Multi-Product Firms and Product Quality*

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Abstract

This paper establishes four new stylized facts about the operations of multi-product firms using detailed customs data for China. First, manufacturers generate higher bilateral and global sales from their more expensive products. Second, exporters focus on their top-ranked 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 products. Finally, export prices are positively correlated with input prices across products within a firm. We propose that product quality varies across a manufacturer's merchandise and depends on the quality of intermediate inputs. Moreover, exporters observe a product hierarchy and their core competency lies in expensive varieties of superior quality. We formalize this explanation with a model of heterogeneous multi-product, multi-quality firms. Our results have implications for the aggregate and distributional effects of trade reforms and exchange rate movements.

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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 and ultimately aggregate trade outcomes.

This paper establishes four new stylized facts about multi-product firms using detailed customs data for China. First, manufacturers generate higher bilateral and global sales from their more expensive products. Second, exporters focus on their top-ranked 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 products. Finally, export prices are positively correlated with input prices across products within a firm. Taken together, these results suggest that product quality varies across a manufacturer's merchandise and depends on the quality of intermediate inputs. Moreover, exporters observe a hierarchy of products which is relatively stable across destinations. In particular, they add goods in decreasing order of quality and their core competency lies in expensive varieties of superior quality. We formalize this explanation with a model of heterogeneous multi-product, multi-quality firms and show that it is consistent with the patterns in the data.

Our analysis 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 marginal costs rise sufficiently quickly with quality, 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. For this reason, the prior literature has 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 is consistent with 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.

[1] See for example Verhoogen (2008), Kugler and Verhoogen (2008), Hallak and Sivadasan (2008), Iacovone and Javorcik (2008), and Manova and Zhang (2009).

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 optimally 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 analysis help validate the quality interpretation we offer. First, our results are more pronounced in sectors with greater scope for quality differentiation. In particular, 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 input quantities 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 existing models with different demand structures. With CES, the relative contribution of two products to a firms' revenues in a given market depends only on these products' attributes (such as quality and marginal cost). It is thus unaffected by contractions or expansions in the exporter's product range. By contrast, with linear demand, optimal mark-ups depend on product scope and the potential for product cannibalization. We find that the ratio of export sales of the top to the second-best product within a firm decreases systematically with the number of goods offered. In other words, when firms focus on their core competencies, they adjust both on the extensive margin (by dropping their cheapest, low quality goods) and on the intensive margin (by shifting market share towards their most expensive, high quality goods). These results are consistent with the findings in Mayer et al. (2011) for French firms. While they consider only firms' product rankings by revenues, we also show results for product hierarchies based on price.

To rationalize the patterns in the data, we develop a model of international trade with multi-product firms in which product quality varies across firms and across products within 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 higher quality of any given good, export more varieties, and earn higher revenues. Within each firm, more

[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.

expensive products generate greater sales. Exporters thus observe a hierarchy of products and add goods in decreasing order of quality. While we currently study CES preferences, we plan to adopt linear demand in the next version of the paper. This will additionally imply that suppliers' sales are skewed more towards their core products when they export fewer goods.

Our model can be seen as a quality interpretation of existing treatments of multi-product firms that abstract away from vertical differentiation. 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 conclusions of quality variation across firms and products are internally consistent.

Most directly, our results contribute to the literatures on multi-product firms and on firm heterogeneity in efficiency and output quality (see references above). To the best of our knowledge, we are the first to examine questions at the intersection of these two lines of research using detailed data on firm exports by product and destination in combination with data on firm inputs. Eckel et al. (2011) offer the only other study of multi-product, multi-quality companies. They analyze the domestic sales and total exports of Mexican manufacturers, and also find that high-revenue goods tend to be the most expensive varieties. Data limitations, however, prevent them from exploring the variation in producers' trade activity across destinations. They also do not use information on firms' input prices in order to establish the quality interpretation.

More broadly, our findings shed light on the determinants of firms' export success and the design of export-promoting policies in developing economies. The patterns we uncover suggest that facilitating access to high-quality inputs can allow manufacturers to upgrade 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. Arkolakis et al. (2009) find that, under certain conditions, the effects on aggregate welfare are unaltered by the presence of firm heterogeneity or multi-product firms. Burstein and Melitz (2011), however, suggest that heterogeneity matters under endogenous firm productivity growth. There is also growing evidence that financial and labor market frictions significantly distort cross-border trade (c.f. Manova 2007, Helpman et al. 2010, Cosar et al. 2010). Since producers can choose to upgrade quality, 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, 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 importance 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 section introduces the data and highlights three empirical patterns that motivate our analysis. Section 3 develops the model, while Section 4 summarizes its main predictions and Section 5 presents our empirical results. The last section concludes.

2 A first glance at the data

2.1 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.[3] 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.[4] 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.

Our empirical approach rests on the comparison of prices among a producers' output goods or manufactured inputs. 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. To operationalize this, we need to convert the different units of measurement observed in the data to a unique reference unit of accounting. We thus always demean export (import) unit values by the average observed across all firms exporting (importing) this product. Our results are not sensitive to constructing this average from trade flows at the firm-product or at the firm-product-trade partner country level. For consistency and maximum transparency, in each regression we use the average at the same level of aggregation as the outcome variable.

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

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

[4] 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..

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 companies 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 main results.[5] We do so in order to focus on the operations of firms that both make and trade goods since we are interested in how firms' production efficiency and product quality affect their export activities. Showing direct evidence on firms' imported-input prices is thus an important component of our analysis as they proxy for input quality. We cannot apply this approach to intermediaries because we do not observe their suppliers and cannot interpret their import transactions as input purchases.

We exploit 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, Kroszner and Laeven (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.

2.2 Motivating Facts

Motivation 1 *Export prices vary substantially across firms within a product and across products within a firm.*

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 free-on-board price for each firm-product pair, constructed as the ratio of total revenues and quantities shipped. 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 in a given country and good: 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.

[5] We drop 23,073 wholesalers who mediate a quarter of China's trade. Using the same data, Ahn et al. (2010) identify intermediaries in the same way in order to study wholesale activity.

Finally, there is a lot of variation in unit values across products within a given exporter. Since different goods are recorded in different units of measurement, we demean each firm-product price by the average price across all sellers of that article. The standard deviation of log prices across goods for the average supplier is 0.85 when we consider worldwide exports. This number is 0.74 when we look at the spread of prices across products for the average firm-destination pair. This illustrates the heterogeneity in product attributes across exporters' merchandise.

Motivation 2 *Export prices and revenues are positively correlated across firms within a product.*

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 (2009), and shows that a regression of log export unit values on log export sales produces a positive and significant coefficient after controlling for product fixed effects. This association is 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.

Motivation 3 *Export prices and revenues are positively correlated across products within a firm.*

There is also a well-pronounced positive correlation between export prices and revenues across products within a manufacturer. To demonstrate this, we rank goods within multi-product firms based on either worldwide export revenues or the average export price by firm-product. The top selling or most expensive product within each firm is ranked first, the second most receives second rank, etc. As before, for each firm-product pair, we first construct the average export price as the ratio of total worldwide export revenues and quantities. We then demean these prices by their product-level average across all firms, and rank products within firms according to these demeaned prices. We thus obtain every firm's *global* product rank by sales or price.

Table 2 illustrates that firms' best-selling products tend to be their most expensive goods. Each cell in the table indicates what fraction of all firm-product pairs receive a certain rank by price (columns) and sales (rows). A firm's top product by export revenues is often also its most or second-most expensive product (41% and 18% of the time, respectively). Similarly, a firm's most expensive product is also usually ranked first or second by export revenues (41% and 19% 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 high-quality goods that generate the biggest share of revenues, whereas peripheral products are of low quality and contribute little to sales.

Motivated by these three empirical observations, we next develop a theoretical framework that rationalizes them. This model delivers a number of additional predictions which we take to the data in Section 5.

3 Theoretical Framework

We incorporate quality variation across firms and across products within firms in the Bernard, Redding and Schott (2010a) model of multi-product firms (henceforth BRS), which in turn builds on Melitz (2003). We let firms choose how many products to manufacture, how many markets to enter, and which products to sell in each market. The model retains most features of BRS but inverts the relationships between firm prices and various export outcomes as higher prices are associated with better quality and superior performance. In order to focus on the novel results, the exposition moves quickly and the notation stays close to BRS.

3.1 Set up

Consider a world with $J+1$ countries and a continuum of products i in the interval $[0,1]$. In each country and product category, a continuum of heterogeneous firms produce horizontally and vertically differentiated varieties. Consumers exhibit love of variety, and the utility function for the representative consumer in country j is a CES aggregate over product-specific indices X_{ji}:

$$U_j = \left[\int_0^1 X_{ji}^{\nu} di\right]^{\frac{1}{\nu}}, \quad X_{ji} = \left[\int_{\omega\in\Omega_{ji}} \left(q_{ji}\left(\omega\right) x_{ji}\left(\omega\right)\right)^{\alpha} d\omega\right]^{\frac{1}{\alpha}}, \tag{1}$$

where $q_{ji}(\omega)$ and $x_{ji}(\omega)$ represent the quality and quantity consumed by country j of variety ω of product i, and Ω_{ji} is the set of goods available to j. The elasticity of substitution across varieties within products is greater than the elasticity of substitution across products, $\sigma \equiv 1/(1-\alpha) > \varepsilon \equiv 1/(1-\nu) > 1$ where $0<\alpha<1$ and $0<\nu<1$. If total expenditure on product i in country j is R_{ji}, j's demand for variety ω is

$$x_{ji}\left(\omega\right) = R_{ji}P_{ji}^{\sigma-1}q_{ji}\left(\omega\right)^{\sigma-1}p_{ji}\left(\omega\right)^{-\sigma}, \text{ where } P_{ji} = \left[\int_{\omega\in\Omega_{ji}} \left(\frac{p_{ji}\left(\omega\right)}{q_{ji}\left(\omega\right)}\right)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}} \tag{2}$$

is a quality-adjusted ideal price index and $p_{ji}(\omega)$ 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 that increases the consumer appeal of a product given its price.

3.2 Production and trading technology

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. We present a partial-equilibrium model and do not include subscripts indicating the exporting country.[6]

[6] 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 2008, Manova and Zhang 2009, 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. Moreover, there is a unique input factor, labor, whose wage is normalized to 1 to serve as the numeraire.[7]

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 $q_i(\varphi, \lambda_i) = (\varphi\lambda_i)^{1+\theta}$, $\theta > -1$.[8] 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 (or consumer appeal). $g(\varphi)$ 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.

In addition to the sunk entry cost and marginal production costs, 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} required 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 destination-product specific fixed costs f_{xj} which reflect market research, advertising, product customization and standardization. There are also variable transportation costs of the iceberg variety 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.

3.3 Domestic production

With monopolistic competition and a continuum of varieties, firms take all price indices P_{ji} as given. In addition, because of the nested structure of utility, a firm's price for product i does

[7] See Verhoogen (2008) and Johnson (2010) 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.

[8] 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.

not affect demand for its other products.[9] Firms thus separately maximize profits from each country-product market. Consumer love of variety and the presence of product specific overhead costs f_p further imply that no firm will export a product without also selling it at home.

A profit-maximizing firm with ability φ will choose the domestic (d) price and output level of a product with expertise draw λ_i by solving

$$\begin{aligned} \max_{p,x} \pi_{di}(\varphi, \lambda_i) &= p_{di}(\varphi, \lambda_i) x_{di}(\varphi, \lambda_i) - x_{di}(\varphi, \lambda_i) \varphi \lambda_i - f_p \\ \text{s.t. } x_{di}(\varphi, \lambda_i) &= R_{di} P_{di}^{\sigma-1} q_i(\varphi, \lambda_i)^{\sigma-1} p_{di}(\varphi, \lambda_i)^{-\sigma}. \end{aligned} \tag{3}$$

Producers will therefore charge a constant mark-up over marginal cost and earn the following revenues and profits:

$$p_{di}(\varphi, \lambda_i) = \frac{\varphi \lambda_i}{\alpha}, \qquad r_{di}(\varphi, \lambda_i) = R_{di}(P_{di}\alpha)^{\sigma-1}(\varphi\lambda_i)^{\theta(\sigma-1)}, \qquad \pi_{di}(\varphi, \lambda_i) = \frac{r_{di}(\varphi, \lambda_i)}{\sigma} - f_p. \tag{4}$$

Note that if $\theta = -1$, the model would reduce to the original BRS framework in which firms (firm-products) with lower marginal costs offer lower prices and earn higher revenues and profits. When $\theta > 0$, however, quality increases sufficiently quickly with marginal costs, and more successful firms enjoy bigger revenues and profits despite charging higher prices because they offer products of better quality. Given the results below and the evidence in the prior literature on quality sorting, we assume that $\theta > 0$.

Firms optimally manufacture only products for which they can earn non-negative profits at home. Since profits increase in expertise, for each ability draw φ, there is a zero-profit expertise level $\lambda_i^*(\varphi)$ below which the firm will not produce i. This value is defined by:

$$r_{di}(\varphi, \lambda_i^*(\varphi)) = \sigma f_p. \tag{5}$$

Recall that product expertise is independently and identically distributed across goods. This cut-off will therefore not vary across products and $\lambda_i^*(\varphi) = \lambda^*(\varphi)$ for all i. By the law of large numbers, the fraction of products that a firm with ability φ can manufacture will equal the probability of an expertise draw above $\lambda^*(\varphi)$, or $[1 - Z(\lambda^*(\varphi))]$. Since $d\lambda^*(\varphi)/d\varphi < 0$, 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.

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

3.4 Export markets

The maximization problem for a firm which is considering exporting to country j is similar to (3), but reflects the fixed and iceberg costs associated with international trade:

$$\begin{aligned} \max_{p,x} \pi_{ji}(\varphi,\lambda_i) &= p_{ji}(\varphi,\lambda_i)\, x_{ji}(\varphi,\lambda_i) - \tau_j x_{ji}(\varphi,\lambda_i)\,\varphi\lambda_i - f_{xj} \\ \text{s.t. } x_{ji}(\varphi,\lambda_i) &= R_{ji} P_{ji}^{\sigma-1} q_i(\varphi,\lambda_i)^{\sigma-1} p_{ji}(\varphi,\lambda_i)^{-\sigma}. \end{aligned} \tag{6}$$

The firm's optimal export price is a constant mark-up above marginal cost and exceeds the domestic price by the variable transportation cost which is passed on to consumers. More successful exporters offer higher quality at higher prices and earn bigger profits and revenues:

$$p_{ji}(\varphi,\lambda_i) = \frac{\tau_j \varphi\lambda_i}{\alpha}, \qquad r_{ji}(\varphi,\lambda_i) = R_{ji}\left(\frac{P_{ji}\alpha}{\tau_j}\right)^{\sigma-1}(\varphi\lambda_i)^{\theta(\sigma-1)}, \qquad \pi_{ji}(\varphi,\lambda_i) = \frac{r_{ji}(\varphi,\lambda_i)}{\sigma} - f_{xj}. \tag{7}$$

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 $r_{ji}^{fob}(\varphi,\lambda_i) = R_{ji}(P_{ji}\alpha)^{\sigma-1}(\varphi\lambda_i)^{\theta(\sigma-1)}$.

Firms will only introduce a product in a given market if they expect to make non-negative profits. Since profits rise with product expertise, a firm with ability φ will export product i to country j only if the expertise draw is no lower than $\lambda_{ixj}^*(\varphi)$ given by:

$$r_{ji}\left(\varphi, \lambda_{ixj}^*(\varphi)\right) = \sigma f_{xj}. \tag{8}$$

As before, this cut-off does not vary across products and $\lambda_{ixj}^*(\varphi) = \lambda_{xj}^*(\varphi)$ for all i. The measure of products that a firm with ability φ exports to j will thus equal the probability that the firm draws product expertise above $\lambda_{xj}^*(\varphi)$, or $\left[1 - Z\left(\lambda_{xj}^*(\varphi)\right)\right]$. Since $d\lambda_{xj}^*(\varphi)/d\varphi < 0$, 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, $\lambda_{xj}^*(\varphi) > \lambda^*(\varphi)$, there will be selection into exporting. Across products within a firm, not all goods sold at home will be exported to j. Similarly, across firms selling 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 $\lambda_{xj}^*(\varphi) > \lambda^*(\varphi)$ holds for all j.

For every ability φ, the exporting cut-off for product expertise will vary across destinations because market size R_{ji}, price indices P_{ji}, variable τ_j and fixed f_{xj} 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 (expertise) until it reaches the marginal product which brings zero profits. Within a supplier, higher quality goods will be exported to more countries, earn higher revenues in any given market, and generate higher worldwide sales. A firm's core, top-selling product in every market will be its most expensive, highest-quality good.

Note 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 of 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 finding empirical support in the data.

3.5 Firm profitability

Since profits are independent across countries, firms enter a given market only if total expected revenues there exceed all variable costs, product-level fixed trade costs, and destination-specific overhead headquarters costs. The export profits in j of a firm with ability φ are:

$$\pi_{xj}(\varphi) = \int_{\lambda^*_{xj}(\varphi)}^{\infty} \left[\frac{r_j(\varphi, \lambda)}{\sigma} - f_{xj} \right] z(\lambda)\, d\lambda - f_{hj}. \tag{9}$$

Abler firms have a lower exporting expertise cut-off $\lambda^*_{xj}(\varphi)$ and sell more products in country j. They also earn higher revenues from each good than firms with the same product expertise draw but lower ability. Total export profits from country j thus increase with firm ability, and there is a range of firms whose ability is not sufficiently high to warrant the additional headquarters cost of servicing j. The minimum ability level φ^*_{xj} above which all firms export to j is defined by the following zero-profit condition:

$$\pi_{xj}\left(\varphi^*_{xj}\right) = 0. \tag{10}$$

With asymmetric countries, φ^*_{xj} 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 into production survive. Once firms observe their ability and expertise draws, firms begin production only if their expected profits from all domestic and foreign activities exceed the fixed cost of headquarter services f_h. From (4) and (9), the total profits of a firm with ability φ are given by:

$$\pi(\varphi) = \int_{\lambda^*(\varphi)}^{\infty} \left[\frac{r_d(\varphi, \lambda)}{\sigma} - f_p \right] z(\lambda)\, d\lambda + \sum\nolimits_j \left(\int_{\lambda^*_{xj}(\varphi)}^{\infty} \left[\frac{r_j(\varphi, \lambda)}{\sigma} - f_{xj} \right] z(\lambda)\, d\lambda - f_{hj} \right) - f_h. \tag{11}$$

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.

Firm 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. Firms below a minimum ability level φ^* are therefore unable to break even and exit immediately upon learning their attributes. This cut-off is given by the zero-profit condition:

$$\pi(\varphi^*) = 0. \tag{12}$$

4 Empirical Predictions

Our theory delivers a number of testable predictions that distinguish it from existing models of multi-product firms with efficiency sorting such as BRS. While in those frameworks successful exporters and their core products have low marginal costs and prices, with quality differentiation superior performance is associated with better quality, higher marginal costs and higher prices.

4.1 Variation across products within a firm

In the model, a firm's products can be uniquely ranked based on either price or profitability. While with efficiency sorting lower-priced goods are more profitable, here exporters' best-selling merchandise is their most expensive, highest-quality product.

Proposition 1 *Within a firm, higher-quality goods are more expensive, earn bigger worldwide export revenues, and generate bigger sales in any given destination. The global ranking of a firm's products by either price or revenue is preserved in every market.*

Note that firms might charge different consumer prices in different markets if iceberg transportation costs vary across countries. The CES structure of demand, however, implies that an exporter offers the same free-on-board (f.o.b.) price for a given product to all destinations.

4.2 Variation across destinations within a firm

Product scope and average product quality

From the expression for the exporting expertise cut-off (8), an exporter's average f.o.b. price and quality in market j are:

$$\begin{aligned} \overline{p}_{xj}(\varphi) &= \frac{\varphi}{\alpha}\int_{\lambda^*_{xj}(\varphi)}^{\infty} \lambda z(\lambda)\, d\lambda, \qquad \overline{q}_{xj}(\varphi) = \varphi^{1+\theta}\int_{\lambda^*_{xj}(\varphi)}^{\infty} \lambda^{1+\theta} z(\lambda)\, d\lambda, \\ \overline{p}_{xj}(\varphi) &= \frac{\varphi}{\alpha}\int_{\lambda^*_{xj}(\varphi)}^{\infty} \frac{r_j(\varphi,\lambda)}{r_j(\varphi)} \lambda z(\lambda)\, d\lambda, \qquad \overline{q}_{xj}(\varphi) = \varphi^{1+\theta}\int_{\lambda^*_{xj}(\varphi)}^{\infty} \frac{r_j(\varphi,\lambda)}{r_j(\varphi)} \lambda^{1+\theta} z(\lambda)\, d\lambda \end{aligned} \tag{13}$$

Here the top line represents airthmetic means, the bottom line shows sales-weighted averages, and $r_j(\varphi) = \int_{\lambda^*_{xj}(\varphi)}^{\infty} r_j(\varphi,\lambda)\, z(\lambda)\, d\lambda$ are total firm revenues in j.

A firm φ will thus offer lower average quality at a lower average price in countries where it exports more products, i.e. $\lambda^*_{xj}(\varphi)$ is lower. The correlations of product scope with *revenue-weighted* average quality and price are, however, thereotically ambiguous. This ambiguity arises because when firms expand their product range, they add low-quality cheap products, but these goods generate limited revenues. When the former effect is sufficiently strong, revenue-weighted average price and quality will fall with product scope, but less quickly than the simple averages.

Proposition 2 *Each firm focuses on its core competencies and drops its lowest-quality goods in destinations where it sells fewer products. Product scope is thus negatively correlated with average* *quality and price across markets within a firm. This correlation is less negative or positive for revenue-weighted average price and quality.*

Product scope and firm revenues

If countries are symmetric in size, the product-specific price index P_i and aggregate spending R_{ji} will be the same in each economy. Firms will then earn identical free-on-board revenues for a given good in all markets where it is sold. Product scope could still vary across destinations with different trade costs f_{xj} and τ_j. In particular, firms would export more products at a lower average price and earn higher total revenues in markets with lower penetration costs. This would result in a positive (negative) correlation between product scope (average export price) and total export revenues across destinations within a firm. However, these relationships turn ambiguous when countries differ in both market size and trade costs. It then becomes possible for firms to sell many products yet earn low total revenues in a relatively small country with low trade costs.

Proposition 3 *If export destinations differ only in trade costs but are symmetric in market size, product scope (average export price) will be positively (negatively) correlated with export revenues across destinations within a firm. These relationships are thereotically ambiguous when countries differ in both size and market entry costs.*

For comparison, with efficiency-sorting firms charge a higher average price in countries where they export more products, as they then add more products in increasing order of marginal costs. BRS thus predict a positive correlation between product scope, average export price and total bilateral revenues across destinations within a firm.

4.3 Variation across firms in a destination

Quality sorting across firms

Our framework retains the central prediction of quality-sorting models that more successful exporters earn higher profits and revenues by offering higher quality goods at higher prices. We restate this result here for completeness.

Proposition 4 *Within each destination-product market, firms charging higher f.o.b. prices offer higher quality and earn higher export revenues.*

Product scope and average product quality

Across firms in a given market, abler exporters will offer more products at a higher average quality. To see this, note from (7) that for every destination, there is a minimum product quality (or marginal cost $\varphi\lambda$) above which exporting becomes profitable. Although producers with different ability draws face different expertise thresholds for exports to j, their cut-off product in j has the same quality level. At the same time, the quality of a firm's highest-quality export good rises systematically with firm ability because product expertise is i.i.d. across firms and goods.

For this reason, average product quality increases with firm ability and is positively correlated with export product scope. Revenue-weighted average product quality rises even faster with firm ability and product scope because firms earn bigger revenues from higher-quality products.

Proposition 5 *Firm ability, product scope, (revenue-weighted or arithmetic) average product quality and (revenue-weighted or arithmetic) average export price are positively correlated across firms in a destination.*

Product scope and firm revenues

Recall from (9) that total firm revenues from all goods sold in a given destination increase with firm ability. Combined with the result for product scope and average product quality above, the following relationships follow:

Proposition 6 *Export revenues are positively correlated with firm ability, product scope and average export price across firms in a destination.*

4.4 Discussion

Our model makes specific assumptions about consumer preferences and the nature of firm competition. We surmise that our key predictions concerning the variation in *quality* across firms, products and destinations will hold to alternative modeling choices. Some implications for observed *prices*, however, might have to be modified in the presence of variable mark-ups. We discuss two such refinements here and plan to incorporate them into the model in the future. These are closely related to mechanisms identified in Mayer et al. (2011) and Eckel et al. (2011).

While firms charge a constant mark-up above marginal cost with CES preferences, they lower mark-ups in response to tougher competition with linear demand. Exporters might therefore both sell fewer goods and reduce prices in tougher markets. Conversely, with cannibalization effects across a producers' merchandise, when sellers expand their product range to increase total revenues they might have to set lower mark-ups across all goods. The first of these mechanisms would tend to weaken the negative correlation between product scope and average export prices across destinations within a firm (Proposition 2), while the latter would tend to strengthen it.

These forces could also affect the association between product scope and average export prices across firms within a destination (Proposition 5). When the cannibalization effects are sufficiently strong, for example, this correlation might turn negative if exporters marketing more products in a given market tend to cut mark-ups by more.

CES preferences also imply that within a supplier, 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 products (see (7)). This would no longer be the case with linear demand and the cannibalization effects discussed above. As Mayer et al. (2011) show, firms then concentrate sales in their top articles in markets where they sell fewer varieties. This would generate a negative correlation between product scope and the skeweness of export revenues (towards core products) across destinations within a firm and across firms within a destination.

5 Results

Our empirical analysis proceeds in three steps. We begin by confirming the central prediction of the model that firms' high-quality goods command high prices and generate high revenues. We then examine the relationship between product scope, export revenues, average product quality and sales skewness across destinations within a firm. Finally, we explore these relationships in the cross-section of exporters within specific markets.

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, $price_{fp} = \frac{\sum_d revenue_{fpd}}{\sum_d quantity_{fpd}}$. In order to make these prices comparable across goods, we demean them by their product-specific average unit value across all firms in the data. For notational simplicity, $price_{fp}$ below always refers to these demeaned prices.

Using this measure, we estimate the following specification:

$$\log price_{fp} = \alpha + \beta \log revenue_{fp} + \delta_f + \varepsilon_{fp}, \tag{14}$$

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 or product.

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 our theoretical assumption that $\theta > 0$. 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 log exports is associated with a 11% higher price.

We conduct two sensitivity analyses to ensure that this finding is not driven by measurement error (ME) in export values or quantities that could bias β. First, we explore the variation in the scope for quality differentiation across products using three common proxies from the prior literature. In Column 2, 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 3 and 4 when we instead proxy the potential for quality upgrading with sectors' R&D intensity or combined advertising and R&D intensity. 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 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 5 illustrates, there is a strong positive correlation between products' global rank by price and by 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 conduct a more stringent test of the model and examine the variation across exporters' goods within specific destination markets. We re-estimate equation (14) with the firm-product-country triplet as the unit of observation. The outcome variable is now $\log price_{fpd}$ after it has been demeaned by its product-country specific average across exporters. Similarly, we consider bilateral instead of global trade flows on the right-hand side. By including firm-destination pair fixed effects, the regression implicitly accounts for the variation in total expenditure and consumer price indices across markets as directed by the theory. It additionally controls for cross-country differences in consumer preferences, market toughness, trade costs and other institutional frictions outside our model.

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 significantly higher for goods with greater scope for quality differentiation. It is also robust to using products' price and revenue ranks instead of levels, where these ranks have now been constructed separately for each firm and importing country.

Export prices and imported-input prices

The results in Tables 3 and 4 strongly suggest that firms' best-selling products are their most expensive goods. In our model, this pattern obtains only with quality sorting across goods within a firm. However, other theoretical frameworks might be able to generate the same relationship without it. The systematic differences we document across sectors with varying 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 exporters' products. A large number of Chinese firms use foreign components in the production of final goods for sale abroad. The customs files record the value and quantity for 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.

While this technique has been used in the prior literature, its application poses some challenges in our context. We are interested in exporters that manufacture multiple products using multiple intermediates. 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 consistently find evidence of 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 markets. If the company also manufactures cell phones, the price it pays for SIM cards 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 each producer, we construct a weighted average log input price across all imported materials (e.g. tires, steering wheels) in a given HS-3 digit category (e.g. automobiles). We use import values as weights, but our results are robust to taking an unweighted average instead.[10] We then assign this average input price to all HS-8 digit products exported in the same 3-digit industry (e.g. cars and potentially trucks).

In Column 1 of Table 5, we regress firms' log export price by product on this average log input price. We exploit purely the variation across output goods within a manufacturer by including firm fixed effects. We find a highly statistically and economically significant positive correlation. In Column 4, we document the same pattern when we consider exporters' average log export price across all goods sold within a 3-digit industry (weighted by export revenues). In this specification the outcome and the right-hand side variables are at the same level of aggregation.

[10] Before this manipulation, we demean all import prices by their product-specific average across firms. We do the same for the construction of all other input price proxies.

Our second method of 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 for 139 industries. The relative contribution of two inputs typically varies across output sectors. For example, manufacturing a car might require 1 steering wheel and 4 tires, whereas a truck takes 1 steering wheel and 8 tires.

For any given firm, we can therefore assign some part of every imported input to each of its exported products. For example, if a producer imports 2 steering wheels and 12 tires and exports 1 car and 1 truck, we can easily use the input-output tables to construct an average input price for the car and for the truck. In practice, this allocation process is imperfect because firms do not necessarily use imported inputs in the same proportion as the IO tables suggest. For robustness, we construct an average input price for each firm-product pair in two different ways. Reassuringly, these two methods deliver very similar results.

In Columns 2 and 3 of Table 5, we regress companies' log export price by HS-8 digit product on the two average input prices imputed from the IO tables. In Columns 5 and 6 we repeat the exercise, this time averaging firms' export price to the same level of aggregation as the input prices. In all four specifications we consistently document strong positive correlations. These are also of comparable magnitude to those based on our simpler measure of the relevant input price in Columns 1 and 4.

In sum, there is a strong and robust positive association between export prices, export revenues and input prices across products within firms. These results are consistent with exporters offering a range of products and raising more export revenues from their higher-quality, more expensive goods. This evidence provides empirical support for Proposition 1.

5.2 Variation across destinations within a firm

Product scope, export revenues and average prices

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

We test Propositions 2 and 3 by estimating

$$\begin{aligned} \log revenue_{fd} &= \alpha + \beta \log Nproducts_{fd} + \delta_f + \varepsilon_{fd} \quad \text{and} \\ \log price_{fd} &= \alpha + \beta \log Nproducts_{fd} + \delta_f + \varepsilon_{fd}. \end{aligned} \tag{15}$$

For simplicity, we use the same parameter notation in all estimating equations, realizing that the coefficient point estimates in fact differ across specifications. We report robust standard errors and note that our results continue to hold when we instead cluster errors by firm or destination.

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.

As Panel A of Table 6 shows, exporters earn systematically higher revenues in countries where they sell more products (Column 1). At the same time, product scope is negatively correlated with the average price across a suppliers' merchandise (Column 2). Moreover, this association obtains in the sample of differentiated goods with potential for quality upgrading, but is absent among homogeneous commodities (Columns 3 and 4). While theoretically ambiguous, the relationship between product scope and the revenue-weighted average price is also negative (Column 5). As expected, however, it is markedly weaker than that for the arithmetic average. These patterns are economically significant. The typical firm sees 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 market.

Core products and product hierarchies

The results above are broadly consistent with exporters expanding (restricting) their product offerings across destinations by adding (dropping) 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 exporters' adjustments along the extensive margin of trade.

For each firm and product, we take the firm's global product ranking by sales and assign it to that product in every market where it is sold. We then record the average, 10^{th} percentile and 90^{th} percentile rank observed across the products firm f sells in destination d.[11] If the exporter strictly follows a unique product 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. Thus, there should be no systematic variation in the minimum (10^{th} percentile) product rank across destinations within a firm, while product scope should be positively correlated with the maximum (90^{th} percentile) and with the average product rank. Deviations from these patterns would signal that firms do not adhere to a particular product ladder but instead routinely re-order products across markets.

We evaluate these predictions by regressing each of the three relevant rank measures (jointly

[11] We work with the 10^{th} and 90^{th} percentile instead of the absolute minimum and maximum to guard against idiosyncracies across countries and potential outliers. Qualitatively similar but noisier results obtain if we instead use these extreme values.

referred to as $rank_{fd}$) on the number of bilaterally traded products:

$$rank_{fd} = \alpha + \beta Nproducts_{fd} + \delta_f + \varepsilon_{fd}. \tag{16}$$

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

As Panel A of Table 7 shows, the average global 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 A of Table 8, we re-estimate equation (16) using the global rank of firms' products by *price* instead of by sales. We obtain qualitatively similar results with two exceptions. The average rank is now 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, these results suggest that exporters' core competency lies with their expensive products, which correspond to firms' highest-quality goods. At the same time, the findings in Table 8 raise the possibility that product hierarchies are not perfectly correlated across destinations. We surmise unobserved taste (demand) shocks at the product-destination or firm-product-destination level contribute to these deviations from a perfect product ordering, as in BRS.

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

As a measure of concentration, we take the ratio of free-on-board revenues for the top and second-best product for each firm f and destination d, $revenue_{fd1}/revenue_{fd2}$. We identify these top two products based on either bilateral sales or price. We then regress the log of 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:

$$\log revenue_{fd1}/revenue_{fd2} = \alpha + \beta \log Nproducts_{fd} + \delta_f + \varepsilon_{fd}. \tag{17}$$

As Panel A of Table 9 shows, firms tend to skew their exports towards their top-selling and most expensive product in countries where they sell fewer varieties. Halving the merchandise range is associated with an approximately 20% rise in revenues from the most profitable good relative to the second-best. This pattern suggests that the constant mark-up assumption in our baseline model is not validated in the data. Instead, variable mark-ups and cross-product cannibalization effects are likely important in accounting for the decisions of multi-product exporters.

Indeed, the relationship we identify is considerably stronger among homogeneous articles that have a higher elasticity of substitution and are thus plausibly more subject to cannibalization forces than differentiated varieties.

Overall, the results in this subsection paint a coherent picture broadly in line with the predictions of the model. 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.

5.3 Variation across firms in a destination

As discussed earlier, there already exists strong empirical support for the importance of quality differentiation across suppliers (Proposition 4). A number of studies have found that within each destination-product market, firms charging higher prices earn higher revenues. Prior evidence also links output prices to manufactured input prices, worker skill and wages, and even direct measures of product quality. For this reason, here we focus on Propositions 5 and 6 only.

We are interested in the variation in product scope, export revenues, average prices and sales skewness across exporters within a given importing country. To this end, we re-estimate specifications (15), (16) and (17) replacing the firm fixed effects with destination dummies δ_d.

We document very similar patterns in the cross-section of firms servicing a given market as we did in the cross-section of destinations penetrated by a given producer. As expected, exporters selling more products earn higher revenues (Panel B of Table 6). In unreported results, we have also confirmed that firms' sales are positively correlated with the average export price across their products. Moreover, suppliers shipping more products go further down their product ladder and record higher average and 90^{th} percentile global product rank, by either sales or price. By contrast, their 10^{th} percentile product rank varies substantially less with product scope (Panel B of Tables 7 and 8). These findings are in line with our characterization of the operations of multi-good, multi-quality firms.

At the same time, two other patterns in the data deviate from a strict interpretation of our model. First, there is a significant negative correlation between product scope and average export price across exporters within a destination (Panel B of Table 6). This result contradicts the predictions of the model, and suggests that product cannibalization might indeed be an important factor in firms' export decisions. In particular, producers might have an incentive to lower mark-ups and thus record an overall lower average price when they export more products so as to maximize total export profits. This would be in agreement with the spirit of our model as a lower average price need not signal lower average quality. We leave a more thorough understanding of the mechanisms at play to future work.

Second, across exporters to a particular market, those selling fewer goods concentrate sales in their core products, as ranked by either bilateral sales or price (Panel B of Table 9). This result would be consistent with our formulation of quality heterogeneity across firms and goods if it were extended to incorporate cannibalization effects as alluded to in Section 4.4.

6 Conclusion

We establish four new stylized facts about the operations of multi-product firms using detailed customs data for China. First, manufacturers generate higher bilateral and global sales from their more expensive products. Second, exporters focus on their top-ranked 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 products. Finally, export prices are positively correlated with input prices across products within a firm. Together, these results suggest that product quality varies across a manufacturer's merchandise and depends on the quality of intermediate inputs. We propose a model of heterogeneous multi-product, multi-quality firms that accounts for the empirical variation across products and destinations within firms. Future extensions of this theoretical framework would also be able to explain the similar patterns we document in the cross-section of exporters in a market.

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 and, indirectly, for the associated welfare and distributional consequences.

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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 Price and Revenues

This table ranks products within multi-product firms based on either worldwide export revenues (rows) or export price (columns) by firm-product. 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 first construct the average export price as the ratio of total worldwide export revenues and quantities. We then demean these prices by their product-level average across all firms, and rank products within firms accoridng to these demeaned prices. Each cell in the table shows what percent of all firm-product pairs receive a certain rank by price and revenue.

Product Rank by Price	1	2	3	4	5	>5	Total
Product Rank by Sales							
1	**4.49%**	1.94%	1.09%	0.69%	0.48%	2.05%	10.75%
2	2.02%	**2.03%**	1.08%	0.68%	0.46%	1.97%	8.24%
3	1.12%	1.12%	**1.14%**	0.70%	0.47%	1.95%	6.50%
4	0.71%	0.71%	0.72%	**0.74%**	0.48%	1.93%	5.30%
5	0.48%	0.48%	0.49%	0.49%	**0.50%**	1.95%	4.40%
>5	1.93%	1.96%	1.98%	2.00%	2.01%	**54.94%**	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. Products' scope for quality differentiation is proxied by the Rauch dummy for differentiated goods (Column 2), sectors' R&D intensity (Column 3), or sectors' combined advertising and R&D intensity (Column 4). Column 5 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	Rauch Dummy	R&D Intensity	Adv. + R&D Intensity	Product Rank
	(1)	(2)	(3)	(4)	(5)
(log) Revenue	0.039 (68.94)***	0.028 (17.21)***	0.034 (47.48)***	0.036 (37.83)***	0.076 (17.50)***
(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
R-squared	0.41	0.44	0.42	0.42	0.69
# observations	898,247	619,357	871,596	875,097	898,247
# firms	96,522	84,464	93,514	94,005	96,522

Table 4. 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. Products' scope for quality differentiation is proxied by the Rauch dummy for differentiated goods (Column 2), sectors' R&D intensity (Column 3), or sectors' combined advertising and R&D intensity (Column 4). The last column 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	Rauch Dummy	R&D Intensity	Adv. + R&D Intensity	Product Rank
	(1)	(2)	(3)	(4)	(5)
(log) Revenue	0.040 (84.92)***	0.033 (21.87)***	0.032 (52.66)***	0.035 (43.35)***	0.101 (16.85)***
(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
R-squared	0.53	0.57	0.53	0.53	0.73
# observations	2,179,923	1,494,839	2,130,413	2,139,735	2,179,923
# dest-firm pairs	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 the prices of their imported intermediate inputs. It explores the variation across products within a firm by including firm fixed effects. The outcome variable is firms' (log) export price by HS-8 digit product in Columns 1-3 and the weighted average log export price by HS-3 digit product (by IO sector) in Column 4 (Columns 5-6) using export revenues as weights. The input price is based on imported inputs in the same HS-3 digit product category (Column 1, 4), or on all inputs using input-output tables (Columns 2-3, 5-6). All input prices are weighted averages of (log) import prices of individual inputs, using weights constructed from import values and input-output table coefficients as described in the text. All prices have been demeaned by their product-specific average across firms before any further manipulation. All regressions include a constant term. T-statistics in parentheses, based on robust standard errors. ***, **, and * indicate significance at the1%, 5%, and 10% level.

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

Product Category	HS-8 Product			HS-3 Product	IO Sector	
Inputs	Inputs in Same HS-3	All Inputs (Method I)	All Inputs (Method II)	Inputs in Same HS-3	All Inputs (Method I)	All Inputs (Method II)
	(1)	(2)	(3)	(4)	(5)	(6)
(log) Input Price	0.17	0.13	0.15	0.25	0.19	0.20
	(27.52)***	(15.92)***	(19.95)***	(23.17)***	(14.07)***	(16.17)***
Firm FE	Y	Y	Y	Y	Y	Y
R-squared	0.444	0.374	0.375	0.620	0.481	0.482
# observations	118,381	330,604	330,604	45,649	106,005	106,005
# firms	22,583	36,042	36,042	22,583	36,042	36,042
# product categories	5,153	5,578	5,578	169	89	89

Table 6. Bilateral Export Revenues, Average Price and Product Scope

This table examines the relationship between firms' bilateral export revenues, average export price and product scope. Panel A explores the variation across destinations within a firm by including firm fixed effects, while Panel B explores the variation across firms in a destination by including destination fixed effects. Product scope is measured by the (log) number of products a firm exports to a given destination. For each firm, product and destination, we demean the (log) price by the product-destination specific average across firms. We construct the average (log) export price at the firm-destination level as the arithmetic average of these demeaned prices within each firm-destination pair or the weighted average using the firms' export revenues in that destination as weights. Column 3 (4) restricts the sample to homogeneous (differentiated) goods only. All regressions include a constant term. T-statistics in parentheses, based on robust standard errors. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Panel A. Variation across destinations within a firm

Dep Variable	(log) Revenue	Avg (log) Price			Weighted Avg (log) Price
		All	Hom Goods	Diff Goods	
	(1)	(2)	(3)	(4)	(5)
(log) # Products	1.734 (522.86)***	-0.025 (-18.22)***	0.003 (0.66)	-0.034 (-19.04)***	-0.006 (-4.34)***
Firm FE	Y	Y	Y	Y	Y
R-squared	0.530	0.558	0.603	0.576	0.565
# observations	724,622	724,622	87,459	509,362	724,622
# firms	96,522	96,522	23,390	76,793	96,522

Panel B. Variation across firms in a destination

Dep Variable	(log) Revenue	Avg (log) Price			Weighted Avg (log) Price
		All	Hom Goods	Diff Goods	
	(1)	(2)	(3)	(4)	(5)
(log) # Products	1.126 (393.94)***	-0.033 (-26.87)***	-0.016 (-3.68)***	-0.065 (-40.22)***	-0.013 (-10.27)***
Destination FE	Y	Y	Y	Y	Y
R-squared	0.232	0.014	0.005	0.017	0.012
# observations	724,622	724,622	87,459	509,362	724,622
# destinations	231	231	211	230	231

Table 7. Core Products: Product Scope and Product Rank by Value

This table illustrates that firms focus on their core products when they export fewer goods. Panel A explores the variation across destinations within a firm by including firm fixed effects, while Panel B explores the variation across firms in a destination by including destination fixed effects. For each firm, we rank products based on worldwide export revenues. The top product receives a rank of 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. We then regress these measures on the firm's number of bilaterally exported products. Column 3 (4) 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. T-statistics in parentheses, based on robust standard errors. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Panel A. Variation across destinations within a firm

Dep Variable	Average Rank			10^{th} Perc	90^{th} Perc
Sample	All	Hom Goods	Diff Goods	# Goods ≥ 2	# Goods ≥ 2
	(1)	(2)	(3)	(4)	(5)
# Products	0.43 (46.13)***	0.36 (13.56)***	0.42 (47.34)***	-0.02 (-2.63)***	0.82 (36.13)***
Firm FE	Y	Y	Y	Y	Y
R-squared	0.723	0.659	0.703	0.294	0.829
# observations	724,622	87,459	509,362	330,805	330,805
# firms	96,522	23,390	76,793	70,672	70,672

Panel B. Variation across firms in a destination

Dep Variable	Average Rank			10^{th} Perc	90^{th} Perc
Sample	All	Hom Goods	Diff Goods	# Goods ≥ 2	# Goods ≥ 2
	(1)	(2)	(3)	(4)	(5)
# Products	1.13 (40.03)***	0.82 (23.25)***	1.09 (42.05)***	0.14 (61.29)***	2.31 (35.48)***
Destination FE	Y	Y	Y	Y	Y
R-squared	0.180	0.158	0.192	0.046	0.216
# observations	724,622	87,459	509,362	330,805	330,805
# destinations	231	211	230	223	223

Table 8. Core Products: Product Scope and Product Rank by Price

This table illustrates that firms focus on their core products when they export fewer goods. Panel A explores the variation across destinations within a firm by including firm fixed effects, while Panel B explores the variation across firms in a destination by including destination fixed effects. For each firm, we rank products based on worldwide export prices (worldwide export revenues divided by worldwide export quantities), after these prices have been demeaned by the product-average across all firms. The top product receives a rank of 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, 10th percentile and 90th percentile rank observed across the products sold by a firm in a given destination. We then regress these measures on the firm's number of bilaterally exported products. Column 3 (4) 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. T-statistics in parentheses, based on robust standard errors. ***, **, and * indicate significance at the1%, 5%, and 10% level.

Panel A. Variation across destinations within a firm

Dep Variable	Average Rank			10^{th} Perc	90^{th} Perc
Sample	All	Hom Goods	Diff Goods	# Goods ≥ 2	# Goods ≥ 2
	(1)	(2)	(3)	(4)	(5)
# Products	0.05 (5.47)***	-0.01 (-0.54)	0.06 (6.82)***	-0.29 (-19.75)***	0.37 (27.98)***
Firm FE	Y	Y	Y	Y	Y
R-squared	0.910	0.863	0.902	0.673	0.959
# observations	724,622	87,459	509,362	330,805	330,805
# firms	96,522	23,390	76,793	70,672	70,672

Panel B. Variation across firms in a destination

Dep Variable	Average Rank			10^{th} Perc	90^{th} Perc
Sample	All	Hom Goods	Diff Goods	# Goods ≥ 2	# Goods ≥ 2
	(1)	(2)	(3)	(4)	(5)
# Products	1.66 (32.58)***	0.96 (18.33)***	1.62 (33.85)***	0.45 (27.91)***	2.68 (32.67)***
Destination FE	Y	Y	Y	Y	Y
R-squared	0.141	0.107	0.158	0.086	0.194
# observations	724,622	87,459	509,362	330,805	330,805
# destinations	231	211	230	223	223

Table 9. Product Scope and the Concentration of Sales in Core Products

This table examines the relationship between the (log) number of products that firms export to a given destination and the concentration of export revenues in firms' core products. Panel A explores the variation across firms in a destination by including destination fixed effects, while Panel B explores the variation across destinations within a firm by including firm fixed effects. The outcome variable is the ratio of (log) sales of a firm's top product in a given destination to (log) sales of the second-ranked product in that market. For each firm-destination, we rank products based on the firm's bilateral export sales or bilateral export prices (after they have been demeaned by product-destination specific averages across firms). The sample is restricted to firm-destination pairs with 2 or more products. Columns 2 and 5 (3 and 6) restrict the sample to homogeneous (differentiated) goods only. All regressions include a constant term. T-statistics in parentheses, based on robust standard errors. ***, **, 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

Panel A. Variation across destinations within a firm

Products Ranked by	Revenue			Price		
Sample	All	Hom Goods	Diff Goods	All	Hom Goods	Diff Goods
	(1)	(2)	(3)	(4)	(5)	(6)
(log) # Products	-0.42 (-100.24)***	-0.65 (-17.69)***	-0.42 (-79.50)***	-0.18 (-19.21)***	-0.34 (-4.53)***	-0.21 (-17.22)***
Firm FE	Y	Y	Y	Y	Y	Y
R-squared	0.488	0.578	0.519	0.282	0.484	0.320
# 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

Panel B. Variation across firms in a destination

Products Ranked by	Revenue			Price		
Sample	All	Hom Goods	Diff Goods	All	Hom Goods	Diff Goods
	(1)	(2)	(3)	(4)	(5)	(6)
(log) # Products	-0.64 (-190.15)***	-0.82 (-39.29)***	-0.68 (-160.83)***	-0.16 (-23.34)***	-0.34 (-7.69)***	-0.18 (-21.31)***
Destination FE	Y	Y	Y	Y	Y	Y
R-squared	0.082	0.063	0.086	0.002	0.009	0.003
# observations	330,805	21,793	218,413	330,805	21,793	218,413
# destinations	223	173	222	223	173	222

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

This table reproduces results from Manova and Zhang (2009). It examines the relationship between export prices and revenues across firms within a destination-product market. The outcome variable is the (log) free on board export price by firm, destination and HS-8 product. Products' scope for quality differentiation is proxied by the Rauch dummy for differentiated goods (Column 2), sectors' R&D intensity (Column 3), or sectors' combined advertising and R&D intensity (Column 4). 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