product category (Panel A) or on all inputs using input-output tables (Panel B). All prices have been demeaned by their product-specific average across firms before any further manipulation. In Column 5 only processing imports enter the calculation. Market power in output markets is proxied by the firm's share of total Chinese exports by product category. Market power in input markets is proxied by the firm's average share of total Chinese imports across all inputs matched to the output product. Column 3 (4) restricts the sample to homogeneous (differentiated) export products only. All regressions include a constant term and firm fixed effects. Robust T-statistics in parentheses. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Dependent variable: (log) export price by firm and product category

Panel A. Input price based on imports in same HS-3 product

	Baseline (1)	Market Power (2)	Hom Goods (3)	Diff Goods (4)	Proc Imports (5)	HS-3 Product (6)
(log) Input Price	0.14 (37.83)***	0.14 (37.82)***	0.08 (2.92)***	0.13 (26.85)***	0.17 (27.52)***	0.20 (31.36)***
Input Market Share		0.13 (1.49)				
Output Market Share		-0.06 (-1.16)				
Firm FE	Y	Y	Y	Y	Y	Y
R-squared	0.42	0.42	0.65	0.47	0.44	0.56
# observations	232,966	232,966	13,334	140,197	118,381	87,760
# firms	37,102	37,102	5,936	27,797	22,583	37,102
# product categories	6,120	6,120	1,025	2,732	5,153	171

Panel B. Input price based on all imports and IO tables

	Baseline (1)	Market Power (2)	Hom Goods (3)	Diff Goods (4)	Proc Imports (5)	IO Sector (6)
(log) Input Price	0.11 (24.12)***	0.11 (24.13)***	-0.02 (-0.72)	0.10 (16.87)***	0.13 (15.92)***	0.17 (20.02)***
Input Market Share		-0.46 (-1.50)				
Output Market Share		1.00 (1.95)*				
Firm FE	Y	Y	Y	Y	Y	Y
R-squared	0.39	0.39	0.58	0.43	0.37	0.48
# observations	553,070	553,070	34,548	348,593	330,604	183,336
# firms	55,733	55,733	12,888	45,708	36,042	55,733
# product categories	5,985	5,985	1,150	2,619	5,578	92

Table 6. Export Revenues, Average Price and Product Scope

This table examines the relationship between bilateral export revenues, average export price and product scope across destinations within firms. Product scope is measured by the (log) number of products a firm exports to a given destination. For each firm, product and destination, we first demean the (log) price by its product-destination specific average across firms. We then construct the average (log) export price at the firm-destination level as the arithmetic average of these demeaned prices (Columns 2-5) or the weighted average using the firms' export revenues in that destination as weights (Column 6). Market power is proxied by the firm's average share of total Chinese exports across its products in a destination. Column 4 (5) restricts the sample to homogeneous (differentiated) goods only. All regressions include a constant term and firm fixed effects. Robust T-statistics in parentheses. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Dep Variable	(log) Revenue	Avg (log) Price				Weighted Avg (log) Price
		All	All	Hom Goods	Diff Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
(log) # Products	1.734	-0.025	-0.025	0.003	-0.034	-0.006
	(522.86)***	(-18.22)***	(-17.90)***	(0.66)	(-19.04)***	(-4.34)***
Market Share			0.001			
			(0.26)			
Firm FE	Y	Y	Y	Y	Y	Y
R-squared	0.53	0.56	0.56	0.60	0.58	0.57
# observations	724,622	724,622	724,622	87,459	509,362	724,622
# firms	96,522	96,522	96,522	23,390	76,793	96,522

Table 7. Product Scope and Product Rank

This table illustrates that firms focus on their core expensive products in markets where they export fewer goods. For each firm, we rank products globally based on worldwide export revenues (Panel A) or based on worldwide export prices (worldwide export revenues divided by worldwide export quantities), demeaned by their product-specific average across firms (Panel B). The top product receives rank 1 and the bottom product - a rank equal to the number of products the firm exports. We use this global ranking of products to measure the average, 10^{th} percentile and 90^{th} percentile rank observed across the products sold by a firm in a given destination. Product scope is measured by firms' number of bilaterally exported products. Column 2 (3) restricts the sample to homogeneous (differentiated) goods only. Columns 4 and 5 restrict the sample to firm-destination pairs with 2 or more products. All regressions include a constant term and firm fixed effects. Robust T-statistics in parentheses. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Panel A. Products ranked by global sales

Dep Variable	Average Rank			10^{th} Perc	90^{th} Perc
	All	Hom Goods	Diff Goods	# Goods ≥ 2	# Goods ≥ 2
	(1)	(2)	(3)	(4)	(5)
# Products	0.433	0.364	0.422	-0.017	0.822
	(46.13)***	(13.56)***	(47.34)***	(-2.63)***	(36.13)***
Firm FE	Y	Y	Y	Y	Y
R-squared	0.72	0.66	0.70	0.29	0.83
# observations	724,622	87,459	509,362	330,805	330,805
# firms	96,522	23,390	76,793	70,672	70,672

Panel B. Products ranked by global price

Dep Variable	Average Rank			10^{th} Perc	90^{th} Perc
	All	Hom Goods	Diff Goods	# Goods ≥ 2	# Goods ≥ 2
	(1)	(2)	(3)	(4)	(5)
# Products	0.046	-0.014	0.056	-0.291	0.366
	(5.47)***	(-0.54)	(6.82)***	(-19.75)***	(27.98)***
Firm FE	Y	Y	Y	Y	Y
R-squared	0.91	0.86	0.90	0.67	0.96
# observations	724,622	87,459	509,362	330,805	330,805
# firms	96,522	23,390	76,793	70,672	70,672

Table 8. Product Scope and the Concentration of Sales in Core Products

This table shows that firms concentrate sales in their core expensive products in markets where they export fewer goods. The outcome variable is the (log) ratio of the sales of a firm's top product to the sales of its second-ranked product, by destination. For each firm-destination, we rank products based on the firm's bilateral export sales or bilateral export prices (demeaned by their product-destination specific averages across firms). Columns 2 and 5 (3 and 6) restrict the sample to homogeneous (differentiated) goods only. All regressions include a constant term and firm fixed effects. Robust T-statistics in parentheses. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Dependent variable: (log) ratio of export revenues of top to second-ranked product, by firm and destination

Products Ranked by	Bilateral Sales			Bilateral Price		
	All	Hom Goods	Diff Goods	All	Hom Goods	Diff Goods
	(1)	(2)	(3)	(4)	(5)	(6)
(log) # Products	-0.42	-0.65	-0.42	-0.18	-0.34	-0.21
	(-100.24)***	(-17.69)***	(-79.50)***	(-19.21)***	(-4.53)***	(-17.22)***
Firm FE	Y	Y	Y	Y	Y	Y
R-squared	0.49	0.58	0.52	0.28	0.48	0.32
# observations	330,805	21,793	218,413	330,805	21,793	218,413
# firms	70,672	9,600	52,237	70,672	9,600	52,237

Appendix Table 1. Export Prices and Revenues across Firms within a Destination-Product

This table reproduces results from Manova and Zhang (2012). It examines the relationship between export prices and revenues across firms within a destination-product market. Products' scope for quality differentiation is measured as in Table 3. All regressions include a constant term and destination-product pair fixed effects, and cluster errors by destination-product. T-statistics in parenthesis. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Dependent variable: (log) export price by firm, product and destination

	Baseline	Rauch Dummy	R&D Intensity	Adv. + R&D Intensity
	(1)	(2)	(3)	(4)
(log) Revenue	0.081	0.036	0.077	0.065
	(70.07)***	(9.36)***	(54.61)***	(35.32)***
(log) Revenue x		0.054	0.200	0.616
Quality Differentiation		(12.97)***	(3.17)***	(10.63)***
Destination-Product FE	Y	Y	Y	Y
R-squared	0.744	0.729	0.741	0.741
# observations	2,179,923	1,494,839	2,130,413	2,139,735
# dest-product pairs	258,056	163,873	247,867	249,874

Figure 1. Comparing Prices across Products

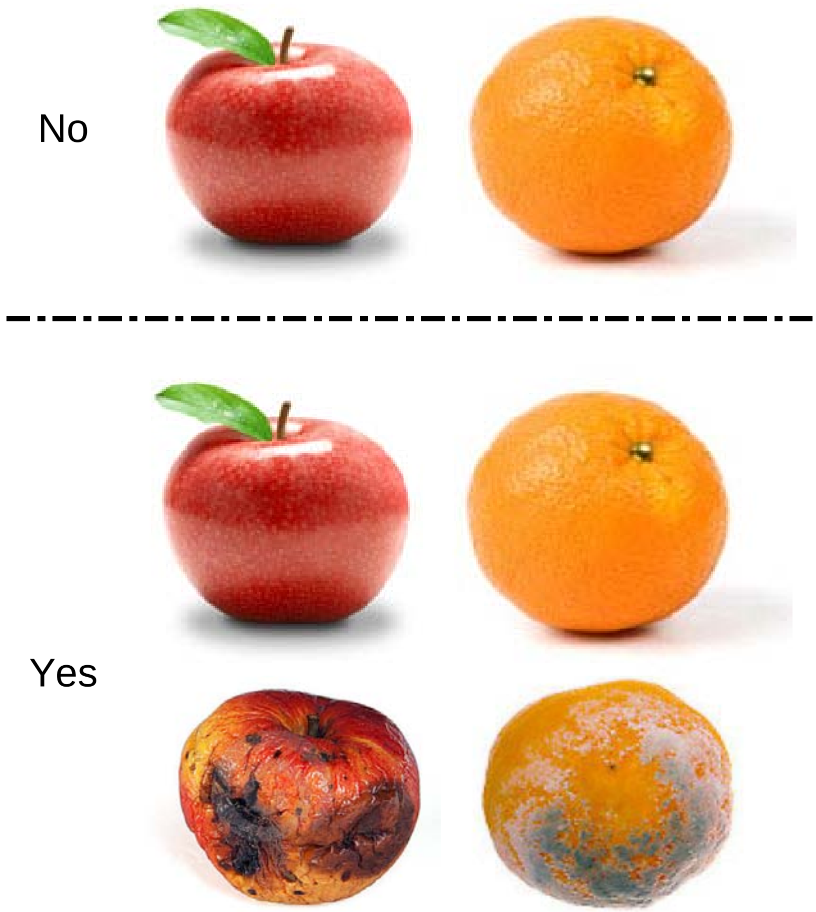

Figure 2. Comparing Prices across Products within Firms