Journal of International Economics 95 (2015) 216–232

Contents lists available at ScienceDirect

Journal of International Economics

journal homepage: www.elsevier.com/locate/jie

Multi-product firms at home and away: Cost- versus quality-based competence[☆]

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ARTICLE INFO

Article history:
Received 10 December 2011
Received in revised form 27 December 2013
Accepted 18 December 2014
Available online 31 December 2014

JEL classification:
F12

Keywords:
Flexible manufacturing
Investment in product and brand quality
Multi-product firms
Quality competition

ABSTRACT

We develop a new model of multi-product firms which invest to improve the perceived quality of both their individual products and their brand. Because of flexible manufacturing, products closer to firms' core competence have lower costs, so firms 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 pattern.

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 et al. (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 behavior 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 the firms' profit-maximizing

☆ We are grateful to Gerardo Leyva and Abigail Duran for granting us access to INEGI data at the offices of INEGI in Aguascalientes subject to the commitment of complying with the confidentiality requirements set by Mexican law. We also thank Matilde Bombardini, Banu Demir, Swati Dhingra, Amit Khandelwal, Sebastian Krautheim, Kalina Manova, Monika Mrázová, Marc-Andreas Muendler, Frédéric Robert-Nicoud, Paul Segerstrom, Bob Staiger, Dan Trefler, Lotta Väänänen, Jonathan Vogel, two anonymous referees, and participants at various conferences and seminars for their valuable comments. Carsten Eckel thanks the German Science Foundation (DFG grant numbers EC 216/4-1 and SFB TR 15) for research support. Peter Neary thanks the European Research Council for funding under the EU's Seventh Framework Programme (FP7/2007–2013), ERC grant agreement no. 295669. The findings, interpretations and conclusions expressed in this paper are entirely those of the authors and do not necessarily represent the views of any institutions with which they are or have been affiliated.

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[1] A large and growing literature includes Antoniades (2009), Baldwin and Harrigan (2011), Baller (2013), Crozet et al. (2012), Demir (2012), Hallak and Schott (2011), Hallak and Sivadasan (2013), Iacovone and Javorcik (2007), Johnson (2012), Khandelwal (2010), Kneller and Yu (2008), Kugler and Verhoogen (2012), Mandel (2009), Manova and Zhang (2012), and Verhoogen (2008).

[2] Hallak and Sivadasan (2013) 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.

http://dx.doi.org/10.1016/j.jinteco.2014.12.012

decisions. Because of flexible manufacturing, products closer to a firm's core competence have lower costs. As a result, firms 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 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 higher prices, 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 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 et al. (2010, 2011), emphasizes asymmetries between products on the demand side due to exogenous stochastic factors. 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 these demand and cost approaches in an endogenous way. We extend the "flexible manufacturing" approach of Eckel and Neary (2010) by allowing costs to affect the profile of investment in quality across different varieties, and develop a model which is more in line with recent work on models of heterogeneous firms that engage in process R&D: see, for example, Bustos (2011) and Lileeva and Trefler (2010) on single-product firms, and Dhingra (2013) on multi-product firms. It is even more closely related to those papers which allow for endogenous investment in quality, such as Antoniades (2009) and Kugler and Verhoogen (2012), 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 (2010). All this work has so far focused on single-product firms only. Our specification is we believe the first to incorporate investment in quality into a model of multi-product firms, combining insights from extensive literatures in both industrial organization and marketing science. From the former, especially Stigler and Becker (1977), we take the view that firms invest in perceived quality through advertising, which enters the utility function directly in a way that is complementary to consumption itself. From the latter, notably Jacoby et al. (1971), Boush et al. (1987), and Aaker and Keller (1990), we take the view that consumers of multi-product firms are affected both by product-specific marketing and by advertising of a firm's overall brand, and that the relative effectiveness of the former is greater when products are more differentiated.

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 infinitesimal 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

[3] Examples of the first approach include Arkolakis and Muendler (2010), Berthou and Fontagné (2013), Eaton et al. (2008), and Mayer et al. (2014). Examples of the second include Bernard et al. (2011), and Goldberg et al. (2010a,b). Baldwin and Gu (2009) 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.

[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 (2008), Ju (2003), Nocke and Yeaple (2014), and Dhingra (2013).

[7] Arkolakis and Muendler (2010) and Mayer et al. (2014) apply this approach to heterogeneous-firm models of monopolistic competition with CES and quadratic preferences, respectively.

[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).

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. Finally, Section 4 summarizes our results and presents some concluding remarks. The Appendix supplements and extends the theoretical results of Section 2, and in particular shows that they extend to a Cournot oligopolistic market with heterogeneous firms.

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 Appendix B, all the results extend to a heterogeneous-firm industry in which firms engage in Cournot competition. Section 2.1 introduces our specification of preferences, while Section 2.2 briefly 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 static properties.

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 $\widetilde{\Omega}$ of differentiated products:

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

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. [9] 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 $\widetilde{z}(i)$ is the perceived quality premium attaching to an individual variety. We defer until Section 2.3 a detailed consideration of how the quality premia $\widetilde{z}(i)$ 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 is to assume 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. In either case, Eq. (1) is only one of the many sub-utility functions, corresponding to separable preferences for different groups of products. In our empirical work we will allow for the possibility that key parameters, and especially the product differentiation parameter e, may vary across markets and countries. To economize on notation we do not make this explicit in Eq. (1).

Maximization of Eq. (1) subject to the budget constraint $\int_{i\in\widetilde{\Omega}} p(i)q(i)di = I$ (where I is individual expenditure on the set of differentiated products $\widetilde{\Omega}$) 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:

$$\begin{gathered} p(i) = a(i) - \widetilde{b}[(1-e)x(i) + eX], \qquad i \in \Omega \\ \widetilde{b} \equiv \frac{b}{L} \qquad X \equiv \int_{i\in\Omega} x(i)di \qquad a(i) = a^0 + \beta\widetilde{z}(i). \end{gathered} \tag{2}$$

Here $p(i)$ is the price that consumers are willing to pay for an extra unit of variety i. This depends negatively on a weighted average of $x(i)$, 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 $\widetilde{\Omega}$, $\Omega \subset \widetilde{\Omega}$. We will show below how Ω is determined. Finally, the demand price also depends positively, through the intercept $a(i)$, on the perceived quality of the individual variety, $\widetilde{z}(i)$.

2.2. Cost-based competence

Consider next the technology and behavior 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 Eq. (1), so utility does not depend on quality. Though it is convenient to make explicit the variety-specific intercepts $a(i)$ 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:

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

Here t is a uniform trade cost payable by the firm on all the varieties it sells. The marginal cost function $c(i)$ 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.[10] More precisely, 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

[9] It is well-known that, with these preferences, firms' mark-ups depend on both marginal cost and product quality, which would not be the case in a CES preference system. In this respect, it is the CES case that is special rather than the quadratic: any preference system which generates demands that are less convex than CES demands (e.g., the Stone-Geary, CARA or translog) implies that mark-ups are increasing in sales. See Mrázová and Neary (2013) for further discussion.

[10] We assume that production costs are independent of the market served. Mayer et al. (2014) 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 et al. (2011).

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 Fig. 1.[11]

To derive the firm's behavior, 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 (Eq. (2)).[12] The first-order conditions with respect to $x(i)$ are:

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

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. [13] 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:

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

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 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 Fig. 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 Eq. (5) into the first-order condition (4) to obtain the profit-maximizing profile of prices:

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

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 $x(\delta)$.[14] All this is illustrated in Fig. 1.

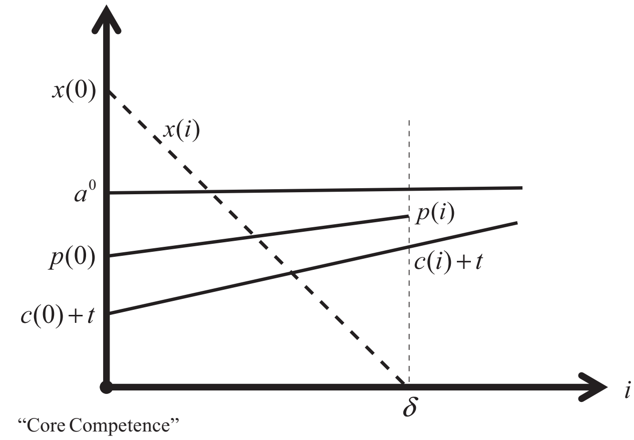

Fig. 1. Profiles of outputs, prices and costs with cost-based competence.

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:

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

Here $z(i)$ is the variety-specific component of quality, and $\overline{Z}$ is the quality of the firm's brand as a whole. In the terminology of the marketing literature, our $z(i)$ includes both "intrinsic cues", such as the physical characteristics of a product, and "extrinsic cues" such as individual, product-specific brand names, both of which influence consumers' perceptions of product quality.[15] The firm-wide parameter $\overline{Z}$ can be thought of as a "family brand" or "umbrella brand" that affects the perceived quality of all a firm's products. [16]

Our modeling of preferences and investment in perceived quality draws on previous work in both industrial organization and marketing science. Our assumption that both perceived quality and the physical quantities of goods consumed enter the utility function is consistent with the "complementary view" of advertising in the industrial organization literature. This can be traced back to Stigler and Becker (1977, p. 84), who argue that "utility depends not only on the quantity of the good but also the consumer's knowledge of its true or alleged properties" and that "the knowledge, whether real or fancied, is produced by the advertising of producers". Bagwell (2007, p. 1720) adds that a "consumer may value 'social prestige', and advertising by a firm may be an input that contributes towards the prestige that is enjoyed when the firm's product is consumed." By distinguishing between product-specific investments in perceived quality and investments in

[11] Figs. 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.

[12] 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 (Eq. (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 Eq. (4).

[13] 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.)

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

[15] See Zeithaml (1988) for definitions and an overview of the marketing literature. Examples of intrinsic cues come from Fiore and Damhorst (1992), who study how color, drape, leg shape, and pocket style affect how consumers perceive the quality of trousers.

[16] For umbrella brands, see Sullivan (1990). Examples include "Apple", with product-specific brands "iMac", "iPhone", "iPad", etc.; "Colgate", with "Total Advanced", "Max White", "SpongeBob", etc.; or "Johnson & Johnson", with "Band-Aid", "Johnson's Baby", "Listerine", etc. An example of an umbrella brand that comprises multiple non-branded products is "Nivea". For simplicity, we use the term "brand" in the text to refer only to the firm-level umbrella brand.

the quality of a firm's (umbrella) brand, we extend this framework to a multi-product setting.

As for our distinction between product- and firm-level perceived quality, and our assumption that their relative importance to the consumer varies with the degree of product differentiation, this draws on an extensive literature in marketing science. In particular, there is ample evidence that product-specific marketing has a stronger impact on perceived quality when products are more different, and that a firm's overall brand affects the perceived quality of individual varieties more if products are better substitutes. See, for example, Jacoby et al. (1971), Boush et al. (1987) and Aaker and Keller (1990). These studies justify our assumption in Eq. (7) that consumers value the variety-specific component of quality relatively more than the quality of the firm's brand, the greater the degree of product differentiation (i.e., the lower is e).[17] Note that $\overline{Z}$ is *not* equal to $\int_{i\in\Omega} z(i)di$, the aggregate of individual varieties' quality. 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.

Next, we need to specify how the components of quality $z(i)$ and $\overline{Z}$ 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. The firm can invest to enhance both the perceived quality of each of its individual varieties, as well as the perceived quality of its overall brand.[18] 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 a linear–quadratic specification for the costs of and returns to investment in quality.[19] With $k(i)$ denoting the firm's investment in the quality of variety i, we assume that the cost incurred equals $\gamma k(i)$, 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 $\Gamma\overline{K}$ and raises brand quality at a diminishing rate: $\overline{Z} = 2\Theta\overline{K}^{0.5}$. Total firm profits in the market are thus given by:

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

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:

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

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 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, $K\equiv\int_0^\delta k(i)di$, with investment in brand quality $\overline{K}$:

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

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 Eq. (9)-(ii) with the expression for outputs in Eq. (5) allows us to write the output of each variety as a function of exogenous variables and of total sales only:

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

Here, η and $\overline{\eta}$ 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. So, for example, η is higher the more consumers value quality (the higher 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 $\overline{\eta}$ cannot be too high: both $\tilde{b}-\eta(1-e)$ and $\tilde{b}-\overline{\eta}e$ must be positive from the second-order conditions for optimal choice of outputs and investment. To see the implications of Eq. (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:

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

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

[17] The linear specification of Eq. (7) simplifies the derivations but is not essential. We show in the Appendix, Section 5, that all our results go through if the quality premium is a general function of $z(i)$, $\overline{Z}$ and e, with $\tilde{z}(i)$ less responsive to $\tilde{z}(i)$ and more responsive to $\overline{Z}$ the higher is e.

[18] 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.

[19] Here we follow a large literature on process R&D in both industrial organization and trade. See for example, d'Aspremont and Jacquemin (1988), Leahy and Neary (1997), Antoniades (2009), Bustos (2011), and Dhingra (2013).

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.

Eq. (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:

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

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 Eq. (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 Fig. 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 the case of a single monopoly firm, but it is independent of the extent of competition which the firm faces. We

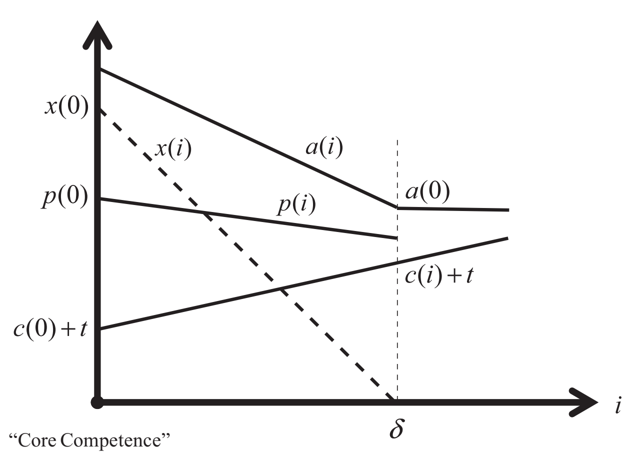

Fig. 2. Profiles of outputs, prices and costs with quality-based competence.

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 inter-firm competition affect the scale and scope of production as well as the level of investment in quality, but do not influence the within-firm profile of prices across products, which is the focus of our empirical analysis.

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 Eq. (12), the average cost of investing in the quality of each variety can be shown to equal:

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

Hence the full marginal cost equals:

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

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

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 Eq. (11) at the marginal variety $i = \delta$, recalling that $x(\delta)$ equals zero. This yields one equation in X and δ:

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

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

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

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

An increase in the marginal effectiveness of investment in brand quality, $\overline{\eta}$, 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:

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

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 $\overline{\eta}$ relative to η).[20]

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 $\eta_j = \overline{\eta}_j = 0$, so there is no investment, does an increase in market size leave the initial distribution of output across firms unchanged: $\frac{dlnX_j}{dlnL} = 1$ and $\frac{dln\delta_j}{dlnL} = 0$ for all j and for all e, $0 \le e \le 1$.

[20] We show in the Appendix, Section 5, that, with appropriate restrictions, this result continues to hold when the quality premium is a general function of $z(i)$ and $\overline{Z}$.

Table 1
Comparative statics responses.

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

3. Empirics

Our theoretical model makes a number of novel predictions about the behavior 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 subsections present the results of testing it and consider various robustness checks.

3.1. The data

We begin by reviewing the data set.[21] 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 Estadstica Geografa 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".[22] It includes information on 3183 unique products produced by over 6000 plants.[23] 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.[24]

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

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

[23] The classification system has a total of 4085 potential products. However, this includes headings entitled "Other unspecified products" and "Other non-generic products" in each *clase*. Excluding the latter, 3183 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 et al. (2010) contain approximately 1800 product codes, while the US export data used by Bernard et al. (2011) contain approximately 8000 product codes, though these include agricultural products and raw materials as well as manufactures.

[24] 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).

Table 2 shows that the number of plants in the sample varies from 6291 in 1994 to 4424 in 2004. Between 1579 and 2137 plants were engaged in exporting.[25] The decline in the number of establishments during the period under analysis is due to exit.[26] In our empirical analysis, consistent with our theoretical model, we refer to each plant-product combination as a "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 2844 in 1994 to 3118 in 2004, reaching a peak of 4193 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 et al. (2009)). The results were consistent with the model presented in Section 2, and also broadly in line with empirical patterns found in other recent studies of multi-product firms.[27] 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.

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 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 in a theory-consistent way? In our theoretical model, all goods are symmetrically differentiated, and so they are directly comparable with one another both in terms of prices and of quantities. By contrast, with real-world data, different products are measured in different units which are not directly comparable.[28] Moreover, the units may change over time, because of changes in product specification, package size, etc. To deal with these problems, we distinguish between *true* and *observed* prices. Let p_{ijt} denote the true underlying price of product i from plant j at time t, exactly as in the theoretical sections above.[29] The observed prices P_{ijt} are related to the true prices by a conversion factor $\zeta_{it}: P_{ijt}\equiv\zeta_{it}p_{ijt}$. We assume the conversion factor varies with i and t, though not with plant j. When we take logs of this identity, the conversion factor appears as a product-year fixed effect.[30] This resolves the problem of units of measurement for our left-hand side variable. As for the right-hand side, we rank products by sales value rather than volume: $s_{ijt}\equiv p_{ijt}x_{ijt}$. As we consider products further from a firm's core competence, output definitely falls but price may rise or fall as we have seen. However, as we show in Appendix C, 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. Moreover, it is a better proxy than sales volume, since it is not affected by units of measurement: whereas prices are *inflated* by the conversion factor, sales are *deflated*:

$$P_{ijt}\equiv\zeta_{it}p_{ijt},\quad X_{ijt}\equiv x_{ijt}/\zeta_{it}\quad\Rightarrow\quad s_{ijt}\equiv p_{ijt}x_{ijt}=P_{ijt}X_{ijt} \tag{20}$$

Hence, measured sales volume X_{ijt}, like measured price P_{ijt}, depends on units, but their product s_{ijt} does not.

In all the tables below, the estimating equation is therefore:

$$lnP_{ijt}=\beta_0+\sum_{r=1}^{\delta_{jt}}\beta_r D^r_{ijt}+\omega_{it}+\nu_{jt}+\varepsilon_{ijt}. \tag{21}$$

Table 2
Number of plants and products.

Year	Number of plants					Number of products	
	Total	Owned by MPFs[1]	Other	Exporters		Produced	Exported
				Total	Adjusted[2]		
1994	6291	1259	5032	1582	1579	19,154	2844
1995	6011	1245	4766	1844	1842	18,568	3406
1996	5747	1256	4491	2024	2023	17,662	3881
1997	5538	1256	4282	2138	2137	16,938	4092
1998	5380	1268	4112	2095	2094	16,419	4193
1999	5230	1279	3951	1951	1950	15,885	3889
2000	5100	1280	3820	1901	1899	15,279	3737
2001	4927	1258	3669	1770	1766	14,714	3509
2002	4765	1237	3528	1686	1684	14,182	3321
2003	4603	1193	3410	1678	1675	13,507	3282
2004	4424	1159	3265	1602	1599	12,887	3118
Total	58,016	13,690	44,326	20,271	20,248	175,195	39,272

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

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

26 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.

27 See, for example, the studies of Bernard et al. (2010) and Goldberg et al. (2010a), who look at home production by multi-product firms in the U.S. and India respectively; and of Arkolakis and Muendler (2010), Bernard et al. (2011) Berthou and Fontagné (2013), and Mayer et al. (2014) who apply models of multi-product firms similar to ours to export data for Brazil, Chile, the U.S. and France.

28 Putting this differently, the utility function written in terms of observable quantities contains unobservable product-specific weights. This issue is familiar in the CES literature: see in particular Feenstra (1994) who notes that it makes the aggregate price level unobservable, but that a Sato-Vartia true index of the change in prices between periods can nonetheless be calculated. We are not aware of any study which addresses this issue with quadratic preferences, so we hope that our approach may be of general interest.

29 In practice we measure prices throughout by unit values, equal to sales value divided by sales quantity.

30 In effect, this deflates each price by the geometric mean of the prices of all varieties of the same product produced in or exported from all Mexican plants in the same year. In earlier versions of this paper, we adopted a different approach, taking as our dependent variable the log of each price deflated by the arithmetic mean of the prices of all varieties of the same product produced or exported in the same year. (We experimented with both unweighted averages and with averages weighted by domestic or export sales.) This "price premium" approach has the advantage of greater transparency, whereas using product-year fixed effects is more conventional econometrically. Both approaches yield very similar results.

The dependent variable is the log of the unit value of product i from plant j at time t; D^r_{ijt} is a dummy variable, which equals one if product i is ranked r in the value of production or exports of plant j in year t, and zero otherwise; $\omega_{it} \equiv ln\zeta_{it}$ is a product-year fixed effect; ν_{jt} is a plant-year fixed effect; and ε_{ijt} is a stochastic error term. The product-year fixed effects control for differences between true and observed prices as already discussed; while the plant-year fixed effects control for differences in overall efficiency between plants as shown by the unit cost terms on the right-hand side of our key equation (13). We present results for a range of values of the number of products δ_{jt} produced by a plant in a given year, 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.

We wish to use estimates of Eq. (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.[31] 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.[32] We are thus able to explore how the relationship 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 Eq. (21) over different subsets of the data on all plant/product/year observations for which the plant in question sells at least five products. Each column gives the results of regressing the corresponding price on product-year and plant-year fixed effects and on dummy variables for the highest to fourth-highest selling products. Thus, in the first equation, the coefficient 0.091 gives the estimated price premium on the top-selling product in the home market relative to the average price on the excluded category of all products ranked fifth or lower in home sales. This coefficient is highly significant, indicating that, on average, the highest-selling product from each plant commands a price premium of 9.1% (i.e., exp (0.091)-1). This provides strong evidence of quality-based competence, in the sense in which we have used the term in our theoretical model.

The other coefficients in this equation are also highly significant, and fall steadily in size, again confirming a pattern of quality-based competence. 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 product equal to 0.162 and highly significant, the coefficients on the next two not significantly different from that of the top-selling product, and all three significantly greater than the last coefficient, for the top fourth-selling product.

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, each coefficient for differentiated products is significantly greater than the corresponding coefficient for non-differentiated ones, exactly as our theory predicts.[33] This difference between the two categories of products is repeated but to an even more striking extent in the export market, as the fifth and sixth equations show. The top three coefficients for differentiated exports are all highly significant and significantly larger than in the home market, implying even higher price premia for the top-selling products in this category. By contrast, the coefficients on the top four non-differentiated export products are all negative, implying that these products exhibit cost-based rather than quality-based competence.

Table 3
Price profiles for all plants selling five or more products.

Market:	Home			Export		
Varieties:	All	Diff.	Non-diff.	All	Diff.	Non-diff.
	(1)	(2)	(3)	(4)	(5)	(6)
Top product	0.091***	0.109***	0.031***	0.162***	0.205***	−0.138*
	[0.010]	[0.013]	[0.012]	[0.058]	[0.063]	[0.071]
Top 2nd	0.072***	0.097***	0.001	0.179***	0.223***	−0.072
	[0.009]	[0.012]	[0.010]	[0.063]	[0.074]	[0.062]
Top 3rd	0.064***	0.077***	0.021**	0.178***	0.237***	−0.132**
	[0.009]	[0.011]	[0.010]	[0.052]	[0.059]	[0.059]
Top 4th	0.058***	0.069***	0.024***	0.059	0.076	−0.100*
	[0.009]	[0.011]	[0.009]	[0.053]	[0.062]	[0.054]
R^2	0.972	0.970	0.976	0.978	0.976	0.990
N	73,154	52,878	20,276	8932	6720	2212

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

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 $\hat{\beta}_r^{DX}$ is the estimated coefficient of the dummy variable for the differentiated product of rank r in the export market, etc. 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. As for differences across markets, the 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. The significant negative coefficients for the top non-differentiated export products shows that Mexican firms find it harder to build up brand recognition in these markets, and so are compelled to compete on cost rather than quality.

So far we have only considered the subset of firms selling five or more products. Tables 4–7 extend the analysis to observations in which the same plant sold at least two, three or four products in the one year. In each equation the residual category is all products with ranks lower than the lowest-ranking dummy variable included, and the final equation is repeated for reference from Table 3. The advantage of focusing on plants that export fewer than five products is a considerable increase in degrees of freedom, and the results are qualitatively similar to those in Table 3.

[31] Our results are robust to excluding reference-priced goods from the sample.

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

[33] For example, the difference between the coefficients 0.109 and 0.031 in the second and third equations is significant at the 10% level. The corresponding differences in Tables 4 to 7 below are larger and considerably more significant.

Table 4
Price profiles at home: differentiated products.

Market	Home			
Plants with	2+ products	3+ products	4+ products	5+ products
Top product	0.040***	0.072***	0.091***	0.109***
	[0.008]	[0.010]	[0.011]	[0.013]
Top 2nd		0.059***	0.076***	0.097***
		[0.009]	[0.010]	[0.012]
Top 3rd			0.055***	0.077***
			[0.010]	[0.011]
Top 4th				0.069***
				[0.011]
R^2	0.973	0.971	0.970	0.970
N	82,506	72,682	62,218	52,878

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

Table 6
Price profiles away: differentiated products.

Market	Export			
Plants with	2+ products	3+ products	4+ products	5+ products
Top product	0.082***	0.123***	0.177***	0.205***
	[0.031]	[0.044]	[0.055]	[0.063]
Top 2nd		0.061	0.142**	0.223***
		[0.043]	[0.059]	[0.074]
Top 3rd			0.171***	0.237***
			[0.050]	[0.059]
Top 4th				0.076
				[0.062]
R^2	0.985	0.982	0.979	0.976
N	14,975	11,528	8812	6720

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

Tables 4 and 5 confirm that the pattern of quality-based competition which Table 3 showed for plants selling five or more products on the home market also applies to plants selling fewer products. For differentiated products, Table 4 shows that the implied price premium for the top product ranges from 4.1% when all plants producing two or more products are included, to 11.5% when only those producing five or more are included. In Table 5 the corresponding figures are 3.9% and 3.1%, showing once again that non-differentiated products exhibit significantly less quality-based competition than differentiated ones, as our theory predicts. Also of considerable interest is that the pattern of prices falling with a product's rank which was found in Table 3 continues to hold for the larger samples of plants selling fewer products. Not only are most coefficients of the dummy variables for second- and lower-ranking products in these equations significantly different from zero, but there is a clear and in many cases significant downward trend in the coefficients in each column. 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 the price profile of exports in differentiated sectors is qualitatively similar to that 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 price premium for the top product ranges from 8.5% when all plants producing two or more products are included, to 22.8% when only those producing five or more are included, compared with 4.1% and 11.5% respectively in Table 4.

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 the overall pattern is one of increasing coefficients as we move down each column. Unlike Tables 4, 5 and 6, this provides strong evidence against quality-based competence, and suggestive 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 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 tend to 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 Eq. (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 behavior very different from that predicted by our model; for example, that plants sell different products in the home and foreign markets, or

Table 5
Price profiles at home: non-differentiated products.

Market	Home			
Plants with	2+ products	3+ products	4+ products	5+ products
Top product	0.038***	0.024***	0.023**	0.031***
	[0.007]	[0.008]	[0.010]	[0.012]
Top 2nd		0.001	0.006	0.001
		[0.007]	[0.009]	[0.010]
Top 3rd			0.019**	0.021**
			[0.008]	[0.010]
Top 4th				0.024***
				[0.009]
R^2	0.984	0.979	0.978	0.976
N	41,698	33,878	26,661	20,276

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

Table 7
Price profiles away: non-differentiated products.

Market	Export			
Plants with	2+ products	3+ products	4+ products	5+ products
Top product	−0.018	−0.001	−0.049	−0.138*
	[0.030]	[0.037]	[0.052]	[0.071]
Top 2nd		0.032	0.009	−0.072
		[0.033]	[0.046]	[0.062]
Top 3rd			−0.016	−0.132**
			[0.040]	[0.059]
Top 4th				−0.100*
				[0.054]
R^2	0.994	0.993	0.991	0.990
N	7354	5131	3365	2212

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

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. We also present results for various subsets of the data, including firms with only a single plant and plants that are either domestically- or foreign-owned.

Table 8 addresses 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, so the numbers of observations are the same at home and abroad. It can be seen that the conclusions drawn from the earlier tables survive this robustness check. There is clear evidence of quality-based competition in differentiated products in both home and foreign markets, and this contrasts with the absence of a pattern in the coefficients for non-differentiated products. Even in the latter case, the size and sign of the coefficients, though not their significance, are consistent with those from the larger samples in Table 3. We can conclude that the evidence from this smaller sample is less overwhelmingly in support of different behavior 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 strong in both domestic and export markets.

Table 9 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, home sales of differentiated products exhibit quality-based competence, while those of non-differentiated products do not. Bearing in mind that the plants in Table 9 are identical to those whose exporting behavior is shown in Tables 6 and 7, our earlier conclusions are reinforced. Exporting plants in differentiated sectors exhibit quality-based competence in the home market, whereas those in non-differentiated sectors do not, so the very different behavior 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 ignores 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.[34]

Table 10 gives the results of this robustness check, for single-plant firms selling at least five products. The evidence for quality-based competence remains very strong for both categories of home sales and for differentiated exports. For these three categories, most coefficients are highly significant, 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 is weaker than in earlier tables, though the hypothesis that these sales exhibit quality-based competence is strongly rejected. We can conclude that our earlier results are robust to excluding plants owned by multi-plant firms in 2003.

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

Table 8
Price profiles for products both exported and sold at home: plants with five or more products.

Market	Home			Export		
Varieties	All	Diff.	Non-diff.	All	Diff.	Non-diff.
Top product	0.186***	0.208***	0.015	0.188***	0.217***	−0.129
	[0.061]	[0.066]	[0.091]	[0.064]	[0.066]	[0.092]
Top 2nd	0.171***	0.198***	−0.024	0.213***	0.236***	−0.015
	[0.063]	[0.069]	[0.090]	[0.071]	[0.077]	[0.086]
Top 3rd	0.204***	0.232***	0.016	0.188***	0.228***	−0.110
	[0.057]	[0.062]	[0.088]	[0.057]	[0.062]	[0.069]
Top 4th	0.010	0.009	−0.043	0.073	0.087	−0.099
	[0.060]	[0.067]	[0.062]	[0.061]	[0.066]	[0.069]
R^2	0.980	0.979	0.993	0.975	0.973	0.992
N	7399	5708	1691	7399	5708	1691

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

A final concern we address is whether our specification is more applicable to Mexican-owned plants or to foreign-owned ones. On the one hand, 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, at least for sales in their export markets, and perhaps in their home market too. This would suggest that the considerations we have highlighted in our theoretical model should apply more to Mexican-owned plants. On the other hand, we would expect multinational companies to have stronger world brands and so to exhibit more quality-based competence in all markets. It seems appropriate therefore to check whether the results hold when we consider the two groups of plants separately. Tables 11 and 12 show that the pattern summarized in Eq. (22) continues to hold for both groups of plants, though there are interesting differences between them. First, domestically-owned plants have almost flat price profiles in export markets, showing that even in differentiated sectors these plants do not compete on quality, though the results suggest that non-differentiated exports come closer to exhibiting cost-based competence. Second, foreign-owned plants compete strongly on quality even in the home market, as we might expect, leveraging their superior brands even in non-differentiated sectors. But they too compete more on cost in export non-differentiated sectors, showing that their exports of these goods do not command quality premia. Overall, the broad pattern from previous tables is confirmed for both groups of plants, and is most pronounced for foreign-owned plants.

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 behavior 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 endogenizes 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

Table 9
Price profiles for home sales of exporting plants.

Market	Home							
Varieties	Differentiated				Non-differentiated			
Top product:	0.033**	0.068***	0.104***	0.131***	0.017	0.000	−0.011	−0.018
	[0.014]	[0.017]	[0.020]	[0.023]	[0.014]	[0.018]	[0.022]	[0.026]
Top 2nd:		0.054***	0.078***	0.118***		0.024	0.03	−0.007
		[0.016]	[0.019]	[0.022]		[0.019]	[0.022]	[0.025]
Top 3rd:			0.085***	0.111***			0.011	−0.016
			[0.018]	[0.021]			[0.019]	[0.023]
Top 4th:				0.105***				−0.001
				[0.023]				[0.024]
R^2	0.976	0.974	0.972	0.971	0.986	0.982	0.983	0.982
N	40,068	34,869	29,812	25,168	18,924	14,627	10,936	7769

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

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. We prove these results in the text for the case of a single multi-product firm, and show in the Appendix that they also hold in an oligopolistic model with heterogeneous firms.

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 behavior 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 behavior at plant level too. Finally, the patterns we have found are exhibited by both home-owned and foreign-owned plants. We can 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.

Turning to policy, a full consideration of the costs and benefits of different export-promotion strategies is beyond the scope of this paper. Nevertheless, our results are suggestive. Export-promotion policies take a variety of forms, and in the light of our results we can distinguish between those that focus on cost and those that focus on quality. The former type of intervention includes measures to stimulate investment in cost-saving technologies and worker training. The latter type of intervention includes marketing campaigns to stress the

Table 10
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:	0.103***	0.116***	0.049***	0.191**	0.210**	−0.042
	[0.012]	[0.015]	[0.015]	[0.087]	[0.090]	[0.132]
Top 2nd:	0.077***	0.095***	0.015	0.236**	0.281***	−0.105
	[0.011]	[0.013]	[0.013]	[0.097]	[0.105]	[0.108]
Top 3rd:	0.076***	0.086***	0.037***	0.192**	0.232***	−0.147
	[0.010]	[0.013]	[0.013]	[0.077]	[0.081]	[0.109]
Top 4th:	0.066***	0.076***	0.030**	0.083	0.092	−0.035
	[0.010]	[0.012]	[0.012]	[0.076]	[0.081]	[0.109]
R^2	0.974	0.971	0.978	0.983	0.981	0.995
N	55,480	42,103	13,377	5327	4229	1098

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

Table 11
Price profiles for domestically-owned plants with five or more products.

Market	Home			Export		
Varieties	All	Diff.	Non-diff.	All	Diff.	Non-diff.
Top product:	0.087***	0.109***	0.025**	−0.032	−0.016	−0.094
	[0.011]	[0.015]	[0.012]	[0.125]	[0.151]	[0.128]
Top 2nd:	0.057***	0.079***	0.002	0.011	0.013	−0.031
	[0.010]	[0.014]	[0.011]	[0.098]	[0.128]	[0.106]
Top 3rd:	0.053***	0.066***	0.018*	0.076	0.151	−0.142
	[0.010]	[0.013]	[0.011]	[0.083]	[0.100]	[0.093]
Top 4th:	0.053***	0.062***	0.027***	−0.02	0.007	−0.106
	[0.009]	[0.012]	[0.010]	[0.088]	[0.108]	[0.096]
R^2	0.976	0.972	0.978	0.991	0.989	0.995
N	51,850	36,653	15,197	4308	3016	1292

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

Table 12
Price profiles for foreign-owned plants with five or more products.

Market	Home			Export		
Varieties	All	Diff.	Non-diff.	All	Diff.	Non-diff.
Top product:	0.142***	0.147***	0.126	0.232**	0.255**	−0.243
	[0.044]	[0.046]	[0.081]	[0.110]	[0.107]	[0.347]
Top 2nd:	0.174***	0.180***	0.138	0.293**	0.317**	−0.046
	[0.046]	[0.048]	[0.094]	[0.129]	[0.131]	[0.172]
Top 3rd:	0.134***	0.111**	0.305***	0.223**	0.237**	0.022
	[0.045]	[0.046]	[0.115]	[0.100]	[0.101]	[0.189]
Top 4th:	0.100*	0.106**	0.063	0.036	0.03	0.008
	[0.051]	[0.054]	[0.083]	[0.120]	[0.120]	[0.222]
R^2	0.951	0.946	0.986	0.961	0.959	0.993
N	10,448	8514	1934	3048	2489	559

***, **, and * denote coefficients that are significant at the 1%, 5%, and 10% levels, respectively; all regressions have product-year and plant-year fixed effects; and figures in parentheses are standard errors which are clustered by plant-year.

advantages of national products, and reductions in the costs of quality certifications (e.g. ISO 9000 or 14000) to improve the producer's image. Without further research, it would be premature to suggest that, in the light of our findings, export-promotion efforts in middle-income countries such as Mexico should focus on helping producers to lower production costs in non-differentiated-good sectors and on improving perceived product quality in differentiated-good sectors. Nevertheless, our findings that Mexican firms compete in foreign markets on either cost or quality, depending on whether they operate in relatively homogeneous or relatively differentiated-good sectors, suggest that a "one-size-fits-all" policy may not be the most effective way of promoting exports.

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.

Appendix A. General functional form for the quality premium

In the text we use a specific linear form for the relation between the quality premium $\tilde{z}(i)$ and the two components of quality, the variety-specific component of quality $z(i)$, and the quality of the firm's brand $\overline{Z}$. In this appendix, we show that our results also hold for a more general functional form of the quality premium.

The quality premium $\tilde{z}(i)$ is now given by the following function ζ:

$$\tilde{z}(i) = \zeta\left[z(i), \overline{Z}, e\right], \qquad e \in (0, 1). \tag{23}$$

We assume that this function ζ has the following properties: $\zeta_z\left[z(i), \overline{Z}, e\right] \equiv \frac{\partial \zeta}{\partial z(i)} > 0$, $\zeta_Z\left[z(i), \overline{Z}, e\right] \equiv \frac{\partial \tilde{z}(i)}{\partial \overline{Z}} > 0$, $\zeta_{ze}\left[z(i), \overline{Z}, e\right] \equiv \frac{\partial^2 \tilde{z}(i)}{\partial z(i) \partial e} < 0$ and $\zeta_{Ze}\left[z(i), \overline{Z}, e\right] \equiv \frac{\partial^2 \tilde{z}(i)}{\partial \overline{Z} \partial e} > 0$. Clearly, the perceived quality premium must be increasing in both components of quality, so that the first derivatives of ζ with respect to $z(i)$ and $\overline{Z}$ must be positive. In addition, we assume that the responsiveness of the quality premium with respect to the variety-specific component is decreasing in e while its responsiveness with respect to the brand quality is increasing in e. These additional properties are based on our considerations in the paragraphs following Eq. (7).

Given Eq. (23), the first order conditions for the firm's optimal choice of investment in quality are now

$$\text{(i) } \gamma k(i)^{0.5} = \beta \zeta_z\left[z(i), \overline{Z}, e\right] \theta x(i), \qquad i \in [0, \delta] \qquad \text{and} \tag{24}$$
$$\text{(ii) } \Gamma \overline{K}^{0.5} = \beta \zeta_Z\left[z(i), \overline{Z}, e\right] \Theta X$$

and the optimal levels of $z(i)$ and $\overline{Z}$ are given implicitly by

$$\text{(i) } z(i) = 2\theta^2 \frac{\beta}{\gamma} \zeta_z\left[z(i), \overline{Z}, e\right] x(i), \qquad i \in [0, \delta] \qquad \text{and} \tag{25}$$
$$\text{(ii) } \overline{Z} = 2\Theta^2 \frac{\beta}{\Gamma} \zeta_Z\left[z(i), \overline{Z}, e\right] X.$$

Together with the expression for individual outputs

$$2\tilde{b}(1-e)x(i) = a^0 + \beta \zeta\left[z(i), \overline{Z}, e\right] - c(i) - t - 2\tilde{b}eX \tag{26}$$

and the definition of firm output $X = \int_0^\delta x(i)di$, these four equations determine simultaneously $z(i)$, $\overline{Z}$, $x(i)$, and X.

The price profile $p'(i) \equiv \partial p(i)/\partial i$ can be calculated from the price equation $p(i) = c(i) + t + \tilde{b}(1-e)x(i) + \tilde{b}eX$

$$p'(i) = c'(i) + \tilde{b}(1-e)x'(i), \tag{27}$$

where $x'(i) \equiv \partial x(i)/\partial i$ can be calculated from Eqs. (26) and (25)-(i) as

$$x'(i) = -\frac{c'(i)}{2\tilde{b}(1-e) - 2\eta \zeta_z\left[z(i), \overline{Z}, e\right]^2} < 0. \tag{28}$$

As in the main text, $\eta \equiv \frac{\beta^2 \theta^2}{\gamma}$ $\left(\text{and } \overline{\eta} \equiv \frac{\beta^2 \Theta^2}{\Gamma}\right)$, and we require that $\tilde{b}(1-e) > \eta \zeta_z\left[z(i), \overline{Z}, e\right]^2$ (second order conditions).

Eqs. (27) and (28) yield

$$p'(i) = \frac{\tilde{b}(1-e) - 2\eta \zeta_z\left[z(i), \overline{Z}, e\right]^2}{2\tilde{b}(1-e) - 2\eta \zeta_z\left[z(i), \overline{Z}, e\right]^2} c'(i). \tag{29}$$

The condition for a negative price profile ("quality-based competence") is now

$$\frac{\tilde{b}}{2\eta} < \frac{\zeta_z\left[z(i), \overline{Z}, e\right]^2}{(1-e)}. \tag{30}$$

For Corollary 1 (iii) to hold, we now require that the right-hand side of Eq. (30) is decreasing in e. It is a necessary condition that $\zeta_{ze}\left[z(i), \overline{Z}, e\right] < 0$. The necessary and sufficient condition is

$$2\zeta_{ze}\left[z(i), \overline{Z}, e\right] \frac{e}{\zeta_z\left[z(i), \overline{Z}, e\right]} < -\frac{e}{(1-e)}. \tag{31}$$

The expression on the left hand side of Eq. (31) is the elasticity of ζ_z^2 with respect to e. On the right hand side we have the elasticity of $\partial p(i)/\partial x(i)$ (from Eq. (2)) with respect to e. A decrease in e (products are more differentiated) has two effects on the price profile. Because products are weaker substitutes, larger outputs of individual varieties have a stronger impact on their prices. This tends to accentuate the negative relation between outputs and prices, and can be measured by the elasticity $\partial p(i)/\partial x(i)$ with respect to e. The second effect comes from the investment behavior. A decrease in e makes perceived quality more responsive to variety-specific quality ($\zeta_{ze} < 0$), and this boosts investment in $z(i)$. This effect is more pronounced for larger outputs, and thus tends to reverse the relation between outputs and prices. It is this second effect that drives our result of a "quality-based competence" price profile. Therefore, we require that this quality effect dominate the price elasticity effect. In our linear case, where $\zeta_z = 1 - e$ and $\zeta_{ze} = -1$, condition (31) is always fulfilled.

In addition to the slope of the price profile, the functional form of $\widetilde{z}(i)$ also matters for the ambiguous result of the impact of an increase in the market size on scope in Eq. (19). With the more general functional form used here this equation changes to

$$\frac{d\delta}{dL} \propto \overline{\eta}\frac{\zeta_Z\left[z(i),\overline{Z},e\right]^2}{e} - \eta\frac{\zeta_Z\left[z(i),\overline{Z},e\right]^2}{(1-e)}. \tag{32}$$

Here, our result with respect to the degree of product differentiation, that more varieties are sold in a larger market, the less products are differentiated, continues to hold if $\zeta_Z\left[z(i),\overline{Z},e\right]^2/(1-e)$ is decreasing in e and if $\zeta_Z\left[z(i),\overline{Z},e\right]^2/e$ is increasing in e. The first condition is discussed above, and the second condition holds if $2\zeta_{Ze}\frac{e}{\zeta_Z}>1$. Again, the left-hand side is the relative change in the responsiveness of perceived quality (with respect to $\overline{Z}$), and the right-hand side is the elasticity of $\partial p(i)/\partial X$ with respect to e. The economic intuition is similar. If goods are less differentiated, the firm invests more in brand quality, and this tends to increase demand for marginal products. At the same time, aggregate output rises, and this tends to depress output of the marginal variety because of the cannibalization effect. We assume that the quality effect dominates.

Appendix B. 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, $\overline{m}$, 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 $\overline{M}$ 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: $c_j(i),\ j = 1, \ldots, \overline{m}$. The utility function is unchanged from Eq. (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 Eq. (2), except that total consumption is now $Y = \sum_{j\in\overline{M}} X_j$.

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

$$x_j(i) = \frac{a_j(i) - c_j(i) - t_j - \widetilde{b}eX_j - \widetilde{b}eY}{2\widetilde{b}(1-e)} \quad i \in \Omega_j,\ \ j \in \overline{M} \tag{33}$$

where $\Omega_j = \{0,\ldots, \delta_j\}$ 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 Eq. (9).[35] Substituting these into $a_j(i)$ and proceeding as in the text gives, instead of Eq. (12):

$$x_j(i) = \frac{c_j\left(\delta_j\right) - c_j(i)}{2\left[\widetilde{b} - \eta_j(1-e)\right](1-e)}, \quad i \in \left[0, \delta_j\right],\ \ j \in \overline{M}. \tag{34}$$

This in turn leads to an equation for prices just like Eq. (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 $\widetilde{b} > \eta_j(1-e)$, independent of the number of firms m and m^*.

Consider next the comparative statics of an initial equilibrium. We seek a set of $\overline{m}$ equations, one per firm, which relate changes in the total output of each firm, X_j, to changes in exogenous variables $\chi = \left(\eta_j, \overline{\eta}_j, L, t\right)$. 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 Eq. (34) to get:

$$X_j = \frac{\phi_j\left(\delta_j\right)}{2\left[\widetilde{b} - \eta_j(1-e)\right](1-e)}, \quad \phi_j\left(\delta_j\right) \equiv \int_0^{\delta_j}\left[c_j\left(\delta_j\right) - c_j(i)\right]di,\ \ j \in \overline{M}. \tag{35}$$

To obtain a second equation linking X_j and δ_j, evaluate Eq. (33) at $i = \delta_j$ to obtain:

$$\begin{aligned} c_j\left(\delta_j\right) &= a_j\left(\delta_j\right) - t_j - \widetilde{b}eX_j - \widetilde{b}eY \\ &= a_j^0 - t_j - \left(\widetilde{b} - 2\overline{\eta}_j e\right)eX_j - \widetilde{b}eY \quad j \in \overline{M}. \end{aligned} \tag{36}$$

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

To proceed, first totally differentiate Eqs. (35) and (36):

$$dX_j = \frac{1}{2\left[\widetilde{b} - \eta_j(1-e)\right](1-e)}\left[\delta_j c_j'\left(\delta_j\right)d\delta_j + 2\frac{\widetilde{b}}{L}(1-e)X_j dL + 2(1-e)^2 X_j d\eta_j\right] \tag{37}$$

$$c_j'\left(\delta_j\right)d\delta_j = -dt_j - \left(\widetilde{b} - 2\overline{\eta}_j e\right)edX_j - \widetilde{b}edY - \frac{\widetilde{b}}{L}e\left(X_j + Y\right)dL + 2e^2 X_j d\overline{\eta}_j. \tag{38}$$

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:

$$A_j^{-1}dX_j + \widetilde{b}edY = d\chi_j \tag{39}$$

where:

$$A_j^{-1} \equiv \frac{1}{\delta_j}\left[2\left\{\widetilde{b} - \eta_j(1-e)\right\}(1-e) + \left(\widetilde{b} - 2\overline{\eta}_j e\right)e\delta_j\right] \tag{40}$$

and

$$d\chi_j \equiv -dt_j + \frac{\widetilde{b}}{L}\left[2(1-e)\frac{X_j}{\delta_j} + e\left(X_j + Y\right)\right]dL + \frac{2}{\delta_j}(1-e)^2 X_j d\eta_j + 2e^2 X_j d\overline{\eta}_j \tag{41}$$

$d\chi_j$ is a composite term summarizing the exogenous shocks to firm j's reaction function. Solving these $\overline{m}$ reaction functions (Eq. (39)) allows

[35] 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.

us to derive the comparative statics effects of changes in the exogenous variables.

To solve Eq. (39), we follow Dixit (1986). Multiply Eq. (39) by A_j, sum the reaction functions over all $\overline{m}$ firms, and collect terms to solve for total output Y:

$$dY = \frac{\sum_{j'} A_{j'} d\chi_{j'}}{1 + \widetilde{b}e \sum_{j'} A_{j'}}. \tag{42}$$

Next, substitute into Eq. (39) to solve for the change in the output of an individual firm:

$$\begin{aligned} dX_j &= A_j d\chi_j - A_j \widetilde{b}e \frac{\sum_{j'} A_{j'} d\chi_{j'}}{1 + \widetilde{b}e \sum_{j'} A_{j'}} \\ &= \frac{A_j}{1 + \widetilde{b}e \sum_{j'} A_{j'}} \left[d\chi_j + \widetilde{b}e \sum_{j'} A_{j'} \left(d\chi_j - d\chi_{j'} \right) \right]. \end{aligned} \tag{43}$$

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.

B.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 Eq. (43) the effect of a foreign tariff on the output of a foreign import-competing firm is:

$$dX_j = A_j \frac{\widetilde{b}e \sum_{j' \in M} A_{j'}}{1 + \widetilde{b}e \sum_{j'} A_{j'}} dt > 0, \quad j \in M^*. \tag{44}$$

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:

$$dX_j = -A_j \frac{1 + \widetilde{b}e \sum_{j' \in M*} A_{j'}}{1 + \widetilde{b}e \sum_{j'} A_{j'}} dt < 0, \quad j \in M. \tag{45}$$

Hence a reduction in foreign trade barriers raises the export sales of all home firms. From Eq. (35), 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.

B.2. Effects of the marginal effectiveness of brand-enhancing investment

In this case we have $d\chi_{j'} = 2e^2 X_j d\overline{\eta}_j, \ j' = j$ and $d\chi_{j'} = 0, \ j' \neq j$. Hence from Eq. (43):

$$dX_j = 2e^2 A_j \frac{1 + \widetilde{b}e \sum_{j' \neq j} A_j -}{1 + \widetilde{b}e \sum_{j'} A_{j'} -} X_j d\overline{\eta}_j > 0. \tag{46}$$

As for firm j's scope, it follows immediately from Eq. (35) that it too must rise. By contrast, both scale and scope of all other firms must fall.

B.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 Eq. (43):

$$dX_j = 2(1-e)^2 \frac{A_j}{\delta_j} \frac{1 + \widetilde{b}e \sum_{j' \neq j} A_j -}{1 + \widetilde{b}e \sum_{j'} A_{j'} -} X_j d\eta_j > 0. \tag{47}$$

It also follows immediately that the output of all other firms must fall. As for the implications for scope, substituting dX_j into Eq. (37) yields:

$$d\delta_j = \left[2\left\{ \widetilde{b} - \eta_j(1-e) \right\}(1-e) \frac{A_j}{\delta_j} \frac{1 + \widetilde{b}e \sum_{j' \neq j} A_j -}{1 + \widetilde{b}e \sum_{j'} A_{j'} -} - 1 \right] \frac{2(1-e)^2 X_j}{\delta_j c_j'\left(\delta_j\right)} d\eta_j. \tag{48}$$

Substituting for $\frac{A_j}{\delta_j}$ from Eq. (40), this becomes:

$$d\delta_j = -\left[1 - \frac{2\left\{ \widetilde{b} - \eta_j(1-e) \right\}(1-e)}{2\left\{ \widetilde{b} - \eta_j(1-e) \right\}(1-e) + \left(\widetilde{b} - 2\overline{\eta}_j e \right) e\delta_j} \frac{1 + \widetilde{b}e \sum_{j' \neq j} A_{j'}}{1 + \widetilde{b}e \sum_{j'} A_{j'}} \right] \frac{2(1-e)^2 X_j}{\delta_j c_j'\left(\delta_j\right)} d\eta_j. \tag{49}$$

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.

B.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 Eq. (41) into Eq. (43) gives:

$$\begin{aligned} \frac{dX_j}{dlnL} = \frac{\widetilde{b}A_j}{1 + \widetilde{b}e\Sigma_{j'} A_{j'}} &\left[\left\{ 2(1-e)\frac{X_j}{\delta_j} + e\left(X_j + Y \right) \right\} \right. \\ &\left. + \widetilde{b}e\Sigma_{j'} A_{j'} \left\{ 2(1-e)\left(\frac{X_j}{\delta_j} - \frac{X_{j'}}{\delta_{j'}} \right) + e\left(X_j - X_{j'} \right) \right\} \right]. \end{aligned} \tag{50}$$

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, Eq. (50) becomes: $\frac{dX_j}{dlnL} = \frac{A_j}{1 + \widetilde{b}\Sigma_{j'} A_{j'}} \left[X_j + Y + \widetilde{b}\Sigma_{j'} A_{j'} \left(X_j - X_{j'} \right) \right] \widetilde{b}$, with $A_j^{-1} = \widetilde{b} - 2\overline{\eta}_j$. Though simpler than Eq. (50), 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:

$$\frac{dlnX}{dlnL} = \frac{\{2(1-e) + (\overline{m}+1)e\delta\}\widetilde{b}}{2\left\{ \widetilde{b} - \eta(1-e) \right\}(1-e) + \left\{ (\overline{m}+1)\widetilde{b} - 2\overline{\eta}e \right\} e\delta}. \tag{51}$$

This is greater than one provided either η or $\overline{\eta}$ is strictly positive, so firms engage in either or both type of investment. Finally, when firms are heterogeneous but do not invest, because $\eta_j = \overline{\eta}_j = 0$, Eq. (50) reduces to $\frac{dlnX_j}{dlnL} = 1$.

Turning to the effect on scope, Eq. (38) can be rewritten to give:

$$\frac{dln\delta_j}{dlnL} = \frac{1}{E_j} \left[\frac{dlnX_j}{dlnL} - \frac{\widetilde{b}}{\widetilde{b} - \eta_j(1-e)} \right] \tag{52}$$

where $E_j \equiv \frac{\delta_j \phi'_j(\delta_j)}{\phi_j(\delta_j)} = \frac{\delta_j^2 c'_j(\delta_j)}{\phi_j(\delta_j)}$ 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 $\eta_j = \overline{\eta}_j = 0$, so firms do not invest, scope is independent of market size, $\frac{dln\delta_j}{dlnL} = 0$, as noted in Eckel and Neary (2010), Proposition 13. As for the case where firms are symmetric, Eq. (52) reduces to:

$$\frac{dln\delta}{dlnL} = \frac{\widetilde{b}e\delta}{E} \frac{2\overline{\eta}e - (\overline{m}+1)\eta(1-e)}{\left[2\left\{\widetilde{b} - \eta(1-e)\right\}(1-e) + \left\{(\overline{m}+1)\widetilde{b} - 2\overline{\eta}e\right\}e\delta\right]\left\{\widetilde{b} - \eta(1-e)\right\}}. \tag{53}$$

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 $\overline{\eta}e - \eta(1-e)$, the case discussed in the text.

Appendix C. 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 $s(i)$:

$$\frac{ds(i)}{di} = p(i)\frac{dx(i)}{di} + x(i)\frac{dp(i)}{di} \tag{54}$$

The derivatives of $p(i)$ and $x(i)$ with respect to i can be found by differentiating Eqs. (13) and (11). Substituting this and $p(i) = c(i) + t + \widetilde{b}[(1-e)x(i) + eX]$ from the first-order condition for output (4) gives:

$$\frac{ds(i)}{di} = -\frac{c(i) + t + 2\eta(1-e)^2 x(i) + \widetilde{b}eX}{2\left[\widetilde{b} - \eta(1-e)\right](1-e)} \frac{dc(i)}{di} < 0. \tag{55}$$

Since $c(i)$ rises with i it follows that sales value must fall with distance from the firm's core competence. Finally, dividing $dp(i)/di$ from Eq. (13) by Eq. (55) we obtain:

$$\frac{dp(i)}{ds(i)} = -\frac{(1-e)\left[\widetilde{b} - 2\eta(1-e)\right]}{c(i) + t + 2\eta(1-e)^2 x(i) + \widetilde{b}eX}. \tag{56}$$

This equation shows that prices are related to sales value according to the sign of the term $\widetilde{b} - 2\eta(1-e)$.

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