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ABSTRACT

Multi-Product Firms at Home and Away: Cost- versus Quality-based Competence*

We develop a new model of multi-product firms which invest to improve both the quality of their individual products and of their brand. Because of flexible manufacturing, products closer to firms' core competence have lower costs, so they produce more of them, and also have higher incentives to invest in their quality. These two effects have opposite implications for the profile of prices. Mexican data provide robust confirmation of the model's key prediction: firms in differentiated-good sectors exhibit quality-based competence (prices fall with distance from core competence), but export sales of firms in non-differentiated-good sectors exhibit the opposite.

JEL Classification: F12
Keywords: flexible manufacturing, multi-product firms and quality competition

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1 Introduction

What makes a successful exporting firm? This question has attracted much interest from policy makers, keen to design effective export promotion programs, and from academics, keen to understand the implications of globalization for economic growth. Two answers have been proposed. The first focuses on firm productivity. Studies by Clerides, Lach and Tybout (1998) and Bernard and Jensen (1999), among others, have found that firms self select into export markets on the basis of their successful performance at home. This evidence inspired the theoretical work by Melitz (2003) where only the most productive firms find it worthwhile to cover the extra costs of exporting. The second answer focuses on product quality. A growing body of work has provided evidence that successful exporters charge higher prices on average, suggesting that quality matters.[1]

This study integrates these two views and shows both theoretically and empirically that firms may choose to compete on the basis of either cost or quality depending on the characteristics of the products they sell and the markets in which they operate.[2] Unlike other studies which have compared the behaviour of different firms, and emphasized the between-firm extensive margin, we focus on the portfolio of products sold by multi-product firms, and highlight what Eckel and Neary (2010) call the "intra-firm extensive margin." Our theoretical innovation is to construct a model of multi-product firms in which the quality of goods is determined endogenously by firms' profit-maximizing decisions. Because of flexible manufacturing, products closer to a firm's core competence have lower costs. As a result, they produce more of those products, but they also have higher margins on them, and therefore higher incentives to invest in their quality. These two effects have opposite implications for the profile of prices and, depending on which effect dominates, the model implies one of two possible configurations which we call "cost-based" and "quality-based" competence, respectively. The former corresponds to the case where a firm's core products are sold at lower prices, in order to induce consumers to buy more of them. In the words of Jack Cohen, founder of the UK supermarket chain Tesco, firms "pile 'em high and

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[1] A large and growing literature includes Antoniades (2009), Baldwin and Harrigan (2007), Crozet, Head and Mayer (2009), Hallak and Schott (2010), Hallak and Sivadasan (2009), Iacovone and Javorcik (2007), Johnson (2010), Khandelwal (2009), Kneller and Yu (2008), Kugler and Verhoogen (2008), Mandel (2009), Manova and Zhang (2009), and Verhoogen (2008).

[2] Hallak and Sivadasan (2009) also integrate the productivity and quality approaches in a model of international trade by assuming two sources of exogenous firm heterogeneity: productivity and "caliber", the latter being the ability to produce quality using fewer fixed inputs. Provided exporting requires attaining minimum quality levels, their model explains the empirical fact that firm size is not monotonically related to export status, and predicts that, conditional on size, exporters sell products of higher quality and at higher prices. However, they confine attention to single-product firms.

sell 'em cheap". As a result, the profile of prices across a firm's products is inversely correlated with its profile of sales. By contrast, quality-based competence corresponds to the case where the dominant effect comes from firms' investing more in enhancing the quality of their core products. As a result, these products command quality premia, and so the profile of prices across a firm's products is positively correlated with its profile of sales.

Our model not only allows for different profiles of prices but also makes predictions about which kinds of goods should exhibit which profile. In particular, it predicts that a higher level of product differentiation encourages firms to invest relatively more in the quality of individual varieties than in the quality of their overall brand. As a result, quality-based competence should be more in evidence in sectors where products are more differentiated. We test this prediction using a rich Mexican data set already used by Iacovone and Javorcik (2007, 2010). Most previous empirical studies of multi-product firms at plant level have been constrained to use data on export sales only, or to combine export and production data at different levels of disaggregation.[3] By contrast, a unique characteristic of our data is that it provides consistently disaggregated information on both the home and export sales of all goods produced by a large representative sample of manufacturing establishments.[4] As we show, the Mexican data provide robust confirmation of the model's key prediction: comparing price profiles with sales profiles, we find that firms in differentiated-good sectors exhibit quality-based competence to a much greater extent than firms in non-differentiated-good sectors, both at home and abroad. The contrast is particularly striking in export markets, where Mexican producers in non-differentiated-good sectors engage in cost- rather than quality-based competence. Our results are robust to focusing attention on a variety of subsamples, including only those products sold both at home and abroad, only those plants which sell on the home market and also select into exporting, and only single-plant firms.

Our paper builds on and extends the existing literature on multi-product firms in international trade. While there already existed a large literature on multi-product firms in the theory of industrial organization, our model is one of a number of recent trade models which is

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[3] Examples of the first approach include Arkolakis and Muendler (2009), Berthou and Fontagné (2009), Eaton, Eslava, Kugler and Tybout (2008), and Mayer, Melitz and Ottaviano (2010). Examples of the second include Bernard, Redding and Schott (2006), and Goldberg, Khandelwal, Pavcnik and Topalova (2010a, 2010b). Baldwin and Gu (2005) use compatible data on production and exports by Canadian plants, but implement a theoretical framework which imposes symmetry between a firm's products, an issue which we discuss in more detail below.

[4] While our data set is unique in providing information at the same level of disaggregation on both home and export sales, we cannot distinguish between different export destinations. Fortunately, this problem is not so severe in the case of Mexico, since the U.S. is by far the dominant market for most Mexican manufacturing exports.

more applicable to the kinds of large-scale firm-level data sets which are increasingly becoming available.[5] Within this latter tradition, existing models impose one or other profile of a firm's prices by assumption. One class of models assumes that products are symmetric on both the demand and supply sides, with the motivation for producing a range of products coming from economies of scope. As a result, all products sell in the same amount and at the same price.[6] A different approach, pioneered by Bernard, Redding and Schott (2006, 2010), emphasizes asymmetries between products on the demand side. Before they decide to enter, firms draw their overall level of productivity and also a set of product-market-specific demand shocks. The latter determine the firm's scale and scope of sales in different markets, and imply that its price and output profiles are always positively correlated. By contrast, Eckel and Neary (2010) develop a model that emphasizes asymmetries between products on the cost side and implies that price and output profiles are always negatively correlated.[7] The present paper integrates the demand and cost approaches by assuming that costs determine the profile of investment in quality across different varieties, and develops a model which is more in line with recent work on models of heterogeneous firms that engage in process and product R&D: see, for example, Bustos (2010) and Lileeva and Trefler (2010) on single-product firms, and Dhingra (2010) on multi-product firms. It is even more closely related to those papers which allow for endogenous investment in quality, such as Antoniades (2009), including the view that quality is really perceived quality, which may be market-specific, so investment in quality includes spending on marketing as in Arkolakis (2007). All this work has so far focused on single-product firms only.

This brief review of the literature on multi-product firms highlights our main interest: how the theoretical models differ in the way they model the demand for and the decision to supply multiple products. The models also differ in other ways which are of less interest in the present application. One type of difference is in the assumptions made about market structure. In particular, most recent models assume that markets can be characterized by monopolistic competition, in which firms produce a large number of products but are themselves infinitesi-

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[5] Most models of multi-product firms in industrial organization make one or more assumption which makes them harder to apply to large firm-level data sets. In particular, they typically assume that products are vertically but not horizontally differentiated; and/or that the number of products produced by a firm is fixed, so the key question of interest is where in quality space it will choose to locate; and/or that the number of products produced is relatively small. For examples from a large literature, see Brander and Eaton (1984), Klemperer (1992), and Johnson and Myatt (2003). Baldwin and Ottaviano (2001) apply this kind of model in a trade context.

[6] See, for example, Allanson and Montagna (2005), Feenstra and Ma (2009), Nocke and Yeaple (2006), and Dhingra (2009).

[7] Arkolakis and Muendler (2009) and Mayer, Melitz and Ottaviano (2010) apply this approach to heterogeneous-firm models of monopolistic competition with CES and quadratic preferences, respectively.

mal relative to the size of the overall market.[8] By contrast, Eckel and Neary (2010) assume in their core model that markets are oligopolistic. In this paper, we know little about the market environment facing individual firms: we do not know with which other Mexican plants in the sample they compete directly, and we have no information at all on their foreign competitors. Hence we prefer to remain agnostic on this issue, where possible deriving predictions which will hold at the level of individual firms irrespective of the market structure in which they operate. A further dimension of difference concerns the level of analysis, whether partial or general equilibrium. Some of the trade theory papers, including Eckel and Neary (2010), highlight general-equilibrium adjustments working through factor markets as an important channel of transmission of external shocks. However, with the data set we use, it is not possible to ascertain how factor prices are affected by general-equilibrium adjustments to changes in trade policy. Hence, we concentrate on testing implications of the model in partial equilibrium.

Section 2 of the paper presents the model and shows how differences in technology, tastes and market characteristics determine whether a multi-product firm exhibits cost-based or quality-based competence. Section 3 describes the data and explores the extent to which they confirm our theoretical predictions. The Appendix shows how the results of Section 2 extend to a Cournot oligopolistic market with heterogeneous firms, and also presents some additional robustness checks on the empirical findings.

2 The Model

As already explained, the paper extends the flexible-manufacturing model of Eckel and Neary (2010) to allow for the interaction of quality and cost differences between the varieties produced by a multi-product firm. To simplify ideas and notation, we focus in the text on a single monopoly firm, but, as we show in the Appendix, all the results extend to a heterogeneous-firms industry in which firms engage in Cournot competition. Section 2.1 introduces our specification of preferences, while Section 2.2 reviews the earlier model, which allowed for cost-based competence only, showing how a firm chooses its product range, its total sales, and their distribution across varieties in a single market. Section 2.3 explores the additional complications which quality-based competence introduce and derives our main theoretical result, and Section 2.4 considers the model's comparative statics properties.

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[8] This is true, for example, of all the theoretical models cited in the preceding paragraph, including Section 5.1 of Eckel and Neary (2010).

2.1 Preferences for Quantity and Quality

Consider a single market, in which each one of L consumers maximizes a quadratic sub-utility function defined over the consumption and quality levels of a set $\tilde{\Omega}$ of differentiated products:

$$
\begin{gathered}
u = u_1 + \beta u_2 \qquad (1) \\
u_1 = a^0 Q - \frac{1}{2} b \left[(1-e) \int_{i \in \tilde{\Omega}} q(i)^2 \, di + e Q^2 \right], \qquad Q \equiv \int_{i \in \tilde{\Omega}} q(i) \, di \\
u_2 = \int_{i \in \tilde{\Omega}} q(i) \, \tilde{z}(i) \, di
\end{gathered}
$$

Utility is additive in a component that depends only on quantities consumed, u_1, and one that depends on the interaction of quantity and quality, u_2. The first component is a standard quadratic function, where $q(i)$ denotes the consumption of a single variety and Q denotes total consumption. The parameter e is an inverse measure of product differentiation, assumed to lie strictly between zero and one (which correspond to the extreme cases of independent demands and perfect substitutes respectively). The second component shows that additional utility accrues from consuming goods of higher quality, where $\tilde{z}(i)$ is the perceived quality level of an individual variety. We defer until Section 2.3 a detailed consideration of how the quality levels $\tilde{z}(i)$ are determined.

As discussed in the introduction, we remain agnostic in the paper about whether this sub-utility function is embedded in a general or partial equilibrium model: our analysis is compatible with both approaches. All we need assume is that the marginal utility of income can be set equal to one. This is ensured if the sub-utility function (1) is part of a quasi-linear upper tier utility function, with all income effects concentrated on the "numéraire" good. Alternatively, as in Eckel and Neary (2010), (1) can be one of a mass of sub-utility functions without an outside good, with the marginal utility of income set equal to unity by choice of numéraire.

Maximization of (1) subject to the budget constraint $\int_{i \in \tilde{\Omega}} p(i) \, q(i) \, di = I$ (where I is individual income) generates linear demand functions for the typical consumer. These individual demand functions can then be aggregated over all L identical consumers in the market. Imposing market-clearing, so sales volume $x(i)$ equal total demand $Lq(i)$, gives the market inverse demand functions faced by the monopoly firm:

$$p\left(i\right) = a\left(i\right) - \tilde{b}\left[\left(1-e\right)x\left(i\right) + eX\right], \quad i \in \Omega \tag{2}$$
$$\tilde{b} \equiv \frac{b}{L} \qquad X \equiv \int_{i\in\Omega} x\left(i\right)di \qquad a\left(i\right) = a^0 + \beta\tilde{z}\left(i\right)$$

Here $p\left(i\right)$ is the price that consumers are willing to pay for an extra unit of variety i. This depends negatively on a weighted average of $x\left(i\right)$, the sales of that variety, and X, the total volume of all varieties produced and consumed in the market. Note that X is defined over the set of goods actually consumed, Ω, which is a proper subset of the exogenous set of potential products $\tilde{\Omega}$, $\Omega \subset \tilde{\Omega}$. We will show below how Ω is determined. Finally, the demand price also depends positively, through the intercept $a\left(i\right)$, on the perceived quality of the individual variety, $\tilde{z}\left(i\right)$.

2.2 Cost-Based Competence

Consider next the technology and behaviour of the firm in a single market, which is segmented from the other markets in which the firm operates. The firm's objective is to maximize profits by choosing both the scale and scope of production, as well as choosing how much to invest in enhancing the quality of individual varieties and of its overall brand. We begin by abstracting from the quality dimension in this sub-section, and recapping the results of Eckel and Neary (2010) for the case where the firm's competence derives from differences between varieties in production costs only. This is most easily done by setting β equal to zero in equation (1), so utility does not depend on quality. Though it is convenient to make explicit the variety-specific intercepts $a\left(i\right)$ in all equations, we do not consider the implications of differences between them until the next sub-section.

With no investment in quality, the firm's problem is to maximize its operating profits only:

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

Here t is a uniform trade cost payable by the firm on all the varieties it sells. The marginal cost function $c\left(i\right)$ embodies an assumption which Eckel and Neary (2010) identify as a key aspect of flexible manufacturing: marginal costs differ between varieties and rise as the firm moves away from its "core competence" variety, the one with lowest marginal cost.[9] More precisely,

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[9] We assume that production costs are independent of the market served. Mayer, Melitz and Ottaviano (2009)

the firm's marginal cost of production for variety i is independent of the amount produced of that variety, is lowest for the core-competence variety indexed "0", and rises monotonically as the firm moves away from its core competence: $c'(i) > 0$. With uniform trade costs included, this is shown by the upward-sloping locus $c(i) + t$ in Figure 1.[10]

To derive the firm's behaviour, we first consider the optimal choice of output for each variety produced, i.e., for all i in the set Ω. In choosing the output of each variety, the firm must take account of its effect on the demand for all the varieties it produces, through the demand functions (2).[11] The first-order conditions with respect to $x(i)$ are:

$$\frac{\partial \pi}{\partial x(i)} = [p(i) - c(i) - t] - \tilde{b}[(1-e)x(i) + eX] = 0, \quad i \in \Omega \tag{4}$$

These imply that the net price-cost margin for each variety, $p(i) - c(i) - t$, equals $\tilde{b}$ times a weighted average of the output of that variety and of total output, where the weights depend on the degree of product substitutability. The presence of total output in this expression reflects the "cannibalization effect": an increase in the output of one variety will, from the demand function (2), reduce its sales of *all* varieties. Taking this into account induces the firm to reduce its sales relative to an otherwise identical multi-divisional firm where decisions on the output of each variety were taken independently.[12] Combining the first-order conditions with the demand function (2) we can solve for the output of each variety as a function of its own cost and of the firm's total output:

$$x(i) = \frac{a(i) - c(i) - t - 2\tilde{b}eX}{2\tilde{b}(1-e)} \quad i \in \Omega \tag{5}$$

With $a(i)$ independent of i, the outputs of different varieties are unambiguously ranked from larger to smaller by their distance from the firm's core competence. Hence the problem of

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add an exogenous market-specific adaptation cost function which augments the production costs $c(i)$. With existing data sets, this is observationally equivalent to exogenous market-specific taste shifts $a(i)$, as in Bernard, Redding and Schott (2006).

[10] Figures 1 to 2 are drawn under the assumption that the cost function $c(i)$ is linear in i. Though a convenient special case, this assumption is not needed for any of the results.

[11] Strictly speaking, the firm is choosing the whole output schedule $\{x(i)\}$, which is a calculus of variations problem. However, it is helpful to think of it instead as choosing the output of each variety, one at a time. The first-order condition is: $\frac{\partial \pi}{\partial x(i)} = [p(i) - c(i) - t] - \int_{i' \in \Omega} \frac{\partial p(i)}{\partial x(i')} x(i')\, di' = 0$. Bearing in mind that $X = \int_{i' \in \Omega} x(i')\, di'$, the effect of a small change in the output of variety i on prices (2) can be written as: $\frac{\partial p(i)}{\partial x(i')} = -\tilde{b}e$ when $i \neq i'$, and $\frac{\partial p(i)}{\partial x(i')} = -\tilde{b} = -\tilde{b}[(1-e)+e]$ when $i = i'$. Substituting gives equation (4).

[12] Each division of such a firm would independently set $p(i) - c(i) - t$ equal to $\tilde{b}x(i)$. In doing so, it would forego the gains from internalizing the externality which higher output of one variety imposes on the firm by reducing the demand for all other varieties. Such a myopic firm would also be indistinguishable from a set of single-product firms which happened to have the same profile of marginal costs. (Thanks to Jonathan Vogel for the latter point.)

choosing the set of products to produce, Ω, reduces to the problem of choosing the product range, which we denote by δ. From Eckel and Neary (2010), the first-order condition for choice of δ is that the output of the marginal variety is exactly zero: $x(\delta) = 0$. Hence the profile of outputs is as shown by the downward-sloping locus $x(i)$ in Figure 1. Finally, since demands are symmetric when $a(i) = a^0$, the prices which will induce this pattern of demand must be increasing in i. To induce consumers who, *ceteris paribus*, are indifferent between varieties to buy more of those closest to its core competence, the firm must "pile 'em high and sell 'em cheap". This is confirmed when we substitute for outputs $x(i)$ from (5) into the first-order condition (4) to obtain the profit-maximizing profile of prices:

$$p(i) = \frac{1}{2}\left[a(i) + c(i) + t\right] \tag{6}$$

Thus prices increase with costs, though less rapidly, implying that the firm's mark-up is lower on non-core varieties. However, it makes a strictly positive mark-up on all varieties: because of the cannibalization effect, it would not be profit-maximizing to set price equal to marginal cost on the marginal variety $x(\delta)$.[13] All this is illustrated in Figure 1.

2.3 Quality-Based Competence

Consider next the case where consumers care about quality as well as quantity, so β in the utility function (1) is positive. Consumers therefore perceive a quality premium $\tilde{z}(i)$ attaching to each variety, which we assume can be decomposed as follows:

$$\tilde{z}(i) = (1-e)\,z(i) + e\bar{Z} \tag{7}$$

Here $z(i)$ is the variety-specific component of quality, and $\bar{Z}$ is the quality of the firm's brand as a whole. Note that $\bar{Z}$ is *not* equal to $\int_{i\in\tilde{\Omega}} z(i)\,di$, the aggregate of individual varieties' quality. Here too, product differentiation matters. If varieties are close to independent in demand (so e is close to zero), then the consumer perceives little benefit from a higher quality brand in itself. By contrast, if varieties are close substitutes (so e is close to one), then the consumer attaches more importance to the quality of the brand as a whole than to that of individual varieties. In general, the perceived quality of each individual variety is a weighted average of the variety-

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[13] The price-cost margin on the marginal variety is $p(\delta) - c(\delta) - t = \tilde{b}eX > 0$, using (4) and the fact that $x(\delta)$ is zero. For a multi-divisional firm which ignored the cannibalization effect, it would be zero.

specific quality component and that of the firm's brand as a whole, where the weights are $1-e$ and e respectively.[14]

Next, we need to specify how the components of quality are determined. It would be possible to assume that the perceived qualities of different varieties and of the firm's brand vary exogenously, perhaps determined by a random process as in Bernard et al. (2010). However, this would be hard to reconcile with the assumption of flexible manufacturing, where a firm's products are ranked by their distance from its core competence. We assume instead that, in the absence of investment in quality, consumers are indifferent between all varieties. However, the firm can invest to enhance the perceived quality of each of its individual varieties, as well as the perceived quality of its overall brand.[15] As we will see, this generates a rich framework where differences between varieties are ultimately determined by costs, but where the profiles of outputs and prices may exhibit what we call "quality-based competence" if investment in quality is sufficiently effective.

To allow for explicit solutions, we assume that the costs of and returns to investment take simple functional forms. With $k(i)$ denoting the firm's investment in the quality of variety i, we assume that the cost incurred is linear in $k(i)$, equal to $\gamma k(i)$, while the benefits come in the form of higher quality, though at a diminishing rate: $z(i) = 2\theta k(i)^{0.5}$. Similarly, investment in the quality of the brand incurs costs of $\Gamma \bar{K}$ and raises brand quality at a diminishing rate: $\bar{Z} = 2\Theta \bar{K}^{0.5}$. Total firm profits in the market are thus given by:

$$\Pi = \int_{i\in\Omega} \left[\{p(i) - c(i) - t\} x(i) - \gamma k(i)\right] di - \Gamma \bar{K} \tag{8}$$

The first-order conditions for scale and scope are as before. The new feature is the firm's optimal choice of investment in quality, which is determined by the following first-order conditions:

$$\text{(i) } \gamma k(i)^{0.5} = \beta(1-e)\theta x(i), \quad i \in [0,\delta] \qquad \text{and} \qquad \text{(ii) } \Gamma \bar{K}^{0.5} = \beta e \Theta X \tag{9}$$

The first equation shows that the firm will invest in the quality of variety i up to the point where the marginal cost of investment γ equals its marginal return. The latter is increasing in β, the weight that consumers attach to quality as a whole, and in θ, the effectiveness of investment

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[14] The linear specification of (7) simplifies the derivations but is not essential. All our results go through qualitatively provided only that $\tilde{z}(i)$ is less responsive to $z(i)$ and more responsive to $\bar{Z}$ the higher is e.

[15] Brand-specific investment ranges from neon signs on skyscrapers to sponsorship of sports and cultural events; variety-specific investment includes setting up and maintaining websites with detailed specifications of individual varieties, as well as renting more or less prominent shelf space in stores to showcase them.

in raising quality. However, it is decreasing in the substitution parameter e: as goods become less differentiated the incentive to invest in the quality of an individual variety falls. Exactly analogous considerations determine the optimal level of investment in the firm's brand, with one key difference: for given total output this is increasing rather than decreasing in the substitution parameter e. The more consumers view the firm's varieties as close substitutes, the greater the pay-off to investing in the brand.

The relationship between the different components of investment is highlighted by comparing total investment in the quality of individual varieties, $K \equiv \int_0^\delta k\left(i\right) di$, with investment in brand quality $\bar{K}$:

$$\frac{K}{\bar{K}} = \left(\frac{1-e}{e}\frac{\theta}{\Theta}\frac{\Gamma}{\gamma}\right)^2 \Phi \quad \text{where:} \quad \Phi \equiv \frac{\int_0^\delta x\left(i\right)^2 di}{X^2} \tag{10}$$

Not surprisingly, investment in varieties is higher than in the overall brand the more effective it is (the higher is θ relative to Θ) and the less expensive it is (the lower is γ relative to Γ). It is also higher the less substitutable are different varieties (the lower is e). In addition, it is also higher the greater is Φ, which Eckel and Neary (2010) define as an ex post measure of the flexibility of technology of a multi-product firm. Intuitively, the more flexible is its technology the more the firm wants to differentiate its marketing spending across different varieties; by contrast, if Φ is low, the distribution of outputs across varieties is more even and the firm will tend to focus on promoting its brand as a whole.

Consider next the implications of investment in quality for the pattern of the firm's sales across varieties. The first-order condition (9)-(i) shows that the firm will invest more in a variety with greater sales volume. The latter is endogenous of course, but combining this and (9)-(ii) with the expression for outputs in (5) allows us to write the output of each variety as a function of exogenous variables and of total sales only:

$$x\left(i\right) = \frac{a^0 - c\left(i\right) - t - 2(\tilde{b} - \bar{\eta}e)eX}{2[\tilde{b} - \eta\left(1-e\right)]\left(1-e\right)}, \quad i \in [0, \delta] \quad \eta \equiv \frac{\beta^2\theta^2}{\gamma} \quad \bar{\eta} \equiv \frac{\beta^2\Theta^2}{\Gamma} \tag{11}$$

Here, η and $\bar{\eta}$ are composite parameters which we can call, following Leahy and Neary (1997), the "marginal effectiveness of investment" in the quality of individual varieties and of the firm's brand respectively.[16] So, for example, η is higher the more consumers value quality (the higher

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[16] Similar parameter combinations appear in many models in trade and industrial organization where investment in process innovation or in quality enhancement takes a linear-quadratic form. See for example, d'Aspremont and Jacquemin (1988) and, in the literature on heterogeneous firms and trade, Antoniades (2009), Bustos (2010), and Dhingra (2009).

is β), the more effective is investment in quality (the higher is θ), and the less costly it is (the lower is γ). Note that η and $\bar{\eta}$ cannot be too high: both $\tilde{b} - \eta(1-e)$ and $\tilde{b} - \bar{\eta}e$ must be positive from the second-order conditions for optimal choice of outputs and investment. To see the implications of (11) more clearly, evaluate it at $i = \delta$ and use the fact that the output of the marginal variety is zero, $x(\delta) = 0$. The output of each variety can then be expressed in terms of the difference between its own cost and that of the marginal variety:

$$x(i) = \frac{c(\delta) - c(i)}{2[\tilde{b} - \eta(1-e)](1-e)}, \quad i \in [0, \delta] \tag{12}$$

This confirms that the profile of outputs across varieties is the inverse of the profile of costs: outputs fall monotonically as the firm moves further away from its core competence. Moreover, it shows that the output profile is steeper the higher is η. The greater the marginal efficiency of investment in the quality of individual varieties, the more a firm faces a differential incentive to invest in the quality of its most efficient varieties, those closer to its core competence, since they have the highest mark-ups in the absence of investment.

Equation (12) shows that investment in quality increases the variance of outputs but does not change their qualitative profile. By contrast, it can reverse the slope of the firm's price profile. To see this, substitute from the expression for output (12) into the first-order condition (4) to solve for the equilibrium prices:

$$p(i) = \frac{\tilde{b} - 2\eta(1-e)}{2[\tilde{b} - \eta(1-e)]}c(i) + \frac{\tilde{b}}{2[\tilde{b} - \eta(1-e)]}c(\delta) + t + \tilde{b}eX, \quad i \in [0, \delta] \tag{13}$$

The coefficient of $c(i)$ in this expression gives one of our key results. Recalling that the denominator must be positive from the second-order conditions, the slope of the price profile depends on the sign of the numerator $\tilde{b} - 2\eta(1-e)$. When the direct effect of an increase in i, working through a higher production cost, dominates, the numerator is positive, and the price profile exhibits "cost-based competence": varieties closer to the firm's core competence must sell at a lower price to induce consumers to purchase more of them. The extreme case of this is where investment in the quality of individual varieties is totally ineffective, so η is zero and the coefficient of $c(i)$ in (13) reduces to one half as in the last sub-section. By contrast, if the indirect effect of an increase in i, working through a higher value of $a(i)$, is sufficiently strong, so the firm invests disproportionately in the quality of products closer to its core competence, then it charges higher prices for them, and the price profile slopes downwards, as illustrated in Figure

2. We call this case one of "quality-based competence". Summarizing:

Proposition 1 *The profile of prices across varieties increases with their distance from the firm's core competence if* $\tilde{b} > 2\eta(1-e)$, *whereas it decreases with the distance if* $\tilde{b} < 2\eta(1-e) < 2\tilde{b}$.

Proposition 1 gives the necessary and sufficient condition for each outcome, but for completeness and because we will draw on them in the empirical section, it is useful to spell out its implications:

Corollary 1 *Quality-based competence, the case where prices of different varieties are positively correlated with sales, is more likely to dominate: (i) when investment in quality is more effective, so* η *is larger; (ii) when market size* L *is larger, so* $\tilde{b}$ *is smaller; and (iii) when products are more differentiated, so* e *is smaller.*

This result has been derived for the case of a single monopoly firm, but it is independent of the extent of competition which the firm faces. We show formally in the Appendix that it continues to hold in a heterogeneous-firms Cournot oligopoly market, but the intuition is straightforward. With all goods symmetrically differentiated, firms compete against each other only at the level of total output, not at the level of individual varieties. Changes in the extent of competition affect the scale and scope of production as well as the level of investment in quality, but do not influence the profile of prices across products.

It should be noted that our distinction between cost- and quality-based competence is an *ex post* one, based on the observable correlation between the slopes of the price and sales profiles. In a fundamental sense, a firm's core competence in our model is always based on production costs, since these determine the firm's incentives to invest in improving the quality of different varieties. It is also possible to consider how the firm's "full marginal costs", i.e., its marginal production cost plus the average cost of investing in the quality of each variety, varies as it moves away from its core competence. Combining the first-order condition for investment with the expression for output in (12), the average cost of investing in the quality of each variety can be shown to equal:

$$\gamma \frac{k(i)}{x(i)} = \frac{\eta(1-e)}{2[\tilde{b} - \eta(1-e)]} \left[c(\delta) - c(i)\right], \quad i \in [0, \delta] \tag{14}$$

Hence the full marginal cost equals:

$$c(i) + \gamma \frac{k(i)}{x(i)} = \frac{2\tilde{b} - 3\eta(1-e)}{2[\tilde{b} - \eta(1-e)]} c(i) + \frac{\eta(1-e)}{2[\tilde{b} - \eta(1-e)]} c(\delta), \quad i \in [0, \delta] \tag{15}$$

Combining this with Proposition 1, we can conclude that neither marginal production costs nor full marginal costs predict the profile of prices across varieties. There are three cases:

(i) If cost-based competence dominates, so $\eta(1-e) < \frac{1}{2}\tilde{b}$, then both prices and full marginal costs rise with i.

(ii) If quality-based competence dominates, but mildly, so $\frac{1}{2}\tilde{b} < \eta(1-e) < \frac{2}{3}\tilde{b}$, then prices fall with i but full marginal costs rise with i.

(iii) If quality-based competence strongly dominates, so $\frac{2}{3}\tilde{b} < \eta(1-e) < \tilde{b}$, then *both* prices and full marginal costs fall with i.

Note that in case (ii), both measures of cost rise with i, despite which prices fall with i. However, the mark-up over full marginal cost, $\mu(i)$, is always decreasing in i, and takes a particularly simple form:

$$\mu(i) \equiv p(i) - \left\{ c(i) + \gamma \frac{k(i)}{x(i)} \right\} = \frac{1}{2}[c(\delta) - c(i)] + t + \tilde{b}eX, \quad i \in [0, \delta] \tag{16}$$

This is independent of η and $\bar{\eta}$ for given X and δ. Hence the relative contribution of different varieties to total profits is independent of the effectiveness of investment in quality: $\mu(i) - \mu(i') = -\frac{1}{2}[c(i) - c(i')]$.

2.4 Comparative Statics

The predictions of the model for the shape of the firm's equilibrium price profile given in Proposition 1 are the ones that we take to the data in the next section. It is also of interest to explore the comparative statics properties of the model. Here we note the effects of exogenous shocks on the scale and scope of a single monopoly firm, while in the Appendix we show that our results generalize to the case of a group of firms engaged in Cournot competition.

With a continuum of first-order conditions for both outputs and investment levels, it might seem difficult to derive the comparative statics of the equilibrium. However, we can follow the approach used in Eckel and Neary (2010) to express the equilibrium in terms of two equations which depend on total output X and firm scope δ only. First, evaluate equation (11) at the marginal variety $i = \delta$, recalling that $x(\delta)$ equals zero. This yields one equation in X and δ:

$$c(\delta) = a^0 - t - 2\left(\tilde{b} - \bar{\eta}e\right) eX \tag{17}$$

Next, consider the alternative expression for individual outputs, equation (12), and integrate it over i to obtain a second equation:

$$X = \frac{\int_0^\delta [c(\delta) - c(i)]\, di}{2[\tilde{b} - \eta(1-e)](1-e)} \tag{18}$$

These two equations can now be solved for X and δ and the result for X plugged back into equation (11) to solve for the outputs of individual varieties. Table 1 gives the implications for the effects on firm behaviour of increases in the marginal effectiveness of either kind of investment, in market access costs, and in market size.

Increase in:	$\bar{\eta}$	η	t	L
X	$+$	$+$	$-$	$+$
$x(0)$	$+$	$+$	$-$	$+$
δ	$+$	$-$	$-$	$+/-$

Table 1: Comparative Statics Responses

An increase in the marginal effectiveness of investment in brand quality, $\bar{\eta}$, is neutral across varieties, and so it leads the firm to expand in both size and scope. By contrast, an increase in the marginal effectiveness of investment in the quality of individual varieties, η, accentuates the incentive to focus on the firm's core competence. Hence it leads to what Eckel and Neary (2010) call a "leaner and meaner" response: a rise in total output but a fall in scope. As for an increase in market access costs t, this induces a contraction in both scale and scope. The only ambiguity in the table is the effect of an increase in market size L on scope. While the firm always sells more in total in a larger market, this may or may not come with an increase in scope. The outcome depends on the relative effectiveness of the two kinds of investment and on the degree of substitutability in demand between varieties:

$$\frac{d\delta}{dL} \propto \bar{\eta}e - \eta(1-e) \tag{19}$$

Thus, more varieties are sold in a larger market, the less products are differentiated (the higher is e), and the more effective is investment in brand quality relative to investment in the quality of individual varieties (the higher is $\bar{\eta}$ relative to η).

All these results are proved in the Appendix in the general case with heterogeneous multi-product firms, both home and foreign-based, engaging in oligopolistic competition. We show there that the results continue to hold without qualification, except for the effects of market size. An increase in market size raises the output of all firms if they are identical. However, with heterogeneous firms, the outcome exhibits a "superstar firms" tendency as in Neary (2010). Firms with above average total output X_j and output per variety X_j/δ_j tend to grow faster with market size, while those below average grow more slowly or may even suffer falls in output as they are squeezed by larger more profitable firms. As a result, the size distribution of firms becomes more dispersed. This tendency is not peculiar to markets with multi-product firms, but is a general feature of Cournot competition between heterogeneous firms that invest in R&D or quality. As we show in the Appendix, even when goods are homogeneous ($e = 1$), so firms are single-product, an increase in market size still implies the "superstar firms" result. Only when $\eta_j = \bar{\eta}_j = 0$, so there is no investment, does an increase in market size leave the initial distribution of output across firms unchanged: $\frac{d \ln X_j}{d \ln L} = 1$ and $\frac{d \ln \delta_j}{d \ln L} = 0$ for all j and for all e, $0 \leq e \leq 1$.

3 Empirics

Our theoretical model makes a number of novel predictions about the behaviour of multi-product firms. One of these in particular is unique to our model, has both theoretical and policy interest, and lends itself to empirical testing with our data. This is the prediction from Corollary 1 that the profile of prices across the different goods produced by a multi-product firm is more likely to be positively correlated with the corresponding profile of outputs, thus exhibiting what we have called quality-based competence, when products are more differentiated. In the remainder of the paper we subject this prediction to empirical testing. We first describe the data and document the profiles of sales across firms' products which it exhibits; then we explain how we operationalize the prediction about price profiles; subsequent sub-sections present the results of testing it and consider various robustness checks.

3.1 The Data

We begin by reviewing the data set.[17] A unique characteristic of our data is the availability of plant-product level information on the value and the quantity of sales for *both* domestic and export markets. Our data source is the *Encuesta Industrial Mensual* (EIM) administered by the *Instituto Nacional de Estadística Geografía e Informática* (INEGI) in Mexico. The EIM is a monthly survey conducted to monitor short-term trends and dynamics in the manufacturing sector. As we are not primarily interested in short-term fluctuations, we aggregate the monthly EIM data into annual observations. The survey covers about 85% of Mexican industrial output, with the exception of "maquiladoras."[18] It includes information on 3,183 unique products produced by over 6,000 plants.[19] Plants are asked to report both values and quantities of total production, total sales, and export sales for each product produced, making the data set particularly valuable for our purposes. Note that the unit of observation is the plant rather than the firm: we return to this issue in our robustness checks below.

Products in the survey are grouped into 205 *clases*, or activity classes, corresponding to the 6-digit level CMAP (Mexican System of Classification for Productive Activities) classification. Each *clase* contains a list of possible products, which was developed in 1993 and remained unchanged during the entire period under observation. The classification of products is similar in level of detail to the 6-digit international Harmonized System classification, though with differences that reflect special features of the structure of Mexican industrial production.[20]

Table 2 shows that the number of plants in the sample varies from 6,291 in 1994 to 4,424 in 2004. Between 1,579 and 2,137 plants were engaged in exporting.[21] The decline in the number of establishments during the period under analysis is due to exit.[22] In this paper, we refer to

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[17] For a more complete account, see Iacovone and Javorcik (2007).

[18] Maquiladoras are mostly foreign-owned plants located close to the U.S. border, almost exclusively engaged in assembling imported inputs for export.

[19] The classification system has a total of 4,085 potential products. However, this includes headings entitled "Other unspecified products" and "Other non-generic products" in each *clase*. Excluding the latter, 3,183 is the number of products actually produced at some point in the sample period. For comparison, the US production data at the five-digit SIC code level used by Bernard, Redding and Schott (2010) contain approximately 1,800 product codes, while the US export data used by Bernard, Redding and Schott (2006) contain approximately 8,000 product codes, though these include agricultural products and raw materials as well as manufactures.

[20] For instance, the *clase* of *Distilled Alcoholic Beverages* (identified by the CMAP code 313014) lists 13 products: gin, vodka, whisky, other distilled alcoholic beverages, coffee liqueurs, "habanero" liqueurs, "rompope", prepared cocktails, hydroalcoholic extract, and other alcoholic beverages prepared from either agave, brandy, rum, or table wine. However, it does not include tequila, which is included, along with six other related products, in a separate *clase*, *Produccion de Tequila y Mezcal* (identified by the CMAP code 313011).

[21] We exclude a very small number of plant-year observations (23 in total) which reported positive exports but no production: see Table 2.

[22] Plants that exited after 1994 were not systematically replaced in our sample. This does not bias our results, as our main focus is on within-year rather than panel features of the data.

each plant-product combination as a product variety. The number of varieties sold ranges from 19,154 in 1994 to 12,887 in 2004, while the number of varieties exported rose from 2,844 in 1994 to 3,118 in 2004, reaching a peak of 4,193 in 1998.

3.2 Sales Profiles

As a first step in exploring the properties of the data through the lens of our theoretical model, we considered the patterns of sales across the varieties produced by different plants in our sample. (Details are given in a background paper: Eckel, Iacovone, Javorcik and Neary (2009).) The results were unsurprising. In particular, the data show that exporting plants are larger, and that larger plants produce more products. The vast majority of plants sell more products at home, and most exported products are also sold at home. Finally, the profile of sales across products is highly non-uniform, with a broadly similar ranking of products by sales in the home and foreign markets. These patterns are consistent with the model presented in Section 2. They are also broadly in line with the empirical patterns found in other recent studies of multi-product firms.[23]

3.3 Empirical Strategy

Consider next the theoretical prediction which is unique to our model: if and only if $\frac{b}{L} < 2\eta(1-e)$, then quality-based competence should prevail, so prices *fall* with distance from a firm's core competence, or, equivalently, prices and sales values are *positively* correlated across a firm's products. In our theoretical section we showed that this holds for a single firm or (as shown in the Appendix) for a group of firms competing against each other in an oligopolistic market. Given our large data set, it is natural to explore how this prediction fares when we consider different values of the exogenous variables, η, L and e. Unfortunately, we cannot observe the marginal effectiveness of investment η, which is itself a composite of parameters representing the costs and benefits to the firm of investment in product quality. As for market size L, the condition for quality-based competence states that it is more likely to hold the larger the market. However, we should be careful of interpreting this too literally: since we do not have data on sales in individual export markets, we cannot take for granted that the

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[23] See, for example, the studies of Bernard, Redding and Schott (2010) and Goldberg, Khandelwal, Pavcnik and Topalova (2010), who look at home production by multi-product firms in the U.S. and India respectively; and of Arkolakis and Muendler (2009), Bernard, Redding and Schott (2006), Berthou and Fontagné (2009), and Mayer, Melitz and Ottaviano (2010), who apply models of multi-product firms similar to ours to data sets for Brazil, Chile, the U.S. and France.

rest of the world is a larger market than the domestic Mexican market. This will be true for some firms but not for others, depending on the foreign customers they target and on their past history of investment in marketing and product quality. This leaves only the degree of product differentiation e. Fortunately, thanks to Rauch (1999), we have good information on which goods are more differentiated. Hence we can test the implication of the model that more differentiated products are more likely to exhibit a quality-based price profile.

How do we operationalize testing this prediction? The first issue to be addressed is how to measure the distance of each product from the firm's core competence. In our theoretical model, with all goods symmetrically and horizontally differentiated from each other, it was natural to look at products ranked by sales volume. This can be thought of as measuring volumes in terms of the true units of measurement in which all goods can be compared. However, when we come to apply the model to real data we do not observe sales volumes in terms of these underlying units of measurement. Fortunately, we can still operationalize the model by focusing on the profiles of *sales value* rather then volume: $s(i) = p(i)x(i)$. As i rises, so we consider products further from the firm's core competence, output definitely falls but price may rise or fall as we have seen. However, as we show in the Appendix, Section 5.2, the output effect must dominate. Hence sales value, like sales volume, unambiguously falls as the firm moves away from its core competence, and so can be used as an empirical proxy for the distance of a product from the firm's core competence.

A related issue we need to address is "prices relative to what?" In the theoretical model, all goods are symmetrically differentiated and so, as with outputs, their prices are directly comparable. By contrast, with real-world data, we have to compare the price of each good with the average price of an appropriate set of comparator goods. The strategy we adopt is the following. Prices are measured throughout by unit values, equal to sales value divided by sales quantity. For each product i, let J_i denote the number of plants that produce a variety of that product. We measure the relative price of each variety as its own price relative to the average price of all varieties of the same product. More precisely, in all the regressions below, the dependent variable is the log of the unit value of product i from plant j at time t, relative to the weighted average unit value of all J_i varieties of product i produced in or exported from Mexico at time t. We call this the price premium:

$$\ln\ Price\ Premium_{ijt} \equiv \ln\ \frac{Unit\ Value_{ijt}}{\sum_{j=1}^{J_i} \omega_{ijt} Unit\ Value_{ijt}} \tag{20}$$

Note that we are comparing the price of a particular variety of each product with different varieties of the same good, which in all cases are produced in different plants. The weights ω_{ijt} are either $1/J_i$ or shares in domestic sales or exports; in practice this choice makes very little difference to the results.

Given our price premia, we relate them to the ranking of products produced or exported by the same plant. Thus our measure of how close a product is to its plant's core competence relies on observable production or export data, not on unobservable cost data. In all the tables below, the estimating equation is then:

$$\ln\ Price\ Premium_{ijt} = \beta_0 + \sum_{r=1}^{R} \beta_r D_{ijt}^r + X + \varepsilon_{ijt} \tag{21}$$

where D_{ijt}^r is a dummy variable, which equals one if product i is ranked r in the production or exports of plant j in year t, and zero otherwise; X is a vector of plant fixed effects; and ε_{ijt} is a stochastic error term. We present results for a range of values of the number of products R, trading off the improvement in the fine detail of the price profile which we are able to estimate against the loss of degrees of freedom as we exclude more plants which produce or export only a small number of products.

Finally, as already mentioned, we wish to use estimates of (21) to test the prediction of Proposition 1 that a higher degree of product differentiation should make firms more likely to exhibit a price profile that reflects quality-based rather than cost-based competence. To implement this test, we need independent observations on the degree of product differentiation, and for this purpose we make use of the classification developed by Rauch (1999). He grouped goods by the Standard International Trade Classification (SITC), Revision 2, four-digit classification into three categories, "differentiated," "traded on organized exchanges" or "reference priced." We combine the latter two into a catch-all "non-differentiated" category, and follow many authors in adopting the so-called "liberal" classification, which maximizes the number of goods classified as non-differentiated. To implement this classification with our Mexican data, we had to make a concordance between the *clases* in our data and the SITC system. Fortunately, this was possible without too much arbitrariness.[24] We are thus able to explore how the relationship

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[24] Examples of differentiated *clases* include: 311901: Produccion de chocolate y golosinas a partir de cocoa o

between the price and sales profiles of multi-product firms varies with the degree of product differentiation.

3.4 Results for Price Profiles at Home and Away

Table 3 gives the results of estimating equation (21) over different subsets of the data on all plant/product/year observations for which the plant in question sells at least two products. Each column gives the results of regressing the corresponding price premium on plant fixed effects and on a dummy variable for the highest selling product.[25] Thus, in the first equation, the coefficient 0.042 gives the estimated price premium on the top-selling product relative to the average price premium on the excluded category of all products ranked second or lower in production. This coefficient is highly significant, indicating that, on average, the highest-selling product from each plant commands a price premium of 4.3%.[26] This provides overwhelming evidence of quality-based competence, in the sense in which we have used the term in our theoretical model. The positive and highly significant coefficient implies that the product which is closest to a plant's core competence sells for a higher price on average than products lower down the ranking. The fourth equation in the table shows that export sales exhibit a similar pattern on average, with the coefficient on the dummy variable for the top-selling equal to 0.038 and highly significant.

The most interesting feature of the table is the pattern of the estimated coefficients when we disaggregate by type of product and by destination. Looking first at the second and third equations, both differentiated and non-differentiated products sold at home exhibit the same pattern of quality-based competition. However, the coefficient for differentiated products is significantly greater than that for non-differentiated ones, exactly as our theory predicts.[27] This difference between the two categories of products is repeated but to an even more striking extent in the

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chocolate (Production of chocolate and candy from cocoa or chocolate); 323003: Produccion de maletas, bolsas de mano y similares (Production of suitcases, handbags and similar); and 322005: Confeccion de camisas (Ready-to-wear shirts). Examples of non-differentiated ones include: 311201: Pasteurizacion de leche (Pasteurization of milk); 311404: Produccion de harina de trigo (Production of wheat flour); and 341021: Produccion de papel (Production of paper).

[25] Except where otherwise stated, in this and all subsequent tables, ***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have plant fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

[26] The estimated difference between the natural logarithm of the price premium for the top product and that for all other products in the first equation is 0.042, implying a difference in the levels of 4.289%.

[27] The difference between the coefficients 0.048 and 0.033 in the second and third equations is significant at the 10% level, while the corresponding differences in Tables 4 to 7 below are considerably more significant. An alternative way of presenting the results is in terms of a single equation for all 128,493 observations, with a dummy variable for the top-selling product and a second for top-selling products that are differentiated. For home sales in Table 3, this estimated equation is: $\ln \mathit{Price\ Premium} = \beta_0 + 0.033 D^1 + 0.015 D^{1d}$, where the standard error of the second coefficient is 0.008. This alternative format makes it easier to see the difference between the coefficients, but obscures their levels.

export market, as the fifth and sixth equations show. The coefficient for differentiated exports is 0.081, implying an even higher price premium for the top-selling product in this category. By contrast, the coefficient for non-differentiated exports is -0.031, implying that these products exhibit cost-based rather than quality-based competence. (The coefficient is significantly different from zero at the 5% level, and significantly lower than that on differentiated exports at the 1% level.)

It is worth summarizing the empirical findings from Table 3, since the same pattern is repeated, and is nearly always statistically significant, in the vast majority of the equations, estimated for different groupings of the data, given below:

$$\hat{\beta}_r^{DX} > \hat{\beta}_r^{DH} > \hat{\beta}_r^{NH} > 0 > \hat{\beta}_r^{NX} \tag{22}$$

(Here $\hat{\beta}_1^{DX}$ is the estimated coefficient of the dummy variable for the top-selling differentiated product in the export market, etc.; the product rank r equals one in Table 3, and takes other values in later tables.) As already noted, this configuration strongly confirms the predictions of our model for the degree of product differentiation. Firms producing more differentiated products face stronger incentives to enhance their perceived quality, so the extent of quality-based competition is greater for these products. Less consistent with our model is the effect of market size, although, as already discussed, this prediction is not as clear-cut, since the identification of L, the relevant market size, with raw population is problematic. In any case, our results show a systematic tendency for the coefficient on differentiated products to be higher abroad than at home, whereas this pattern is reversed for non-differentiated products.

So far we have only considered the coefficient of the dummy variable for a firm's top-selling product. Tables 4 to 7 extend the analysis to observations in which the same plant sold at least three, four or five products in the one year. In each equation the residual category is all products with ranks lower than the lowest-ranking dummy variable included. For example, in the final equation, the four coefficients give the estimated price premia on the top four products relative to the average price premium on the excluded category of all products ranked fifth or lower in production. In these tables, there is some loss of degrees of freedom as we consider plants selling more products, but nevertheless the results are qualitatively identical to those in Table 3. In addition, they show for plants selling more than two products how the pattern of dummy-variable coefficients varies as we move away from the core competence product.

Tables 4 and 5 confirm that the pattern of quality-based competition which Table 3 showed for plants selling two or more products on the home market also applies to plants selling up to five or more. For differentiated products, Table 4 shows that the implied price premium for the top product ranges from 4.9% when all plants producing two or more products are included, to 10.0% when only those producing five or more are included. In Table 5 the corresponding figures are 3.4% and 4.8%, showing once again that non-differentiated products exhibit significantly less quality-based competition than differentiated ones.[28] Of even greater interest is that, in the second, third and fourth equations, there is clear evidence that the profile of prices falls with a product's rank. Not only is each coefficient of the dummy variables for second- and lower-ranking products in these equations significantly different from zero, almost all of them are also significantly smaller than the coefficient above them in the table. We can thus conclude that there is strong evidence that prices fall with a product's distance from a plant's core competence, so the price and production profiles are negatively correlated, implying that on average the firms in our sample compete on the basis of quality-based competence on the home market.

Tables 6 and 7 show that export sales behave even more differently depending on the degree of product differentiation. Consider first Table 6, which shows that exports of products in differentiated sectors exhibit the same price profile away as they do at home. The evidence for a monotonically decreasing profile is less strong in the case of plants producing five or more products, although this may be due to the smaller number of observations in this sub-sample, and in any case the top three products command a significant price premium over products ranked fifth or lower. Moreover, the quantitative magnitude of the effects is much higher than in Table 4: the implied price premium for the top product ranges from 8.4% when all plants producing two or more products are included, to 16.1% when only those producing five or more are included.

By contrast, Table 7 tells a very different story for exports of non-differentiated products. Not a single coefficient in this table is significantly positive, most are negative, and all the coefficients of the dummy variable for the top product are significantly negative at the 5% level. Unlike Tables 4, 5 and 6, this provides strong evidence against quality-based competence, and clear evidence in favour of cost-based competence for exports of non-differentiated products. Though not as overwhelmingly significant as the results for differentiated products, the results

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[28] As before, these premia are given by the antilogs of the corresponding entries in Tables 4 and 5.

imply that the two groups of products behave very differently, and exactly in the way predicted by Proposition 1. For differentiated exports, prices fall with their distance from the plant's core competence, suggesting that Mexican exporters in these sectors compete on the basis of quality. By contrast, for non-differentiated exports, prices rise with their distance from the plant's core competence, suggesting that competition in such sectors is on the basis of cost rather than quality, exactly as our theory suggests.

Overall, these four tables confirm that the coefficient pattern summarized in equation (22) continues to hold when we consider plants that sell up to five or more products.

3.5 Robustness Checks

A possible concern with the results so far is that the sample sizes are very different in different tables, with more products produced for the home market than for exports. This is perfectly consistent with our model which predicts that higher costs of accessing a foreign market will reduce the range of products sold there. Nevertheless it might suggest a concern that the regularities we have found in our data reflect behaviour very different from that predicted by our model; for example, that plants sell different products in the home and foreign markets, or that plants which select into exporting are very different from those that sell only on the home market. To address these concerns we reestimate our price profile equations first for those products that are sold on both markets, and next for the home sales of exporting plants.

Tables 8 and 9 address the issue of different sample sizes directly by reestimating the equations for only those observations on products that are *both* exported and sold at home. The two tables present results for plants selling two or more and five or more products respectively. It can be seen that the conclusions drawn from the earlier tables survive this robustness check. All significant coefficients in the first five columns in both tables are positive, whereas the significant coefficient in the sixth column, the regression equation for non-differentiated exports, is negative. It is true that the evidence for quality-based competence by plants in non-differentiated sectors is weaker, with no significant coefficients in the third equation in Table 9. However, in Table 8 the coefficient of the dummy variable on the top product when all observations on plants producing two or more products are included remains significant and positive. We can conclude that the evidence from this smaller sample is less overwhelmingly in support of different behaviour by non-differentiated product plants at home and away; but that the evidence for a difference between behavior by plants in differentiated and non-differentiated sectors remains very strong, especially in export markets.

Table 10 addresses the question of whether plants that select into exporting behave differently on the home market. It gives results for home sales by export plants in both differentiated and non-differentiated *clases*, and it is clear that the two behave very similarly to the corresponding samples of all plants selling on the home market, as in Tables 4 and 5. Once again, all home sales exhibit quality-based competence, with those of differentiated products significantly more so. Bearing in mind that the plants in Table 10 are identical to those whose exporting behaviour is shown in Tables 6 and 7, our earlier conclusions are reinforced. Exporting plants in both differentiated and non-differentiated sectors exhibit quality-based competence in the home market, though the latter less strongly, so the very different behaviour of exporters in non-differentiated sectors shown in Table 7 does not reflect any differential selection process of plants into exporting.

A different robustness check addresses the concern that our theory was developed for multi-product *firms*, whereas our data consist of observations on multi-product *plants*. Treating plants as the unit of observation risks ignoring the interdependence of decision-making within multi-plant firms. To deal with this problem empirically we would ideally like to have data on the ownership patterns of plants in all years. Unfortunately, we can only identify which plants were owned by the same firm in the penultimate year of our sample, 2003. We therefore adopt the following strategy. We retain in the sample only those plants which were single-plant firms in 2003, and consider their sales and price profiles in all years. This risks including some observations on plants which did not correspond to single-plant firms either in 2004 because of mergers and acquisitions, or in years prior to 2003 because of divestitures. However, the number of such cases is likely to be small, and this strategy seems preferable to losing many more degrees of freedom by focusing on single-plant firms in 2003 only.[29]

Tables 11 and 12 give the results of this robustness check, for single-plant firms selling at least two and at least five products respectively. The evidence for quality-based competence remains overwhelming for both categories of home sales and for differentiated exports. The profile of the sales-rank dummies is not always monotonically decreasing, and definitely not significantly so. However, all coefficients are significant at the 1% level, implying that products closer to the core sell for higher prices than the non-core products in the default category of each equation. As for exports of non-differentiated products, the evidence for cost-based competence

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[29] Results for 2003 alone have similar coefficients to those reported here, but with larger standard errors.

is much less strong than in earlier tables. At the same time, with all coefficients insignificant, there is no evidence for quality-based competence either. We can conclude that our earlier results are reasonably robust to excluding plants owned by multi-plant firms in 2003.

A related concern is that our model is more applicable to Mexican-owned firms than foreign-owned ones. At least for sales in their export markets, and even in their home market too, we would expect the decisions of foreign-owned Mexican plants to be taken as part of the global operations of their parent multinational companies rather than on a stand-alone basis. It seems appropriate therefore to check that the results hold when foreign-owned plants are excluded. Tables 13 and 14 confirm that this is the case. All coefficients of the dummy variable for the top-selling product are significant and fit the pattern summarized in equation (22).

Finally, it is desirable to check that the results for price profiles which we have uncovered do not reflect features peculiar to only some years in our sample. (The Mexican economy was subjected to a number of major shocks during the early years of our data, including the coming into force of NAFTA in January 1994 and the peso devaluation of December 1994.) Table 15 gives the results of estimating the price profile for plants selling two or more products in each year for each of the four disaggregated categories we have considered so far. Sample sizes are now much smaller of course, especially for export markets, so not all coefficients are significant. Nonetheless, the pattern of coefficients is very much in line with that found already. In eight of the eleven years, it conforms exactly to that given in equation (22), and in the remaining three years there is only one departure from that pattern: in 1995, non-differentiated exports exhibit quality-based competence, though less strongly than any other category; in 1996, differentiated sales exhibit quality-based competence more strongly in the home market than the export market; and in 2004, differentiated products exhibit slightly though not significantly less quality-based competence in the home market than non-differentiated ones. It is tempting to propose *ad hoc* rationalizations for these departures from the norm: the improved competitiveness of Mexican exports following the peso crisis might explain the departures from the general pattern in 1995 and 1996, for example. However, it is probably better to attribute them merely to the relatively small samples available for each year, and to conclude that the patterns for individual years are not substantially out of line with those found in the sample as a whole.

4 Conclusion

This paper has developed a new model of multi-product production in which firms invest to improve the quality of their products as well as the quality of their overall brand. It is thus the first to integrate two important strands of recent work on the behaviour of firms in international markets. On the one hand, the growing evidence that many firms, and especially most large exporters, are multi-product, has inspired theoretical and empirical work which focuses on the "intra-firm extensive margin", changes in the range of products produced by firms, distinct from the inter-firm extensive margin which has attracted so much attention in the literature on heterogeneous single-product firms. On the other hand, an increasing number of authors have suggested that successful firms in international markets compete on the basis of superior quality rather than superior productivity. Our model integrates these two strands in a tractable framework. Crucially, it endogenises both the choice of product range and the choice of quality, or more specifically, the choice of investment in quality, thus allowing a range of issues to be explored which have so far been little studied.

The model has interesting implications for the manner in which firms compete in international markets. In particular, it throws light on the question of whether productivity or quality is the key to successful export performance, and suggests a way of reconciling these two views. Because of flexible manufacturing, firms produce more of products closer to their core competence. They also have incentives to invest more in the quality of those goods. These two effects have opposite implications for the profile of prices. On the one hand, to the extent that consumers view all products as symmetrically differentiated substitutes for each other, firms can only sell more of their core products by charging lower prices for them. Hence, the direct effect of lower production costs for core products is that firms "pile 'em high and sell 'em cheap," implying that the profiles of prices and sales should be negatively correlated, an outcome we call "cost-based competence". On the other hand, firms face stronger incentives to invest in raising the perceived quality of their core products, since these are the products with the highest mark-ups. Even though investment in the quality of an individual product is subject to diminishing returns, this implies that firms will invest more in the quality of their core products, so raising the price which consumers are willing to pay for them. This indirect effect of lower production costs for core products implies that the profiles of prices and sales should be positively correlated, an outcome we call "quality-based competence". We show that both these outcomes are possible in our model, and that which of them prevails depends on a number of exogenous factors. In particular, the greater the degree of product differentiation, the more the firm faces differential incentives to invest in the quality of different products, and so the more likely is the indirect effect to dominate, giving rise to quality-based competence.

This last prediction is the one we explore empirically, drawing on a unique data set on Mexican plants already used by Iacovone and Javorcik (2007, 2010). A great advantage of this data set is that it gives detailed information on both home and foreign sales at the same level of disaggregation, allowing us to test theoretical predictions about their relative profiles. Our findings show that a two-way distinction is crucial: between home sales and exports on the one hand, and between differentiated and non-differentiated products on the other. In the domestic market, we find that both differentiated and non-differentiated products exhibit quality-based competence, with prices falling as sales value falls. However, this pattern is significantly more pronounced for differentiated products, exactly as our theory predicts. The same holds true in the export market, where the difference in price behaviour between the two groups of products is considerably greater: plants in differentiated-product sectors exhibit quality-based competence in export markets, but those in non-differentiated-good sectors exhibit cost-based competence, with core-competence products selling for significantly *lower* prices on average. These results turn out to be robust to a slew of alternative ways of grouping our data. We find very similar results whether we consider all products or only those which are sold in both home and foreign markets; and whether we consider all plants active in either market or only those active in both. They also hold when we consider only the sub-sample of single-plant firms: confirmation that our theory, which was developed for firms, helps in understanding behaviour at plant level too. Finally, the patterns we have found hold in all years in our eleven-year sample, and are particularly in evidence for home-owned as opposed to foreign-owned firms. We can thus conclude that, for this data set, quality-based competence is dominant for firms in differentiated-good sectors, but not for the export sales of firms in non-differentiated-good sectors.

While a full consideration of the costs and benefits of different export promotion strategies is beyond the scope of this paper, our results have interesting implications for the design of such policies. In particular, our finding that exporters from a middle-income country such as Mexico compete in foreign markets on either cost or quality suggests that export promotion efforts should focus on improving perceived product quality in differentiated-good sectors and on helping producers to lower production costs in non-differentiated-good sectors. The former type of intervention can take the form of marketing campaigns to stress the advantages of national products, or reductions in the costs of quality certifications (e.g. ISO 9000 or 14000) to improve the producer's image. The latter type of intervention can focus on stimulating investment in cost-saving technologies and worker training.

Our findings also have broader implications for the nature of competition in international markets. Our data set shows that within-firm product heterogeneity is not just a rich-country phenomenon, but is also important in at least one middle-income country. Moreover, the evidence we present suggests that only firms in differentiated-product sectors compete in export markets on quality. This has a key implication for understanding how firms compete successfully abroad. While previous studies have shown that all exporters have a productivity premium, our results suggest that those in differentiated-product sectors have a quality premium too, whereas those producing non-differentiated goods behave differently at home and away, competing less on quality and more on price in their export markets.

5 Appendix

5.1 Cournot Competition with Heterogeneous Firms

The model in the text considered a single monopoly firm only, whose goal is to maximize the operating profits from all the products it sells in a market. Here we show that the results on sales and price profiles derived in the text also hold for a firm engaged in Cournot competition, that takes as given the outputs of other firms. We also derive the comparative statics effects on such a firm of changes in the marginal effectiveness of both types of investment, in market size, and in market access costs.

To simplify notation, we consider a world of two countries only. We focus on the foreign market, in which we assume there is a fixed number of firms, $\bar{m}$, of which m are from the home country and m^* from the foreign country, each with the flexible manufacturing technology considered in the text. We let M, M^* and $\bar{M}$ denote the sets of firms in the home and foreign countries and in the world, respectively. We allow for arbitrary differences between firms in their cost functions, with the cost function of firm j denoted by: $c_j(i)$, $j = 1, ..., \bar{m}$. The utility function is unchanged from equation (1) in the text, since, in the absence of investment in quality, consumers do not value differently the goods produced by different firms. Hence the demand function is the same as (2), except that total consumption is now $Y = \sum_{j \in \bar{M}} X_j$.

Consider the behaviour of an individual firm. The presence of competitor firms does not affect the first-order condition for the output of each variety in equation (4): each firm continues to equate the price-cost margin of each variety to $\tilde{b}$ times a weighted average of that variety's output and of its total output. Combining this with the demand function, the expression for outputs, equation (5), must be replaced by:

$$x_j(i) = \frac{a_j(i) - c_j(i) - t_j - \tilde{b}eX_j - \tilde{b}eY}{2\tilde{b}(1-e)} \qquad i \in \Omega_j, \quad j \in \bar{M} \tag{23}$$

where $\Omega_j = \{0, ..., \delta_j\}$ is the set of goods sold by firm j, and, as in the monopoly case, the sales of each marginal product are zero: $x_j(\delta_j) = 0$. Note that we write the tariff with firm subscripts: $t_j = t$ for all home exporting firms $j \in M$, and $t_j = 0$ for all foreign import-competing firms $j \in M^*$. As for the first-order conditions for investment in quality, they continue to be given by (9).[30] Substituting these into $a_j(i)$ and proceeding as in the text gives, instead of (12):

$$x_j(i) = \frac{c_j(\delta_j) - c_j(i)}{2[\tilde{b} - \eta_j(1-e)](1-e)}, \quad i \in [0, \delta_j], \quad j \in \bar{M} \tag{24}$$

This in turn leads to an equation for prices just like equation (13) in the text. Hence Proposition 1 is unaffected: the key condition for the profile of a firm's prices to rise with distance from its core competence continues to be $\tilde{b} > \eta_j(1-e)$, independent of the number of firms m and m^*.

Consider next the comparative statics of an initial equilibrium. We seek a set of $\bar{m}$ equations, one per firm, which relate changes in the total output of each firm, X_j, to changes in exogenous variables $\chi = \left(\eta_j, \bar{\eta}_j, L, t\right)$. For simplicity we confine attention to the effects of a change in the relative effectiveness of investment for only one firm j, assumed to be an exporter based in the home country. To eliminate the individual varieties $x_j(i)$, integrate (24) to get:

$$X_j = \frac{\phi_j(\delta_j)}{2[\tilde{b} - \eta_j(1-e)](1-e)}, \quad \phi_j(\delta_j) \equiv \int_0^{\delta_j} [c_j(\delta_j) - c_j(i)]\, di, \quad j \in \bar{M} \tag{25}$$

To obtain a second equation linking X_j and δ_j, evaluate (23) at $i = \delta_j$ to obtain:

$$c_j(\delta_j) = a_j(\delta_j) - t_j - \tilde{b}eX_j - \tilde{b}eY = a_j^0 - t_j - \left(\tilde{b} - 2\bar{\eta}_j e\right) eX_j - \tilde{b}eY \quad j \in \bar{M} \tag{26}$$

Finally, total market sales Y can be eliminated by recalling that it equals the sales of all $\bar{m}$ firms.

To proceed, first totally differentiate (25) and (26):

$$dX_j = \frac{1}{2[\tilde{b} - \eta_j(1-e)](1-e)} \left[\delta_j c_j'(\delta_j)\, d\delta_j + 2\frac{\tilde{b}}{L}(1-e) X_j dL + 2(1-e)^2 X_j d\eta_j\right] \tag{27}$$

$$c_j'(\delta_j)\, d\delta_j = -dt_j - \left(\tilde{b} - 2\bar{\eta}_j e\right) edX_j - \tilde{b}edY - \frac{\tilde{b}}{L}eX_j dL + 2e^2 X_j d\bar{\eta}_j \tag{28}$$

Combining these and eliminating δ_j gives a single equation for each firm, which is the total differential of its reaction function in $\{X_j\}$ space:

$$A_j^{-1} dX_j + \tilde{b}edY = d\chi_j \tag{29}$$

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[30] For simplicity, we abstract from strategic investment by firms. So, we focus only on the open-loop case where decisions on sales, product scope, and investment are taken simultaneously.

where:

$$A_j^{-1} \equiv \frac{1}{\delta_j}\left[2\left\{\tilde{b}-\eta_j(1-e)\right\}(1-e)+\left(\tilde{b}-2\bar{\eta}_j e\right)e\delta_j\right] \tag{30}$$

and

$$d\chi_j \equiv -dt_j+\frac{\tilde{b}}{L}\left[2(1-e)\frac{X_j}{\delta_j}+e(X_j+Y)\right]dL+\frac{2}{\delta_j}(1-e)^2X_jd\eta_j+2e^2X_jd\bar{\eta}_j \tag{31}$$

$d\chi_j$ is a composite term summarizing the exogenous shocks to firm j's reaction function. Solving these $\bar{m}$ reaction functions (29) allows us to derive the comparative statics effects of changes in the exogenous variables.

To solve the equations in (29), we follow Dixit (1986). Multiply (29) by A_j, sum the reaction functions over all $\bar{m}$ firms, and collect terms to solve for total output Y:

$$dY=\frac{\sum_{j'}A_{j'}d\chi_{j'}}{1+\tilde{b}e\sum_{j'}A_{j'}} \tag{32}$$

Next, substitute into (29) to solve for the change in the output of an individual firm:

$$dX_j=A_jd\chi_j-A_j\tilde{b}e\frac{\sum_{j'}A_{j'}d\chi_{j'}}{1+\tilde{b}e\sum_{j'}A_{j'}}=\frac{A_j}{1+\tilde{b}e\sum_{j'}A_{j'}}\left[d\chi_j+\tilde{b}e\sum_{j'}A_{j'}\left(d\chi_j-d\chi_{j'}\right)\right] \tag{33}$$

Thus any exogenous shock affects the output of firm j directly by shifting its own reaction function, and also indirectly to the extent that it shifts differentially the reaction functions of all other firms. We can now consider the effects of different shocks in turn.

5.1.1 Effects of Tariffs

When the foreign tariff increases, we have: $d\chi_j=-dt$, $j\in M$ and $d\chi_j=0$, $j\in M^*$. Hence from (33) the effect of a foreign tariff on the output of a foreign import-competing firm is:

$$dX_j=A_j\frac{\tilde{b}e\sum_{j'\in M}A_{j'}}{1+\tilde{b}e\sum_{j'}A_{j'}}dt>0,\quad j\in M^* \tag{34}$$

This implies that a reduction in foreign trade barriers ($dt<0$) lowers the output of all foreign firms, since it exposes them to more competition. Similarly, the change in the total output of a home exporting firm is:

$$dX_j = -A_j \frac{1 + \tilde{b}e \sum_{j' \in M^*} A_{j'}}{1 + \tilde{b}e \sum_{j'} A_{j'}} dt < 0, \quad j \in M \tag{35}$$

Hence a reduction in foreign trade barriers raises the export sales of all home firms. From (25), each firm's output and scope move together for given L and η_j, and so the effects of a tariff on δ_j are qualitatively the same as its effects on the corresponding X_j.

5.1.2 Effects of the Marginal Effectiveness of Brand-Enhancing Investment

In this case we have $d\chi_{j'} = 2e^2 X_j d\bar{\eta}_j$, $j' = j$ and $d\chi_{j'} = 0$, $j' \neq j$. Hence from (33):

$$dX_j = 2e^2 A_j \frac{1 + \tilde{b}e \sum_{j' \neq j} A_{j'}}{1 + \tilde{b}e \sum_{j'} A_{j'}} X_j d\bar{\eta}_j > 0 \tag{36}$$

As for firm j's scope, it follows immediately from (25) that it too must rise.

5.1.3 Effects of the Marginal Effectiveness of Variety-Enhancing Investment

In this case we have $d\chi_{j'} = \frac{2}{\delta_j} (1-e)^2 X_j d\eta_j$, $j' = j$ and $d\chi_{j'} = 0$, $j' \neq j$. Hence from (33):

$$dX_j = 2(1-e)^2 \frac{A_j}{\delta_j} \frac{1 + \tilde{b}e \sum_{j' \neq j} A_j}{1 + \tilde{b}e \sum_{j'} A_{j'}} X_j d\eta_j > 0 \tag{37}$$

It also follows immediately that the output of all other firms must fall. As for the implications for scope, substituting dX_j into (27) yields:

$$d\delta_j = \left[2\left\{ \tilde{b} - \eta_j (1-e) \right\} (1-e) \frac{A_j}{\delta_j} \frac{1 + \tilde{b}e \sum_{j' \neq j} A_j}{1 + \tilde{b}e \sum_{j'} A_{j'}} - 1 \right] \frac{2(1-e)^2 X_j}{\delta_j c_j' (\delta_j)} d\eta_j \tag{38}$$

Substituting for $\frac{A_j}{\delta_j}$ from (30), this becomes:

$$d\delta_j = -\left[1 - \frac{2\left\{ \tilde{b} - \eta_j (1-e) \right\} (1-e)}{2\left\{ \tilde{b} - \eta_j (1-e) \right\} (1-e) + \left(\tilde{b} - 2\bar{\eta}_j e \right) e\delta_j} \frac{1 + \tilde{b}e \sum_{j' \neq j} A_j}{1 + \tilde{b}e \sum_{j'} A_{j'}} \right] \frac{2(1-e)^2 X_j}{\delta_j c_j' (\delta_j)} d\eta_j \tag{39}$$

Both the fractions in parentheses are less than one, so the whole expression must be negative. Hence product scope must fall for all firms in this case. The firm enjoying more effective investment adopts a "leaner and meaner" profile, while all other firms face tougher competition and so cut back on both scale and scope.

5.1.4 Effects of Market Size

All firms are directly affected by this shock and the outcome turns out to depend a lot on the degree of asymmetry between them. Substituting for dL from (31) into (33) gives:

$$\begin{aligned}\frac{dX_j}{d\ln L} &= \frac{\tilde{b}A_j}{1+\tilde{b}e\Sigma_{j'}A_{j'}}\left[\left\{2\left(1-e\right)\frac{X_j}{\delta_j}+e\left(X_j+Y\right)\right\}\right.\\ &\quad \left.+\tilde{b}e\Sigma_{j'}A_{j'}\left\{2\left(1-e\right)\left(\frac{X_j}{\delta_j}-\frac{X_{j'}}{\delta_{j'}}\right)+e\left(X_j-X_{j'}\right)\right\}\right]\end{aligned} \tag{40}$$

The second set of terms inside the square brackets on the right-hand side exhibits the "superstar firms" tendency discussed in the text: firms with total sales X_j or sales per variety $\frac{X_j}{\delta_j}$ above the industry average tend to grow by more, and conversely for firms below average. In the special case where goods are homogeneous ($e=1$), so firms are single-product, equation (40) becomes: $\frac{dX_j}{d\ln L}=\frac{A_j}{1+\tilde{b}\Sigma_{j'}A_{j'}}\left[X_j+Y+\tilde{b}\Sigma_{j'}A_{j'}\left(X_j-X_{j'}\right)\right]\tilde{b}$, with $A_j^{-1}=\tilde{b}-2\bar{\eta}_j$. Though simpler than (40), this still implies the "superstar firms" result. A different special case is where all firms are identical, in which case the effect on output is:

$$\frac{d\ln X}{d\ln L}=\frac{\left\{2\left(1-e\right)+\left(\bar{m}+1\right)e\delta\right\}\tilde{b}}{2\left\{\tilde{b}-\eta\left(1-e\right)\right\}\left(1-e\right)+\left\{\left(\bar{m}+1\right)\tilde{b}-2\bar{\eta}e\right\}e\delta} \tag{41}$$

This is greater than one provided either η or $\bar{\eta}$ is strictly positive, so firms engage in either or both type of investment. Finally, when firms are heterogeneous but do not invest, because $\eta_j=\bar{\eta}_j=0$, equation (40) reduces to $\frac{d\ln X_j}{d\ln L}=1$.

Turning to the effect on scope, equation (28) can be rewritten to give:

$$\frac{d\ln\delta_j}{d\ln L}=\frac{1}{E_j}\left[\frac{d\ln X_j}{d\ln L}-\frac{\tilde{b}}{\tilde{b}-\eta_j\left(1-e\right)}\right] \tag{42}$$

where $E_j\equiv\frac{\delta_j\phi_j'(\delta_j)}{\phi_j(\delta_j)}=\frac{\delta_j^2c_j'(\delta_j)}{\phi_j(\delta_j)}$ is the elasticity of cost savings from flexible manufacturing, as in Eckel and Neary (2010), p. 201. Even for superstar firms, scope may fall, and a high effectiveness of investment in individual varieties, η_j, tends to encourage this outcome. When $\eta_j=\bar{\eta}_j=0$, so firms do not invest, scope is independent of market size, $\frac{d\ln\delta_j}{d\ln L}=0$, as noted in Eckel and Neary (2010), Proposition 13. As for the case where firms are symmetric, (42) reduces to:

$$\frac{d\ln\delta}{d\ln L} = \frac{\tilde{b}e\delta}{E}\frac{2\bar{\eta}e-(\bar{m}+1)\,\eta\,(1-e)}{\left[2\left\{\tilde{b}-\eta\,(1-e)\right\}(1-e)+\left\{(\bar{m}+1)\,\tilde{b}-2\bar{\eta}e\right\}e\delta\right]\left\{\tilde{b}-\eta\,(1-e)\right\}} \tag{43}$$

Clearly, a higher effectiveness of investment in brand quality encourages an expansion of scope, and a higher effectiveness of investment in the quality of individual varieties encourages a reduction, with increased competition from more rival firms tending to accentuate the latter. With only one firm, the numerator is proportional to $\bar{\eta}e-\eta\,(1-e)$, the case discussed in the text.

5.2 Sales Value and Distance from Core Competence

To show that the profile of sales value falls with distance from core competence, totally differentiate the equation defining $s(i)$:

$$\frac{ds(i)}{di} = p(i)\frac{dx(i)}{di} + x(i)\frac{dp(i)}{di} \tag{44}$$

The derivative of $p\,(i)$ with respect to i can be found by differentiating the first-order condition (4). Substituting this and collecting terms gives:

$$\frac{ds(i)}{di} = \left[p(i)+\tilde{b}\,(1-e)\,x(i)\right]\frac{dx(i)}{di} + x(i)\frac{dc(i)}{di} \tag{45}$$

Next, substituting for both output $x\,(i)$ itself and its derivative with respect to i from equation (5) gives:

$$\frac{ds(i)}{di} = \frac{1}{2\tilde{b}\,(1-e)}\left[\left\{p(i)+\tilde{b}\,(1-e)\,x(i)\right\}\frac{da(i)}{di} - \left\{c\,(i)+t+\tilde{b}eX\right\}\frac{dc(i)}{di}\right] \tag{46}$$

Since $c\,(i)$ rises with i and $a\,(i)$ is either independent of i or falls with it, it follows that sales value must fall with distance from the firm's core competence.

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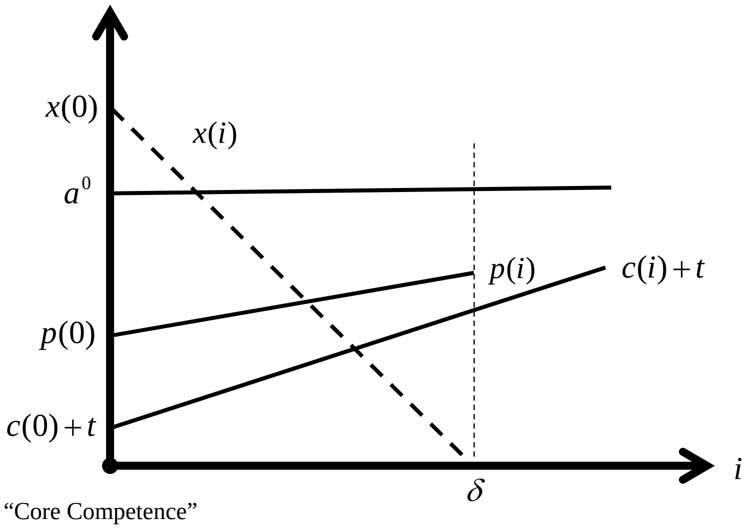

Figure 1: Profiles of Outputs, Prices and Costs with Cost-Based Competence

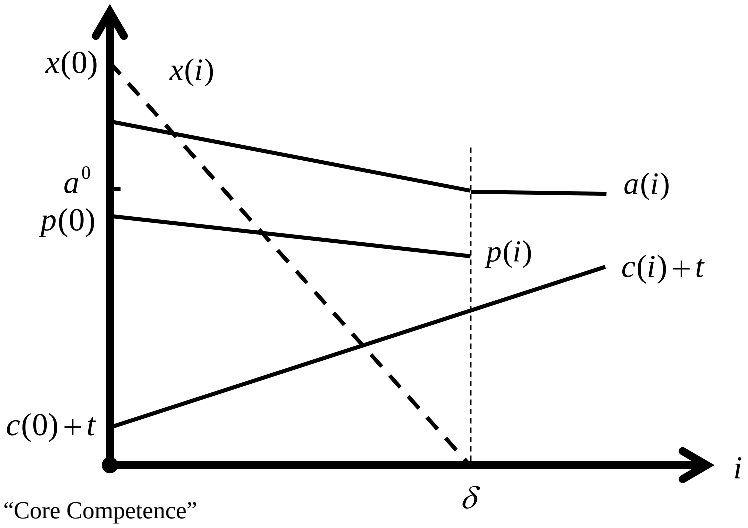

Figure 2: Profiles of Outputs, Prices and Costs with Quality-Based Competence

Year	Number of plants					Number of products	
	Total	Owned by MPFs[1]	Other	Exporters		Produced	Exported
				Total	Adjusted[2]		
1994	6,291	1,259	5,032	1,582	1,579	19,154	2,844
1995	6,011	1,245	4,766	1,844	1,842	18,568	3,406
1996	5,747	1,256	4,491	2,024	2,023	17,662	3,881
1997	5,538	1,256	4,282	2,138	2,137	16,938	4,092
1998	5,380	1,268	4,112	2,095	2,094	16,419	4,193
1999	5,230	1,279	3,951	1,951	1,950	15,885	3,889
2000	5,100	1,280	3,820	1,901	1,899	15,279	3,737
2001	4,927	1,258	3,669	1,770	1,766	14,714	3,509
2002	4,765	1,237	3,528	1,686	1,684	14,182	3,321
2003	4,603	1,193	3,410	1,678	1,675	13,507	3,282
2004	4,424	1,159	3,265	1,602	1,599	12,887	3,118
Total	58,016	13,690	44,326	20,271	20,248	175,195	39,272

Table 2: Number of Plants and Products

(1) MPFs: Multi-plant firms; information on the number of plants owned by a single firm is available for 2003 only.
(2) The adjusted data exclude plants not reporting production in the year in question.

Market:	Home			Export		
Varieties:	All	Diff.	Non-Diff.	All	Diff.	Non-Diff.
Top Product:	0.042^{***} (0.004)	0.048^{***} (0.006)	0.033^{***} (0.005)	0.038^{***} (0.008)	0.081^{***} (0.012)	-0.031^{**} (0.010)
r^2	0.441	0.447	0.381	0.365	0.378	0.303
N	128,493	81,708	46,785	23,227	14,975	8,252

Table 3: Price Profiles for All Plants Selling Two or More Products

Plants with:	2+ products	3+ products	4+ products	5+ products
Top Product:	0.048^{***} (0.006)	0.069^{***} (0.007)	0.088^{***} (0.008)	0.095^{***} (0.009)
Top 2nd:		0.050^{***} (0.007)	0.072^{***} (0.008)	0.087^{***} (0.009)
Top 3rd:			0.057^{***} (0.008)	0.080^{***} (0.009)
Top 4th:				0.057^{***} (0.009)
r^2	0.447	0.423	0.421	0.425
N	81,708	71,932	61,520	52,251

Table 4: Price Profiles at Home: Differentiated Products

Plants with:	2+ products	3+ products	4+ products	5+ products
Top Product:	0.033^{***} (0.005)	0.029^{***} (0.006)	0.025^{***} (0.007)	0.047^{***} (0.009)
Top 2nd:		0.014^{**} (0.006)	0.025^{***} (0.007)	0.041^{***} (0.009)
Top 3rd:			0.030^{***} (0.007)	0.029^{**} (0.009)
Top 4th:				0.041^{***} (0.009)
r^2	0.381	0.347	0.326	0.313
N	$46,785$	$38,436$	$30,634$	$23,557$

Table 5: Price Profiles at Home: Non-Differentiated Products

Plants with:	2+ products	3+ products	4+ products	5+ products
Top Product:	0.081^{***} (0.012)	0.128^{***} (0.015)	0.139^{***} (0.019)	0.149^{***} (0.024)
Top 2nd:		0.072^{***} (0.015)	0.115^{***} (0.020)	0.145^{***} (0.025)
Top 3rd:			0.107^{***} (0.020)	0.151^{***} (0.025)
Top 4th:				0.041^{*} (0.024)
r^2	0.378	0.348	0.341	0.349
N	$14,975$	$11,528$	$8,812$	$6,720$

Table 6: Price Profiles Away: Differentiated Products

Plants with:	2+ products	3+ products	4+ products	5+ products
Top Product:	-0.031^{**} (0.010)	-0.033^{**} (0.014)	-0.053^{**} (0.019)	-0.075^{**} (0.027)
Top 2nd:		0.003 (0.014)	0.006 (0.019)	-0.016 (0.027)
Top 3rd:			0.010 (0.019)	-0.024 (0.027)
Top 4th:				-0.012 (0.027)
r^2	0.303	0.251	0.191	0.187
N	$8,252$	$5,738$	$3,847$	$2,550$

Table 7: Price Profiles Away: Non-Differentiated Products

Market:	Home			Export		
Varieties:	All	Diff.	Non-Diff.	All	Diff.	Non-Diff.
Top Product:	0.045^{***} (0.009)	0.056^{***} (0.013)	0.027^{**} (0.013)	0.037^{***} (0.009)	0.079^{***} (0.012)	-0.033^{**} (0.010)
r^2	0.412	0.421	0.376	0.350	0.361	0.292
N	$20,646$	$13,382$	$7,264$	$20,646$	$13,382$	$7,264$

Table 8: Price Profiles for Products both Exported and Sold at Home:
Plants with Two or More Products

Market:	Home			Export		
Varieties:	All	Diff.	Non-Diff.	All	Diff.	Non-Diff.
Top Product:	0.112^{***} (0.022)	0.162^{***} (0.027)	-0.036 (0.039)	0.092^{***} (0.021)	0.173^{***} (0.040)	-0.070^{***} (0.014)
Top 2nd:	0.099^{***} (0.022)	0.148^{***} (0.027)	-0.048 (0.039)	0.119^{***} (0.022)	0.108^{**} (0.027)	-0.016 (0.027)
Top 3rd:	0.092^{**} (0.022)	0.130^{***} (0.027)	-0.024 (0.039)	0.108^{***} (0.022)	0.102^{**} (0.040)	-0.024 (0.027)
Top 4th:	0.022 (0.022)	0.040 (0.027)	-0.039 (0.039)	0.038^{*} (0.021)	0.005 (0.040)	-0.012 (0.027)
r^2	0.321	0.337	0.265	0.329	0.400	0.380
N	$7,636$	$5,679$	$1,957$	$7,636$	$5,679$	$1,957$

Table 9: Price Profiles for Products both Exported and Sold at Home:
Plants with Five or More Products

Varieties:	Differentiated				Non-Differentiated			
# Prods.:	2+	3+	4+	5+	2+	3+	4+	5+
Top Prod.:	0.039^{***} (0.009)	0.054^{***} (0.010)	0.086^{***} (0.012)	0.095^{***} (0.014)	0.039^{***} (0.008)	0.034^{**} (0.010)	0.032^{**} (0.014)	0.052^{**} (0.018)
Top 2nd:		0.052^{***} (0.010)	0.075^{***} (0.012)	0.100^{***} (0.014)		0.026^{**} (0.011)	0.040^{**} (0.014)	0.058^{**} (0.018)
Top 3rd:			0.079^{***} (0.012)	0.105^{***} (0.014)			0.035^{**} (0.014)	0.020 (0.018)
Top 4th:				0.089^{***} (0.014)				0.035^{*} (0.018)
r^2	0.423	0.400	0.391	0.392	0.348	0.322	0.300	0.280
N	$39,718$	$34,538$	$29,502$	$24,893$	$21,697$	$17,136$	$13,189$	$9,621$

Table 10: Price Profiles for Home Sales of Exporting Plants

Market:	Home			Export		
Varieties:	All	Diff.	Non-Diff.	All	Diff.	Non-Diff.
Top Product:	0.049^{***} (0.005)	0.057^{***} (0.007)	0.035^{***} (0.006)	0.050^{***} (0.011)	0.086^{***} (0.014)	-0.013 (0.014)
r^2	0.439	0.444	0.389	0.384	0.401	0.306
N	95,881	64,720	31,161	14,690	9,896	4,794

Table 11: Price Profiles for Single-Plant Firms with Two or More Products

Market:	Home			Export		
Varieties:	All	Diff.	Non-Diff.	All	Diff.	Non-Diff.
Top Product:	0.093^{***} (0.008)	0.102^{***} (0.011)	0.071^{***} (0.012)	0.121^{***} (0.025)	0.146^{***} (0.031)	0.035 (0.036)
Top 2nd:	0.083^{***} (0.008)	0.091^{***} (0.010)	0.062^{***} (0.012)	0.160^{***} (0.025)	0.205^{***} (0.031)	0.028 (0.036)
Top 3rd:	0.081^{***} (0.008)	0.087^{***} (0.010)	0.065^{***} (0.012)	0.126^{***} (0.025)	0.176^{***} (0.032)	-0.021 (0.037)
Top 4th:	0.066^{***} (0.008)	0.067^{***} (0.010)	0.062^{***} (0.012)	0.055^{**} (0.025)	0.053^{*} (0.031)	0.042 (0.037)
r^2	0.403	0.413	0.318	0.343	0.359	0.203
N	57,579	41,576	16,003	5,600	4,229	1,371

Table 12: Price Profiles for Single-Plant Firms with Five or More Products

Market:	Home			Export		
Varieties:	All	Diff.	Non-Diff.	All	Diff.	Non-Diff.
Top Product:	0.046^{***} (0.005)	0.055^{***} (0.007)	0.033^{***} (0.005)	0.024^{**} (0.010)	0.062^{***} (0.015)	-0.028^{**} (0.013)
r^2	0.442	0.448	0.392	0.369	0.395	0.292
N	92,895	57,481	35,414	12,939	7,661	5,278

Table 13: Price Profiles for Domestically Owned Plants with Two or More Products

Market:	Home			Export		
Varieties:	All	Diff.	Non-Diff.	All	Diff.	Non-Diff.
Top Product:	0.087^{***} (0.008)	0.108^{***} (0.011)	0.045^{***} (0.010)	0.056^{**} (0.026)	0.103^{**} (0.034)	-0.035 (0.037)
Top 2nd:	0.076^{***} (0.008)	0.088^{***} (0.011)	0.035^{***} (0.010)	0.073^{**} (0.026)	0.123^{***} (0.035)	-0.023 (0.038)
Top 3rd:	0.063^{***} (0.008)	0.077^{***} (0.011)	0.035^{***} (0.010)	0.087^{***} (0.026)	0.144^{***} (0.035)	-0.022 (0.037)
Top 4th:	0.049^{***} (0.008)	0.056^{***} (0.011)	0.032^{**} (0.011)	0.045^{*} (0.026)	0.075^{**} (0.034)	-0.016 (0.038)
r^2	0.411	0.420	0.334	0.299	0.325	0.200
N	54,140	36,187	17,953	4,556	3,016	1,540

Table 14: Price Profiles for Domestically Owned Plants with Five or More Products

Market:	Home		Export	
Varieties:	Diff.	Non-Diff.	Diff.	Non-Diff.
1994:	0.050^{**} (0.021; 9,245)	0.037^{**} (0.017; 4,930)	0.066 (0.050; 1,052)	-0.012 (0.037; 549)
1995:	0.049^{**} (0.020; 8,873)	0.037^{**} (0.017; 4,754)	0.080^{*} (0.043; 1,227)	0.022 (0.039; 712)
1996:	0.072^{***} (0.020; 8,283)	0.031^{*} (0.016; 4,660)	0.034 (0.041; 1,426)	-0.075 (0.040; 850)
1997:	0.049^{**} (0.019; 7,867)	0.035^{**} (0.017; 4,506)	0.093^{**} (0.037; 1,547)	-0.050^{*} (0.027; 856)
1998:	0.046^{**} (0.021; 7,631)	0.039^{**} (0.017; 4,351)	0.105^{**} (0.040; 1,661)	0.001 (0.031; 867)
1999:	0.045^{**} (0.021; 7,325)	0.023 (0.016; 4,318)	0.052 (0.042; 1,518)	-0.038 (0.030; 837)
2000:	0.049^{**} (0.021; 7,007)	0.026 (0.016; 4,166)	0.052 (0.040; 1,440)	-0.053 (0.043; 796)
2001:	0.020 (0.021; 6,770)	0.015 (0.017; 4,027)	0.057 (0.040; 1,376)	-0.080^{**} (0.032; 741)
2002:	0.040^{*} (0.023; 6,547)	0.007 (0.017; 3,869)	0.086^{*} (0.042; 1,283)	-0.050 (0.035; 700)
2003:	0.038^{*} (0.022; 6,200)	0.036^{**} (0.017; 3,697)	0.109^{**} (0.041; 1,262)	-0.053 (0.035; 698)
2004:	0.041^{*} (0.023; 5,960)	0.044^{**} (0.018; 3,507)	0.092^{**} (0.038; 1,183)	-0.056 (0.036; 646)

Table 15: Price Profiles by Year

(Standard errors and number of observations in parentheses)