TESTING THE CORE-COMPETENCY MODEL OF MULTI-PRODUCT EXPORTERS*

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Abstract

We review the implications of the "core-competence" model of multi-product firms, including the "market-size puzzle": for most countries, the world market is much larger than the home market, while the costs of accessing foreign markets are relatively low; hence the model predicts that most domestic firms should export more of their core products than they sell domestically; yet, in practice, we do not observe this. Extending the model to allow for investment in export market penetration resolves the puzzle, and Mexican data confirm its predictions: in particular, only the largest firms exhibit the dominance of exports over home sales.

Keywords: Core-competence model; Export-market penetration costs; Flexible manufacturing; Multi-product firms.
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1 Introduction

Recent years have seen an explosion of interest in the behavior of individual firms in global markets. Early work in this vein concentrated on adjustments between firms, highlighting the selection effects of trade liberalization.[1] More recently, as richer data sets have become available, attention has turned to adjustments within firms. One particular focus of recent work has been what Eckel and Neary (2010) call the "intra-firm extensive margin": adjustments in the range of goods produced by multi-product firms. Starting with the findings of Bernard, Redding, and Schott (2010) for the U.S., a growing number of empirical studies for many countries and time periods have shown that multi-product firms dominate exports, and that they frequently vary their product mix. These findings have stimulated a large and growing theoretical and empirical literature.

A feature found in some of this recent work is that of the "core competence" or "competency" of a multi-product firm.[2] The concept of the core competence of a corporation is widely used in the management literature, where it has been defined by Schilling (2005) as "a harmonized combination of multiple resources and skills that distinguish a firm in the marketplace." It was first introduced in this context by Prahalad and Hamel (1990), who argued that core competencies fulfill three criteria: they should make a significant contribution to the perceived customer benefits of the end product; should provide potential access to a wide variety of markets; and should be difficult to imitate by competitors. Eckel and Neary (2010) formalized this concept by making specific assumptions that correspond to each of the three criteria of Prahalad and Hamel (1990): they assumed that a multi-product firm has costs of production which differ across products; that these differences operate at the level of the firm rather than being specific to particular markets; and that all the firm's products are differentiated from rival's products as well as from each other. They showed that this model implies a distinctive pattern of adjustment to shocks that increase both the size of the potential market and the extent of competition they face: multi-product firms with the core-competence technology are encouraged to become "leaner and meaner", dropping some of their marginal products while expanding sales of their core products. The resulting increase in average firm productivity is a novel source of gains from trade, analogous to but distinct from the

[1] The classic theoretical treatment is by Melitz (2003). The large and still growing number of empirical studies includes Clerides, Lach, and Tybout (1998) and Bernard and Jensen (1999).

[2] Prahalad and Hamel (1990) use the terms interchangeably, and we follow their lead.

between-firm selection effects of trade shocks in models with heterogeneous single-product firms.

While the core-competence view of multi-product firms has proved useful in many contexts, it cannot explain all features of multi-product firms in the world economy. In a companion paper, Eckel, Iacovone, Javorcik, and Neary (2015), we showed that the model implies a "price-profile puzzle." If consumers view goods as symmetrically differentiated, then a multi-product firm can only sell more of its core products by charging lower prices for them. This implies that the profiles of prices and sales across a firm's products should be inversely related. However, empirically the opposite configuration is often observed. To account for this puzzle, that paper extended the model by assuming that firms can invest in advertising and marketing to enhance the perceived quality of their products. The paper showed that firms face greater incentives to invest in the quality of their core-competence products, and, hence, the profiles of prices and sales are more likely to be positively related, the more differentiated are their products. This prediction was confirmed by a data set on Mexican firms taken from Iacovone and Javorcik (2010).

The present paper extends the model differently to explain a different counter-factual prediction that we call the "market-size puzzle." For any one country in the modern globalized era, the world market dominates the home market in size, while the costs of accessing some if not all foreign markets are relatively low. According to the model, this combination of assumptions implies that the vast majority of domestic firms should export more of their core products than they sell domestically. Yet, in practice, we do not observe this: most firms sell more of all their products at home than they export; only the largest firms exhibit the dominance of exports that the model seems to predict for all. To explain this puzzle and also to throw light on the model's implications for export sales by firms of different productivity, we extend the core-competence model to allow for investment in export market penetration as in Arkolakis (2010) and Arkolakis, Ganapati, and Muendler (2014). We then explore the extended model's implications using the same data set as in our earlier paper. This gives detailed plant-product-year data on Mexican firms for *both* home and export sales at the *same* level of disaggregation. (The properties of the data are discussed in detail in Iacovone and Javorcik (2010) and in Eckel, Iacovone, Javorcik, and Neary (2015).) We show that our model is consistent with this Mexican data set: most firms sell far less on the world market than they do domestically, and only the most productive firms have high ratios of export to home sales.

This data set also allows us to explore the extent to which different competing models are consistent with the data. Ideally, we would like to devise tests which discriminate clearly between different models. In practice, this is not so easy, since the models differ along more than one dimension, both in their assumptions and in their predictions. The approach adopted here is more heuristic. We start with a simplified version of the model of Eckel and Neary (2010) and extend it to allow for variable trade costs and endogenous fixed costs of market penetration. From the predictions of this extended model we deduce a number of features which we would expect the data to exhibit: some of these are common across models, some are special to our own. We then explore to what extent the data exhibit these features.

As in Eckel, Iacovone, Javorcik, and Neary (2015), our focus is on how behavior differs across firms rather than on the market or on the general-equilibrium environment in which they operate. Since we are interested in cross-section differences between firms, we do not need to take a stand on these broader issues. The market structure can be either monopoly, or oligopoly (as in Eckel and Neary (2010)), or monopolistic competition (as in Arkolakis, Ganapati, and Muendler (2014), Mayer, Melitz, and Ottaviano (2014), and Timoshenko (2015)).

Our paper draws on an extensive recent literature on the theory and empirics of multi-product firms in open economies.[3] Some differences in empirical implications for the pattern of sales across a firm's products can be identified in this literature. First is a group of papers, including some of the pioneering works on the topic, which differ in many respects but share the common feature that they predict a uniform sales profile across a firm's products. This group includes Helpman (1985), Ju (2003), Allanson and Montagna (2005), Feenstra and Ma (2008), Baldwin and Gu (2009), Dhingra (2013), Qiu and Zhou (2013) and Nocke and Yeaple (2014). A different approach, pioneered by Bernard, Redding, and Schott (2010) and Bernard, Redding, and Schott (2011), predicts that sales differ across a firm's products solely or mainly because of market-specific demand shocks. A third group of papers pursue the core-competence model, with its distinguishing, and falsifiable, assumption that differences across a firm's products arise mainly from the supply side, and so the profiles of sales and prices should be qualitatively the same in all the markets it serves. This group includes Eckel and Neary (2010), Mayer, Melitz, and Ottaviano (2014), and Eckel,

[3]There is also an even larger literature on multi-product firms in the theory of industrial organization, but for a variety of reasons these are less applicable to the kinds of large-scale data sets on firm-level export performance which are increasingly becoming available. See Eckel and Neary (2010) for further discussion and references.

Iacovone, Javorcik, and Neary (2015). Finally, two recent papers nest the demand- and supply-side perspectives in different ways: Arkolakis, Ganapati, and Muendler (2014) and Timoshenko (2015).

Section 2 of the paper presents the model and explores its implications for the behavior of multi-product firms in a single market. Section 3 compares behavior in different markets, introduces the market size puzzle, and shows how market penetration costs can be added to the model to explain it. Section 4 explores the extent to which the data confirm our theoretical predictions, while Section 5 concludes.

2 The Core Competence Model

Our starting point is the model of Eckel and Neary (2010). In this section we present the basic framework for a single market before extending it to multiple markets in the next section.

2.1 Preferences

The utility of a representative consumer in a specific market is given by

$$u = aQ - \frac{1}{2}b\left[(1-e)\int_{i\in\tilde{\Omega}} q(i)^2\,di + eQ^2\right], \tag{1}$$

where $q(i)$ is consumption of variety i, $Q \equiv \int_{i\in\tilde{\Omega}} q(i)\,di$ is consumption of all varieties, and $\tilde{\Omega}$ is the set of potentially producible differentiated products. The parameter e is a measure of the degree of substitution between varieties: $e = 0$ implies that products are completely unrelated and $e = 1$ implies perfect substitutability.

Inverse market demand is then given by:

$$p(i) = a - \tilde{b}\left[(1-e)\,x(i) + eX\right], \tag{2}$$

where the parameter $\tilde{b}$ is defined as $\tilde{b} \equiv b/L$, $x(i) = Lq(i)$ is aggregate consumption of good i (with L the mass of consumers), $X \equiv \int_{i\in\Omega} x(i)\,di$, and Ω is the set of actually produced varieties with $i \in \Omega \subset \tilde{\Omega}$. Since the focus of our empirical part is on the cross section only where all firms face the same market conditions and, thus, the same residual demands, we can simplify our framework to the monopoly case where all varieties consumed are produced within a single firm. Extending this to heterogeneous-firm oligopoly or monopolistic competition is relatively straightforward (see Eckel et al., (2015) and Mayer, Melitz, and Ottaviano (2014), respectively) but not necessary for the questions at hand here. Therefore, X is total output of both the firm and the industry.

The marginal utility of income is assumed to be equal to one. This can be rationalized by assuming either that u is a sub-utility function in an additively separable function, or that u is a component of a quasi-linear utility function.

2.2 Technology

Our key assumption is that the firm can produce multiple products by using a "flexible manufacturing" technology, as in Eckel and Neary (2010). With this technology, marginal production costs for a specific variety i are independent of output, but differ across products: $c(i)$. A firm has a "core-competence" product which it produces at lowest costs: $c(0) \equiv c_0 = \min\left\{c(i) \ \forall \ i \in \tilde{\Omega}\right\}$. The firm can add products to its core-competence product, but adding products incurs adaptation costs: $c'(i) > 0$.

One of the issues we want to explore is the implications of differences in productivity between multi-product firms for their scale and scope. To focus on this in the clearest possible way, we model differences in productivity as differences in core-competence production costs c_0, but not in adaptation costs: firms have different values of c_0, but all have the same derivative c'. This implies that the $c(i)$ function is shifted downwards for more productive firms and upwards for less productive firms. Similar approaches to adding firm heterogeneity to flexible manufacturing have been used by Arkolakis, Ganapati, and Muendler (2014) and by Mayer, Melitz, and Ottaviano (2014).

In addition to production costs, the firm has to incur marginal trade costs t, in order to access foreign markets. These trade costs are symmetric across products and firms. Naturally, trade costs are only incurred if the product is sold in a foreign market. In the current section we focus on the domestic market, deferring consideration of trade costs until Section 3.

2.3 Optimal Scale and Scope

Each firm chooses output per variety and the scope of its product range to maximize profits. Ignoring fixed costs, the operating profits of a firm are given by

$$\pi = \int_{i \in \Omega} \left[p\left(i\right) - c\left(i\right) \right] x\left(i\right) di. \tag{3}$$

Differentiating this with respect to the output of a specific product j gives the first-order condition for scale (see Eckel and Neary, 2010):

$$\frac{d\pi}{dx\left(j\right)} = \int_{i \in \Omega} \left\{ \frac{dp\left(i\right)}{dx\left(j\right)} x\left(i\right) + \left[p\left(i\right) - c\left(i\right) \right] \frac{dx\left(i\right)}{dx\left(j\right)} \right\} di = 0 \tag{4}$$

It is important to realize that in this expression the term $dp\left(i\right)/dx\left(j\right)$ takes on different values depending on whether $i = j$. Since demand (2) can also be rewritten as $p\left(i\right) = a - \tilde{b}\left[x\left(i\right) + e\left\{X - x\left(i\right)\right\}\right]$, the term $dp\left(i\right)/dx\left(j\right)$ takes on the value $-\tilde{b}$ if $i = j$, and $-\tilde{b}e$ in all other cases. Also, but more trivially, $dx\left(i\right)/dx\left(j\right)$ equals one if $i = j$ and zero otherwise. Thus, the first-order condition for scale can be rewritten as

$$\frac{d\pi}{dx\left(j\right)} = -\tilde{b}x\left(j\right) + \left[p\left(j\right) - c\left(j\right)\right] - \tilde{b}e\left[X - x\left(j\right)\right] = 0, \tag{5}$$

or

$$\underbrace{p\left(j\right) - \tilde{b}x\left(j\right) - \tilde{b}e\left[X - x\left(j\right)\right]}_{\text{Marginal Revenue}} = \underbrace{c\left(j\right)}_{\text{Marginal Cost}} \tag{6}$$

The right-hand side of (6) is the marginal cost of product j. Since marginal production costs are independent of output, this part of the first-order condition is identical to the equivalent condition for single-product firms. The left-hand side of (6) equals the marginal revenue of product j. The first two terms $p\left(j\right) - \tilde{b}x\left(j\right)$ indicate that the marginal revenue of product j is decreasing in its own output because of the downward-sloping demand curve. This effect is also present for single-product firms. The third term $-\tilde{b}e\left[X - x\left(j\right)\right]$ is exclusive to multi-product firms and reflects the fact that marginal revenues are also decreasing in the output of all other products produced by the firm because of the "cannibalization effect". The firm takes into account that selling one more unit of j not only lowers the price of all units of this product, but also lowers the price of all other products produced by the firm, provided they are substitutes for j ($e > 0$). Finally, since equation (6) holds for all varieties sold, we can relabel it as applying it to variety i and combine it with the price $p(i)$ from equation (2) to derive the profit-maximizing scale of output:

$$x(i) = \frac{a - c(i) - 2\tilde{b}eX}{2\tilde{b}(1-e)}. \tag{7}$$

Next, we turn to the first-order condition for scope. This condition is

$$\frac{d\pi}{d\delta} = [p(\delta) - c(\delta)]\, x(\delta) = 0, \tag{8}$$

where δ is the index for the marginal product, $\Omega = [0, \delta]$, and so measures the firm's product scope. This condition reduces to $x(\delta) = 0$ (see Eckel and Neary, 2010) and implies that:

$$c(\delta) = a - 2\tilde{b}eX. \tag{9}$$

Combining (7) and (9), the first-order condition for scale can also be rewritten as:

$$x(i) = \frac{c(\delta) - c(i)}{2\tilde{b}(1-e)}. \tag{10}$$

Given demand (2) and the first-order condition for scale (7), prices and mark-ups are:

$$p(i) = \tfrac{1}{2}[a + c(i)] \tag{11}$$

and

$$p(i) - c(i) = \tfrac{1}{2}[a - c(i)]. \tag{12}$$

Note that the mark-up of the marginal product δ is strictly positive: $p(\delta) - c(\delta) = \frac{1}{2}[a - c(\delta)] = \tilde{b}eX$. This implies that there are products just beyond the marginal product that are not produced despite the fact that they generate a positive mark-up. The reason they are not produced is - once again - the cannibalization effect: adding a product does not just generate the mark-up for this particular product, but it also deflects demand away from other products within the firm's product range. The firm takes this into account so that the marginal product must have a strictly positive mark-up to compensate for this intra-firm demand deflection.

2.4 The Profile of Sales Revenues

Equations (10) and (11) fully characterize the firm's behavior across varieties. However, in most typical data sets, including the one to be used below, though we can construct data on the real volume of outputs of different varieties, there are no natural units of measurement in which these can be compared across varieties. (By contrast, all the theoretical models assume that every variety affects utility symmetrically.) To bring the models to data it is much more convenient to work with the *value* of sales across varieties. Hence we need to calculate the profile of sales revenue across varieties, which we denote by $r(i)$:

$$r(i) = p(i)\,x(i) = \frac{[a + c(i)]\,[c(\delta) - c(i)]}{4\tilde{b}\,(1 - e)} \tag{13}$$

Since price increases but output falls with movements away from the core-competence variety, the implications for sales revenue are not immediately apparent. However, it is easily shown that the output change dominates, so $r(i)$ is decreasing in i, which yields the first testable implication of the model:

Proposition 1. *The profile of sales revenue across varieties in a given market is not uniform.*

Proof. Differentiating (13) and substituting from (9) yields:

$$\frac{dr(i)}{di} = -\frac{\tilde{b}eX + c(i)}{2\tilde{b}(1 - e)}c'(i) < 0 \tag{14}$$

□

The implication that a multi-product firm sells different amounts of each variety it produces in each market it serves is not too remarkable in itself, and follows directly from our assumption that marginal costs rise monotonically for varieties further from the firm's core competence. By contrast, it is inconsistent with models of multi-product firms which assume that varieties are symmetric in both production and demand, such as those of Helpman (1985), Ju (2003), Allanson and Montagna (2005), Feenstra and Ma (2008), Baldwin and Gu (2009), Dhingra (2013), Qiu and

Zhou (2013) and Nocke and Yeaple (2014).[4] It is fully consistent with the model of Bernard, Redding, and Schott (2010) and Bernard, Redding, and Schott (2011), notwithstanding the fact that the source of heterogeneity across varieties is different in their model. They assume that each variety has the same productivity and a taste parameter which is an independent stochastic draw from a given distribution, rather than a deterministic function of each variety's distance from the core-competence variety as here. This difference is immaterial for the observable implications of Proposition 1, but it matters for a second property which also follows from equation (13):

Proposition 2. *The ranking of sales revenue across varieties is the same in all markets served by the firm.*

Different markets will in general have different access costs, different values of total output X, and different values of the market-size demand parameter $\tilde{b}$. Nevertheless, equation (13) implies that varieties can be ranked by their distance from the core competence in all markets. This prediction is very different from that of Bernard, Redding and Schott (2010, 2011) who assume that taste or productivity draws for a given firm-variety pair are independent across markets.

3 Sales Profiles in Home and Foreign Markets

3.1 Home and Away

So far we have considered the model's predictions for a single market. Consider next what it implies for cross-section differences between markets. We assume for simplicity, and in accordance with the data available, that firms sell on two markets only, which we label "home" and "foreign"; variables for the foreign country are indicated by an asterisk (*).[5] We assume that the costs of accessing the home market are zero; as for the foreign country, we assume that exports incur strictly positive specific trade costs, denoted by $t > 0$. The other difference between countries is in market size, where foreign L^* can be either larger or smaller than home L, though it is presumptively a lot larger - a point to which we return below. Finally, we assume that the markets are segmented.

[4] Nocke and Yeaple assume that marginal costs rise with the number of varieties as in Eckel and Neary (2010). However, they assume that this reflects diseconomies of scope, so for a given number of varieties the marginal cost and hence the price, output, and sales revenue are the same for all.

[5] The model is easily extended to allow for many foreign markets, provided they differ along a small number of dimensions. See for example, Arkolakis and Muendler (2010), Bernard, Redding, and Schott (2011), and Mayer, Melitz, and Ottaviano (2014).

Combined with the assumption that marginal costs are independent of output, this means that the firm's choice of scale and scope in each market can be analyzed independently. Moreover, all the results derived in the previous section also apply to the export market provided we reexpress them in terms of variables specific to that market; in particular, the access costs incurred by the firm for variety i are now $c^*(i) = c(i) + t$ rather than $c(i)$.

3.2 The Extensive Margins at Home and Away

Consider first the extensive margins the firm chooses at home and away. The model makes strong predictions about the range of products which the firm will sell in the two markets: their ratio depends only on variable trade costs.[6] In particular:

Proposition 3. *Irrespective of the relative size of the two markets, the firm's product range in its export market is smaller than in its home market:* $\delta^* \leq \delta$.

Proof. To prove this it is sufficient to show that the firm's product range in its export market is strictly decreasing in the variable trade cost t. To see this, first integrate the expression for the output of a single variety in (10) to get total output in the export market:

$$X^* = \frac{\alpha(\delta^*)}{2b(1-e)} L^* \quad \text{where:} \quad \alpha(\delta^*) \equiv \delta^* c(\delta^*) - \int_0^{\delta^*} c(i) di \tag{15}$$

As shown in Eckel and Neary (2010), the expression $\alpha(\delta^*)$ can be interpreted as the cost savings from flexible manufacturing, relative to the total costs which the firm would incur if all varieties had to be produced using the technology of the marginal variety. This equation in X^* and δ^* can be combined with a second equation in these two variables obtained by evaluating (7) for the marginal variety δ^*:

$$2beX^* = [a - c(\delta^*) - t] L^* \tag{16}$$

Eliminating X^* from these equations yields a single equation which expresses the product range as an implicit function of exogenous variables:

$$c(\delta^*) + \frac{e}{1-e} \alpha(\delta^*) = a - t \tag{17}$$

[6] This result does not hold when the model is extended to allow for endogenous investment in product quality, as in Eckel, Iacovone, Javorcik, and Neary (2015).

Note that the market size L^* cancels in this equation, as the proposition states. Totally differentiating (17) yields:

$$\frac{d\delta^*}{dt} = -\frac{1-e}{1-e+e\delta^*}\frac{1}{c'(\delta^*)} < 0 \tag{18}$$

which is negative as required. □

The next result is largely a corollary of Proposition 3, but it is worth stating separately since it requires a different empirical strategy to test it.

Proposition 4. *All products exported by the firm are also sold at home.*

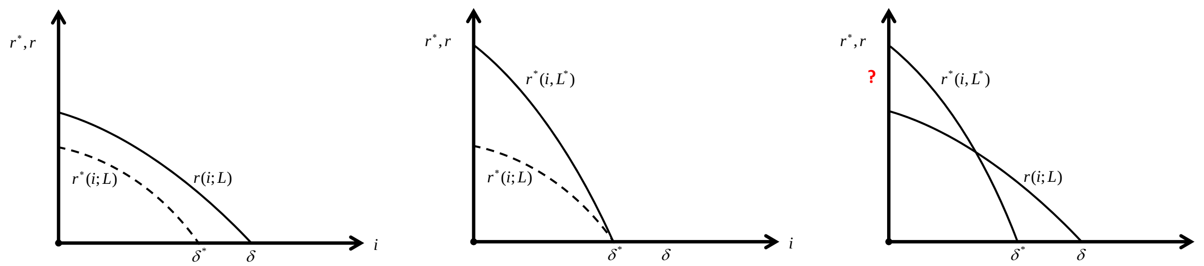
Proof. Proposition 1 implies that $r^*(i) > 0$ for all $i < \delta^*$: all products with indexes lower than δ^* are exported; and, similarly, $r(i) > 0$ for all $i < \delta$: all products with indexes lower than δ are sold on the home market. Moreover, from Proposition 3 we know that $\delta^* \leq \delta$. Hence the result follows. □

3.3 The Market-Size Puzzle

While the product ranges in the two markets can be ranked unambiguously, the same is not true of sales of all products. In particular, sales of the core-competence product can be larger or smaller in the export market. To see this, we first adapt equation (13), which gives home sales of a given variety, to show the value of exports of the same variety:

$$r^*(i) = p^*(i)x^*(i) = \frac{[a + c(i) + t][c(\delta^*) - c(i)]}{4b(1-e)}\,L^* \tag{19}$$

Comparing this with the corresponding equation for home sales, equation (13) itself, we can see that trade costs have two distinct effects on the ratio of export sales to home sales. First, the gross price the firm obtains on exports is higher: because markets are segmented, the firm is able to price discriminate by passing on some of the tariff (exactly half when demand is linear) to foreign consumers, though it must absorb the other half itself. Second, the amount sold to an individual foreign consumer is less than that to an individual home consumer. From Proposition 3, the second effect must dominate for the sales of the marginal product (and by continuity, of those close to it): the range of products supplied contracts, so near-marginal products must either be discontinued altogether or else have a reduced sales value. In addition to these effects of trade costs, a comparison of equations (13) and (19) also shows that any negative effects on the sales of the core-competence product, and, by continuity, of products close to the core, can be offset if the export market is sufficiently larger.



(a) Trade-Cost Effect (b) Market-Size Effect (c) Combined Effect

Figure 1: Sales Profiles at Home and Abroad

The results so far are summarized in Figure 1. Higher trade costs imply from Propositions 3 and 4 that the firm will be "leaner" in the foreign market, selling a proper subset of the varieties that it sells at home: $\delta^* \leq \delta$. In addition, as we have just seen, for a sufficiently large foreign market, it will also be "meaner", selling more of its core products. Combining these two, the net effect on sales of the core-competence product is ambiguous in general.

While these qualitative comparisons suggest that foreign sales of the core-competence product cannot be ranked relative to home sales in general, simple calibrations suggest that, according to the model, exports should be greater than home sales for most firms, at least in the sample of Mexican firms which we consider in the empirical section below. The reasoning is simple. On the one hand, the world market is unquestionably larger than the home market for all Mexican firms: $L^* >> L$. On the other hand, the trade costs they face are relatively low: aggregate data show that 95% of Mexican exports in the goods categories in our data set are to other members of the North American Free-Trade Agreement (NAFTA), to which Mexican firms enjoy near-duty-free access. Thus the negative trade-cost effect shown in panel (a) of Figure 1 should be attenuated, whereas the positive market-size effect shown in panel (b) should be extremely strong. The net effect should be that almost all Mexican firms should export more of their core-competence product. Yet, as we shall see, this is not at all in accordance with the data. We call this the "market-size puzzle", and it seems to call into question the relevance of the core-competence model to this sample of data from a middle-income country.

3.4 Export Market Penetration Costs

To resolve the market-size puzzle, we introduce export market penetration costs, following Arkolakis (2010). Let n ($0 \leq n \leq 1$) denote the proportion of foreign consumers to whom the home firm sells. For simplicity, we assume that the firm sells the same range of goods to all foreign consumers that it chooses to serve, so δ^* is independent of n. Export sales revenue is clearly increasing in n. The downside of reaching more foreign consumers from the firm's perspective is that it must incur market penetration costs, denoted by $f(n)$.[7] We assume that these endogenous fixed costs are increasing and convex in n, and that they rise from zero to infinity as the share of foreign consumers targeted rises from zero to one:

$$f(n): \quad f' > 0, \quad f'' > 0, \quad f(0) = 0, \quad \text{and} \quad \lim_{n \to 1} f(n) = \infty \tag{20}$$

These assumptions imply that any firm which exports will sell only to a proper subset of foreign consumers: the equilibrium value of n is always less than one.

To see the implications of this approach, it is convenient to break the firm's decisions in two: first, the choice of how many products, and how much of each, to sell to each foreign consumer targeted; and, second, the choice of how many foreign consumers to target. Let $q^*(i)$ denote the sales of variety i per consumer in the foreign country. Total exports of variety i are therefore: $x^*(i) = nL^*q^*(i)$. For given n, the optimal choice of scale and scope is determined just as in Section 2. Let $\overline{\pi}^*(c_0)$ denote the maximized value of profits which the firm earns per consumer in the foreign country. Adapting equation (3), this can be written as follows:

$$\overline{\pi}^*(c_0) = \max_{\{q^*(i)\},\delta^*} \left[\int_0^{\delta^*} \{p^*(i) - c(i) - t\}\, q^*(i) di \right] \tag{21}$$

The determination of the optimal sales profile per consumer, $q^*(i)$, and the optimal scope, δ^*,

[7] Arkolakis (2010) assumed CES preferences and a CES-type form for the market penetration cost function: $f(n) = \frac{1-(1-n)^{1-\beta}}{1-\beta}$, $\beta \in (0, \infty)$, $\beta \neq 1$. Here we follow Mrázová and Neary (2011), who show that the comparative statics properties of the model hold more generally.

proceeds exactly as in Section 2. We have already seen how the firm's decisions on scale and scope vary with trade costs and market size. Hence we write the optimal level of profits given by (21) as a function of the firm's core-competence cost of production c_0 only. The final step is the choice of the optimal proportion of consumers to target. The solution to this yields a maximum value of total profits on export sales, which we denote $\Pi^*(c_0)$:

$$\Pi^*(c_0) = \max_n \left[nL^* \,\overline{\pi}^*(c_0) - f(n) \right] \tag{22}$$

The key result is that n is higher for more productive firms, $\frac{dn}{dc_0} < 0$:

Lemma 1. *More productive firms sell to a higher proportion of foreign consumers.*

Proof. From (22), the first-order condition for optimal choice of market penetration is:

$$L^* \overline{\pi}^*(c_0) = f'(n) \tag{23}$$

Totally differentiating and rearranging gives:

$$\frac{dn}{dc_0} = L^* \frac{\frac{d\overline{\pi}^*}{dc_0}}{f''(n)} \tag{24}$$

The denominator of the right-hand side is positive from the assumption that the market penetration cost function is convex in n, which is also a second-order condition for optimal choice of n. As for the numerator, its sign follows from the fact that maximum profits are decreasing in the cost of producing the core-competence product. Differentiating equation (21), making use of the envelope theorem, yields:

$$\frac{d\overline{\pi}^*}{dc_0} = -\int_0^{\delta^*} q^*(i)di = -\frac{X^*}{nL^*} < 0 \tag{25}$$

Hence the expression in (24) is negative, which proves the lemma.[8] □

We are now in a position to resolve the market-size puzzle. Consider the set of goods $i \in [0, \delta^*]$ for which both exports and home sales are positive. Recall that home sales are given by (13), while

[8] Qualitatively, the lemma follows immediately from the fact that (22) implies that $\frac{\partial^2 \Pi^*}{\partial n \partial(-c_0)} > 0$, so Π^* is supermodular in $(n, -c_0)$. (See Mrázová and Neary (2011) for further discussion and references.) However, it is instructive to derive the explicit expression for $\frac{dn}{dc_0}$ as in (24) and (25).

		Effect	$c_0 \downarrow$
(1)	Higher gross prices abroad	> 1	$\uparrow$
(2)	Lower sales per consumer abroad	< 1	$\uparrow$
(3)	Larger market size	$>> 1$	n/a
(4)	Lower foreign market penetration: $0 \leq n \leq 1$	< 1	$\uparrow\uparrow$

Table 1: Comparative Statics of the Ratio of Foreign to Home Sales

export sales are given by (19), amended to allow for the fact that n is less than one. Combining these, we can decompose the ratio of exports to home sales for each good as follows:

$$\frac{r^*(i)}{r(i)} = \underbrace{\frac{a + c(i) + t}{a + c(i)}}_{(1)} \underbrace{\frac{c(\delta^*) - c(i)}{c(\delta) - c(i)}}_{(2)} \underbrace{\frac{L^*}{L}}_{(3)} \underbrace{n}_{(4)} \tag{26}$$

Table 1 presents the four effects highlighted in equation (26), shows their effect on the ratio of foreign to home sales for individual varieties, and (in the final column) shows how this effect changes with firm productivity. Relative to our previous discussion in Section 3.3, endogenous fixed costs of foreign market penetration tend to reduce the ratio of foreign to home sales for all firms and all varieties. However, because these endogenous fixed costs are convex, their negative effect is much attenuated for more productive firms. Summarizing:

Proposition 5. *Convex costs of foreign market penetration reduce the likelihood that firms export more of their core-competence product than they sell it home; but this reduction is less important for more productive firms.*

4 Do the Data Support the Theoretical Predictions?

The data used are the same as in Eckel et al. (2015), to which we refer for further discussion. For the period 1994-2004, we have detailed information on 58,106 Mexican plants, that produce 175,195 products, of which 39,272 are exported. Armed with this rich data set, we now consider whether the patterns it exhibits are consistent with the predictions derived in Sections 2 and 3,

Sold products (value of sales)							
	mean	10th pctile	25th pctile	50th pctile	75th pctile	90th pctile	No. of plants
Ratio of 2nd to top	0.408	0.041	0.140	0.365	0.649	0.857	36,059
Ratio of 3nd to top	0.234	0.015	0.053	0.166	0.360	0.569	24,119
Ratio of 4th to top	0.162	0.008	0.030	0.102	0.239	0.409	16,405
Ratio of 5th to top	0.125	0.005	0.022	0.075	0.180	0.321	11,476
Ratio of 6th to top	0.100	0.004	0.018	0.057	0.141	0.253	8,318
Ratio of 7th to top	0.078	0.003	0.014	0.042	0.106	0.198	6,192
Only plants with 5 products							
Ratio of 2nd to top	0.475	0.108	0.230	0.460	0.708	0.889	3,157
Ratio of 3nd to top	0.241	0.035	0.081	0.185	0.352	0.533	3,157
Ratio of 4th to top	0.119	0.007	0.023	0.071	0.170	0.301	3,157
Ratio of 5th to top	0.052	0.001	0.004	0.019	0.066	0.135	3,157
Only plants with 3 products							
Ratio of 2nd to top	0.392	0.051	0.142	0.336	0.616	0.833	7,697
Ratio of 3nd to top	0.132	0.004	0.016	0.057	0.182	0.376	7,697

Note: products which tied in terms of their rank were excluded from the bottom two panels of the table

Table 2: Ratio of i'th Product Sales to Sales of Core Product

with the numbering of sub-sections that follow matching the propositions stated there.

4.1 Is the profile of sales revenue uniform?

We begin by examining the models' predictions with respect to the revenue profile. To do so, we rank all products within each establishment in terms of their sales revenue. Then we divide the revenue from sales of the second most important product by the revenue associated with the core product. We repeat the exercise for the third, fourth, most important product, etc., and we do this for both total and export sales in Tables 2 and 3 respectively.

The top panel of Table 2 presents the distribution of these ratios for total sales, and the results clearly indicate that the revenue profile is not uniform across products, thus supporting the predictions of Eckel and Neary (2010) and Bernard, Redding, and Schott (2010) and contradicting the assumption of symmetric products made by other authors. On average, the revenues from sales of the second product are 40.8% of the revenues brought by the core product. For the third and fourth products the corresponding figures are 23.4% and 16.2%, respectively. The magnitudes decline as we move away from the core variety. Interestingly, the same pattern is found when we consider the median or other percentiles of the distribution.

Exported products (value of exports)							
	mean	10th pctile	25th pctile	50th pctile	75th pctile	90th pctile	No. of plants
Ratio of 2nd to top	0.374	0.031	0.110	0.313	0.603	0.826	7,915
Ratio of 3nd to top	0.204	0.011	0.043	0.137	0.305	0.501	4,280
Ratio of 4th to top	0.137	0.006	0.023	0.08	0.199	0.359	2,438
Ratio of 5th to top	0.094	0.004	0.016	0.055	0.133	0.249	1,478
Ratio of 6th to top	0.069	0.002	0.009	0.036	0.097	0.187	974
Ratio of 7th to top	0.052	0.002	0.008	0.026	0.064	0.136	631
Only plants with 5 products							
Ratio of 2nd to top	0.500	0.135	0.268	0.488	0.756	0.881	502
Ratio of 3nd to top	0.266	0.039	0.097	0.225	0.365	0.587	502
Ratio of 4th to top	0.137	0.012	0.031	0.082	0.176	0.346	502
Ratio of 5th to top	0.057	0.001	0.005	0.019	0.065	0.166	502
Only plants with 3 products							
Ratio of 2nd to top	0.384	0.046	0.133	0.323	0.617	0.814	1,836
Ratio of 3nd to top	0.134	0.004	0.018	0.067	0.181	0.365	1,836

Note: products which tied in terms of their rank were excluded from the bottom two panels of the table

Table 3: Ratio of i'th Product Export Sales to Exports of Core Product

One may be concerned that the above figures are based on different number of plants (as different plants produce a different number of products), so we repeat the exercise restricting the sample to establishments with exactly five products (middle panel) and establishments with exactly three products (bottom panel). In both cases, the pattern described above is confirmed. Finally, Table 3 shows that the revenue profile is also non-uniform across products in the case of exports.

4.2 Is the ranking of varieties by sales revenue the same in both markets?

Next, we focus on whether the ranking of sales across varieties sold by a multi-product producer is the same at home and abroad. Indeed, this turns out to be the case. The squared correlation coefficient between the product rank based on domestic sales and the product rank based on export sales is 0.58. This high correlation is confirmed by the regressions shown in Table 4, where the product rank based on domestic sales is regressed on the product rank based on export sales. The coefficient on the export rank is 0.837 and is statistically significant at the one percent level. Controlling for establishment fixed effects lowers the magnitude of the coefficient to 0.663, but it remains highly significant.

The concordance between sales ranks at home and abroad is illustrated from a different perspective in Table 5, which gives the number and proportion of products ranked first, second, and so on

Dependent variable: product rank in terms of domestic sales		
Product rank in terms of export sales	0.837***	0.663***
	(0.004)	(0.006)
Intercept	0.746***	1.195***
	(.015)	(0.017)
Plant fixed effects	no	yes
No. of obs.	29,486	29,486
R-squared	0.54	0.60

Note: *** denotes significance at the one percent level

Table 4: Product Ranks at Home and Abroad

		Rank in export sales					
		1	2	3	4	5	Total
	Number of products						
Rank in domestic sales	1	7,430	1,756	459	168	139	9,952
	2	2,615	3,524	846	307	208	7,500
	3	909	1,156	1,440	434	317	4,256
	4	354	446	606	710	421	2,537
	5+	357	527	675	698	2,984	5,241
	Total	11,665	7,409	4,026	2,317	4,069	29,486
	Percentage of products with a given rank in export sales						
Rank in domestic sales	1	75%	18%	5%	2%	1%	100%
	2	35%	47%	11%	4%	3%	100%
	3	21%	27%	34%	10%	7%	100%
	4	14%	18%	24%	28%	17%	100%
	5+	7%	10%	13%	13%	57%	100%
	Total	40%	25%	14%	8%	14%	100%

Table 5: Product Ranks at Home and Abroad in Detail

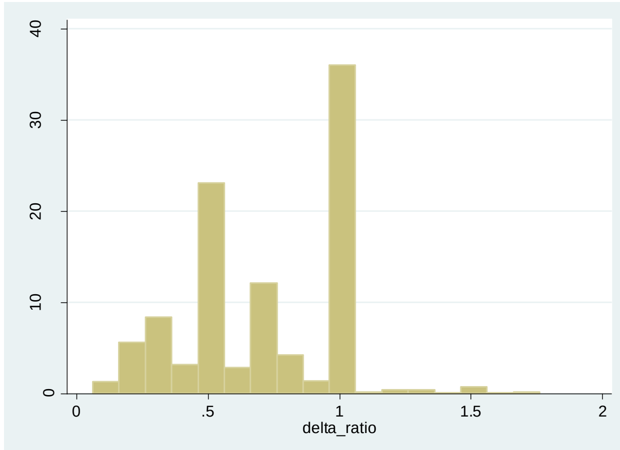


Figure 2: Ratio of the Number of Exported Products to the Total Number

in home sales which have corresponding ranks in export sales. Taken literally, the core-competence hypothesis implies that only entries on the principal diagonal of these matrices should be non-zero. While this is not the case of course, the concordance is impressive: 75% of products ranked first in home sales are also the top product in export sales; for products ranked second in home sales, the proportion with the same rank in export sales is just under half, 47%, while 93% are ranked either first, second or third. Clearly the rank of a product in home sales conveys a lot of information about its rank in export sales, exactly as the core-competence model would lead us to expect.

4.3 Do firms sell more products in their home market?

Another prediction of the model that finds support in the data is that a multi-product producer sells a wider range of products in its home market than abroad. An average exporting establishment in our dataset produces three products, two of which are exported. An exporting establishment at the 90th percentile of the distribution produces six products, four of which are exported. Empirical support for this proposition is also clearly visible in Figure 2 which depicts the distribution of the ratio of the number of exported to total products at the establishment level. The modal value is one, very few firms (2.2%) sell more products abroad than at home, and most (61.9%) sell fewer.

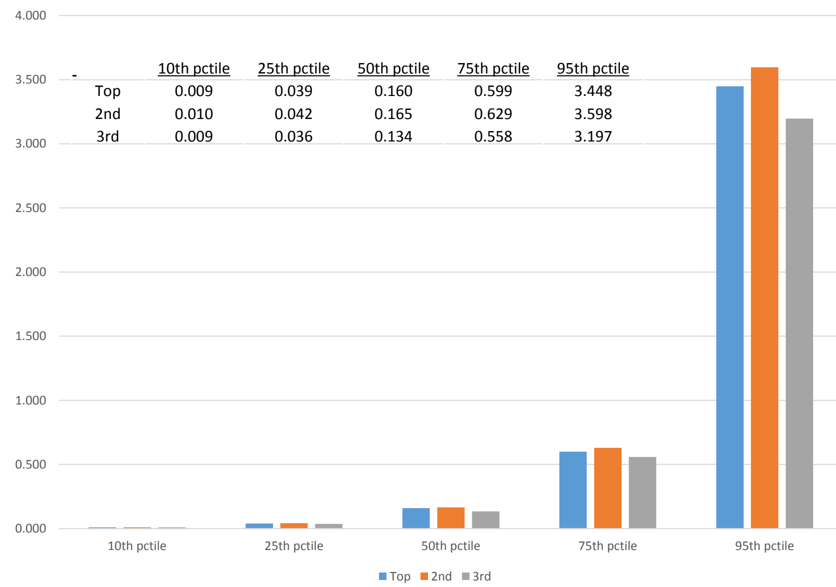


Figure 3: Distribution of Sales Abroad Relative to Home

4.4 Are all exported products also sold at home?

Our theoretical framework predicts that all export products are also sold at home. This prediction is again consistent with the Mexican data. We find that only in 1,851 of 39,272 cases (plant-product-year observations), is an export product not sold domestically. These cases constitute a mere 4.7% of all observations pertaining to exported products.

4.5 Are export sales higher than home sales?

As we have seen, the model is ambiguous on whether the value of domestic or export sales of a given product will be higher, the relative magnitudes being determined by trade costs and relative market size. However, when extended to allow for convex costs of penetrating foreign markets, the model predicts that larger firms should disproportionately exhibit higher sales abroad than at home. Figure 3 shows that this pattern is consistent with the data. For a large majority of producers, export sales are much smaller than domestic sales. For producers at the median of the distribution, exports of the top three products are only between 13.4% to 16.5% 16.5% of the value of domestic sales. Even for producers at the 75th percentile, the corresponding range is 55.8% to 62.9%. However, for producers at the 95th percentile, the corresponding figures are much larger,

	r*(0)/r(0)					
ln(Plant global sales)	-0.011	**0.039*** **	**0.128*** **	**-0.429*** **	**-0.243** **	**0.350** **
	(0.008)	(0.011)	(0.025)	(0.081)	(0.097)	(0.142)
ln(Plant global sales) squared				**0.018*** **	**0.012*** **	-0.010
				(0.003)	(0.004)	(0.006)
6-digit-industry year FE	no	yes	no	no	yes	no
Plant FE	no	no	yes	no	no	yes
Year FE	no	no	yes	no	no	yes
Adj R-squared	0.000	0.134	0.587	0.003	0.134	0.587
No. of obs.	9,770	9,770	9,770	9,770	9,770	9,770

Table 6: Sales of Core Product Abroad Relative to Home

lying between 319.7% and 359.8%. This confirms that for the largest firms, but only for them, the effect of a larger foreign market offsets the trade costs which must be incurred in serving it.

Table 6 confirms that the relationship between relative export sales and total sales is convex. Here we regress the ratio of export to home sales for each firm's core export product on its global sales. A linear specification alone is insignificant, though when industry-year or plant and year fixed effects are added it becomes significant. However, the final three columns show that a quadratic specification is highly significant. This confirms that a convex specification of costs of accessing export markets is a plausible explanation for the pattern of sales at home and abroad.

5 Conclusion

In this paper we have reviewed and extended the core-competence model of multi-product firms introduced in Eckel and Neary (2010), and explored how its predictions hold up against Mexican data. A companion paper, Eckel, Iacovone, Javorcik, and Neary (2015), concentrated on the model's implications for intra-firm price profiles, whereas here we focus on its implications for sales profiles. We found that the data are consistent with the "flexible manufacturing" view that a firm's products can be ranked by their distance from its core competence, and are less consistent with models in which all of a firm's products are either symmetric or differ on the demand rather than the supply side. In particular, the profile of sales across a firm's products is highly non-uniform; the ranking of products is broadly the same in home and export sales; product ranges are weakly larger in the home market; and almost all exported products are sold at home.

At the same time, not all features of the data are consistent with the original version of the core-competence model. In particular, this is true of an anomaly that we call the "market-size puzzle." For Mexican firms, the world market is much larger than the home market, while the costs of accessing the relevant foreign markets are relatively low; under these conditions, the model predicts that most domestic firms should export more of their core products than they sell domestically; yet, in practice, we do not observe this. To resolve this puzzle, we extended the basic model to incorporate investment in export market penetration costs, along the lines of Arkolakis (2010). When extended in this way, the predictions of the model were shown to depend on firm productivity. For all firms, the need to invest in order to access foreign consumers reduces their export sales relative to what they would be in the absence of such costs. However, as firms became more productive, this dampening effect on export sales is reduced, and the model predicts that the ratio of export to home sales of the core product should be increasing and convex in firm productivity. Taking this extended model to the data, we show that it provides a much more persuasive explanation of the pattern of Mexican exports across firms, products, and markets.

References

Allanson, P., and C. Montagna (2005): "Multiproduct Firms and Market Structure: An Explorative Application to the Product Life Cycle," *International Journal of Industrial Organization*, 23, 587–597.

Arkolakis, C. (2010): "Market Penetration Costs and the New Consumers Margin in International Trade," *Journal of Political Economy*, 118(6), 1151–1199.

Arkolakis, C., S. Ganapati, and M.-A. Muendler (2014): "The Extensive Margin of Exporting Products: A Firm-Level Analysis," Working paper, Yale University.

Arkolakis, C., and M.-A. Muendler (2010): "The Extensive Margin of Exporting Products: A Firm-Level Analysis," NBER Working Paper No. 16641.

Baldwin, J., and W. Gu (2009): "The Impact of Trade on Plant Scale, Production-Run Length and Diversification," in T. Dunne, J.B. Jensen and M.J. Roberts (eds.): *Producer Dynamics: New Evidence from Micro Data*, Cambridge, Mass.: NBER, 557–592.

Bernard, A. B., and J. B. Jensen (1999): "Exceptional Exporter Performance: Cause, Effect, or Both?," *Journal of International Economics*, 52(1), 1–25.

Bernard, A. B., S. J. Redding, and P. K. Schott (2010): "Multiple-Product Firms and Product Switching," *American Economic Review*, 100(1), 70–97.

——— (2011): "Multi-Product Firms and Trade Liberalization," *Quarterly Journal of Economics*, 126(3), 1271–1318.

Clerides, S. K., S. Lach, and J. R. Tybout (1998): "Is Learning by Exporting Important? Micro-Dynamic Evidence from Colombia, Mexico and Morocco," *Quarterly Journal of Economics*, 113(3), 903–947.

Dhingra, S. (2013): "Trading Away Wide Brands for Cheap Brands," *American Economic Review*, 103(6), 2554–2584.

Eckel, C., L. Iacovone, B. Javorcik, and J. P. Neary (2015): "Multi-Product Firms at Home and Away: Cost- versus Quality-Based Competence," *Journal of International Economics*, 95(2), 216–232.

Eckel, C., and J. P. Neary (2010): "Multi-Product Firms and Flexible Manufacturing in the Global Economy," *Review of Economic Studies*, 77(1), 188–217.

Feenstra, R., and H. Ma (2008): "Optimal Choice of Product Scope for Multiproduct Firms," in E. Helpman, D. Marin and T. Verdier (eds.) : *The Organization of Firms in a Global Economy*, Harvard University Press, 173–199.

Helpman, E. (1985): "Multinational Corporations and Trade Structure," *Review of Economic Studies*, 52, 443–457.

Iacovone, L., and B. S. Javorcik (2010): "Multi-Product Exporters: Product Churning, Uncertainty and Export Discoveries," *Economic Journal*, 120(544), 481–499.

Ju, J. (2003): "Oligopolistic Competition, Technology Innovation, and Multiproduct Firms," *Review of International Economics*, 11, 346–359.

Mayer, T., M. J. Melitz, and G. I. Ottaviano (2014): "Market Size, Competition, and the Product Mix of Exporters," *American Economic Review*, 104(2), 495–536.

Melitz, M. J. (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71(6), 1695–1725.

Mrázová, M., and J. P. Neary (2011): "Selection Effects with Heterogeneous Firms," Discussion Paper No. 588, Department of Economics, University of Oxford.

Nocke, V., and S. Yeaple (2014): "Globalization and Multiproduct Firms," *International Economic Review*, 55(4), 993–1018.

Prahalad, C., and G. Hamel (1990): "The Core Competency of the Corporation," *Harvard Business Review*, 68(3), 79–91.

Qiu, L. D., and W. Zhou (2013): "Multiproduct Firms and Scope Adjustment in Globalization," *Journal of International Economics*, 91(1), 142–153.

Schilling, M. A. (2005): *Strategic Management of Technological Innovation.* Tata McGraw-Hill Education.

Timoshenko, O. A. (2015): "Product Switching in a Model of Learning," *Journal of International Economics*, 95(2), 233–249.