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A B S T R A C T

We consider a high-quality dominant firm facing a low-quality competitive fringe. We show that the dominant firm’s quantity is (weakly) increasing in its quality if and only if its marginal cost (weakly) exceeds that of the fringe; otherwise it is strictly decreasing in quality. This result is driven by the fact that a quality increase causes the marginal revenue curve to rotate clockwise, rather than shift outwards, and at a height equal to the fringe firms’ marginal cost. This fact, combined with the dominant firm’s MR = MC condition, determines the result. For closely related reasons, the effect of a quality increase on consumer welfare also depends on the relationship between the costs. It is possible that all consumers are (weakly) better off, that some are better off and some worse off, or that all are (weakly) worse off. We also consider several extensions and variations of the model.

1. Introduction

In this paper, we consider a high-quality dominant firm facing a low-quality competitive fringe. We follow standard practice and assume that the fringe firms are price takers characterized by marginal cost pricing, while the dominant firm is strategic and behaves as a monopolist with respect to the residual demand. Using the canonical model of consumer preferences for vertically differentiated products, we consider the comparative statics effect of an increase in the quality of the dominant firm’s product on its equilibrium quantity.

The main insight of the paper is that this effect depends on the marginal cost of the dominant firm relative to that of the fringe firms. The dominant firm’s output increases in its quality when its cost exceeds that of the fringe, is independent of its quality when the marginal costs are equal, and decreases in its quality when the dominant firm’s cost is lower than that of the fringe. What is surprising about this result is that higher quality may cause the dominant firm’s quantity to decrease, but rather that under this standard model, it must cause quantity to decrease whenever the high-quality firm is the low-cost producer.

The driving force behind our main result is that an increase in the dominant firm’s product quality leads to a larger increase in willingness-to-pay for consumers who had higher initial willingness-to-pay, i.e., it does not cause a parallel shift in its residual demand, but rather causes demand to pivot. This pivoting of the dominant firm’s demand causes its marginal revenue curve to rotate clockwise (rather than shift outwards) at a height that we show to be equal to the fringe firms’ (common) marginal cost. When the dominant firm’s marginal cost is above that of the fringe, the intersection of the dominant firm’s marginal revenue and marginal cost moves to the right, leading to an increase in output. When the two marginal costs are the same, the intersection of the dominant firm’s marginal cost and marginal revenue is the point of rotation, and output remains unchanged. Finally, when the marginal cost of the dominant firm is below that of the fringe, the intersection of the dominant firm’s marginal revenue and marginal cost moves to the left, leading to a reduction in

1 A high-quality producer may co-exist with a low-quality/high-cost fringe, because even though it could drive the fringe out of the market by charging a low price, it makes higher profits from a higher price and fewer sales.

2 In a very contrived environment, obtaining such a result can be trivial. For example, suppose a monopolist optimally sells to half of the potential consumers. Next suppose that the willingness-to-pay of consumers in the top quartile of the demand goes up by a large amount, \( L \), while the willingness-to-pay of the remaining consumers goes up a small amount, \( s \). For a sufficiently high value of \( L \), the monopolist will raise his price and serve only the consumers in the top quartile of demand. The results of this paper are much more broadly applicable.
output. To put it another way, a pivoting of the residual demand around a point that is sufficiently high decreases the elasticity of demand to such an extent that the profit-maximizing level of output is reduced.

The effect of an increase in the dominant firm’s quality on consumer welfare is closely related to its effect on quantity. If the dominant firm’s output increases, then (by revealed preference) the utility of the consumers who switched from the fringe to the dominant firm’s product must be better off (since the utility from buying from the fringe is unchanged). The consumers who would buy the dominant firm’s product prior to the quality increase must also be better off, regardless of the relative cost structure. In fact, depending on the curvature of the demand curve, it is possible that all consumers who purchase from the dominant firm become worse off. Interestingly, a quality increase of the product offered by the fringe firms not only increases aggregate consumer welfare, but it makes all consumers strictly better off, regardless of the relative cost structure.

Some markets are in fact characterized by a dominant firm selling a high-quality product competing with a number of much smaller rivals that sell a lower quality product but have equal or higher costs. Indeed, this is often the reason for a firm’s market dominance. Good examples include innovative consumer electronics such as the iPad tablet computer. It has attributes that make most consumers prefer it, but these attributes are not the result of Apple’s use of higher cost inputs. Rather, they reflect Apple’s higher levels of R&D and other factors that contribute to the appeal of its brand. The iPad’s primary competition is with Amazon’s Kindle Fire. It seems some of the mainstream Android vendors are finally beginning to grasp a fact that Amazon, B&N, and Pandigital figured out early on. Namely, to compete in the media tablet market with Apple, they must offer their products at notably lower price points.... Google will enter the market first quarter of 2012, its share of the tablet market was 68% (see the IDC, a leading business information source for the computer industry, at http://www.idc.com/getdoc.jsp?containerId=prU523466712). See the IDC press release referenced above: “It seems some of the mainstream Android vendors are finally beginning to grasp a fact that Amazon, B&N, and Pandigital figured out early on. Namely, to compete in the media tablet market with Apple, they must offer their products at notably lower price points.... Google will enter the market with an inexpensive, co-branded ASUS tablet designed to compete directly on price with Amazon’s Kindle Fire.”

assumptions about consumer preferences. We also discuss an extension in which the dominant firm can offer multiple products with different qualities. Finally, to highlight the mechanism that makes our main result work, we also consider an alternative set of consumer preferences under which it no longer generally holds. However, even in the latter case, the effect that we identify in the baseline model is still present and may still predominate.

There is a substantial literature dealing with competition between firms whose products are vertically differentiated by quality. Key early papers in the literature include Gabszewicz and Thisse (1979) and Shaked and Sutton (1983) which show that, unlike in models of horizontal differentiation, the number of firms in the industry does not generally get arbitrarily large as fixed costs approach zero. This literature provides the vertical quality differentiation framework that we use in this paper.

Another paper that is relevant to ours is Johnson and Myatt (2006). That paper explores the effects of demand “rotation,” by which the authors mean a change in a product’s attributes (or in consumer perception of those attributes) that makes some consumers like the product more and others like it less, or alternatively that widen the product’s appeal but at the cost of making it less attractive to enthusiasts. The paper then analyzes when it is profitable for firms to induce such rotations. Unlike their model, ours is one of pure vertical differentiation; all consumers value a high-quality product more than a low-quality product, but they differ in how much more.

Our paper is also very closely related to the literature on the effect of market structure on prices in markets with horizontal differentiation. Specifically, Rosenthal (1980), Chen and Riordan (2007, 2008) and Zacharias (2009), show that an increase in the number of firms can lead to higher equilibrium prices, and might even reduce consumer surplus. For example, a product that is newly introduced by an entrant is likely more attractive to potential consumers who do not value the incumbent’s product very highly relative to potential consumers who do. This has the effect of making the incumbent’s demand less elastic (it becomes “concentrated” on the customers who value its product the most) and this effect can be so large as to actually increase price. The same intuition applies to comparative statics across market structures with different numbers of firms. In our paper, the market and demand structure are different, but ultimately, the mechanism that leads to increased prices and lower quantities (by the dominant firm in our model) is the same: the increase in the dominant firm’s quality decreases that firm’s demand elasticity to the point that it more than counteracts the “standard” effect that quantity goes up with quality.

2. The baseline model

2.1. Modeling environment

Consider a standard vertically differentiated product category, in which a product is fully described by a single important attribute, that we refer to as “quality.” This could be capacity (for the case of jump drives, RAM memory, or hard-drives), speed (for computing devices), fuel efficiency (for heaters and furnaces), the perceived therapeutic value of a drug, battery life for a hand-held portable device, etc. In these cases, the product attribute is essential, i.e., its complete absence from a product would make that product worthless to all consumers. In other cases, the attribute may be important but not essential, and a product without it remains functional. For example, the resolution of a cell-phone camera may be valuable but not essential as cell-phones

3 In the first quarter of 2012, its share of the tablet market was 68% (see the IDC, a leading business information source for the computer industry, at http://www.idc.com/getdoc.jsp?containerId=prU523466712). See the IDC press release referenced above: “It seems some of the mainstream Android vendors are finally beginning to grasp a fact that Amazon, B&N, and Pandigital figured out early on. Namely, to compete in the media tablet market with Apple, they must offer their products at notably lower price points.... Google will enter the market with an inexpensive, co-branded ASUS tablet designed to compete directly on price with Amazon’s Kindle Fire.”

5 Subsequent papers develop this idea further. Choi and Shin (1992) consider whether the high- and low-quality firms will between them “cover the market”: Lehmann-Grube (1997) and Motta (1993) analyze the case where providing quality is costly. Frascatore (1999) considers the case where the inputs necessary to produce a higher quality product are in fixed supply and so must be competed for. Noh and Moschini (2006) analyze how quality might be strategically chosen to deter entry.
with no camera (zero resolution) are of positive value because they are capable of making phone calls. The product attribute takes on a numerical value, where a higher value means that the product is more desirable.\(^6\) There is a unit mass of consumers, who differ in the marginal willingness-to-pay for the attribute. In particular, the preferences of consumer \(i\) for product \(j\) are described by the indirect utility function

\[
U_{ij} = V_i + \theta_i g(x_{ij}) - P_j, \tag{1}
\]

where \(V_i\) is the willingness of consumer \(i\) to pay for the product in the absence of the attribute, \(\theta_i\) is the marginal willingness of consumer \(i\) to pay for a unit increase in the attribute, \(x_{ij}\) is the value of the attribute for product \(i\), \(g(\cdot)\) is a continuously differentiable and monotonically increasing function, and \(P_j\) is the price of product \(j\). \(V_i\) is distributed with some (possibly degenerate) marginal distribution \(W(V)\) on the interval \([V_{\min}, V_{\max}]\) (note that in most other papers on vertical differentiation, the value of \(V\) is uniformly distributed with marginal distribution \(W(V)\) on the interval \([0, 1]\)).\(^7\) The parameter \(\theta_i\) is distributed with marginal distribution \(H(\theta)\) with support \([\theta_{\min}, \theta_{\max}]\). The value of \(\theta_{\min}\) could be as low as 0, while the value of \(\theta_{\max}\) could be arbitrarily high. The dispersion in \(\theta\) could be driven by differences in consumer income or by differences in preferences.\(^8\) The correlation or joint distribution of \(V_i\) and \(\theta_i\) need not be specified as it has no bearing on the results. In what follows, we never compute the profit-maximizing level of the product attribute. Rather, we consider the effect of changes in that level regardless of the source of the change, whether exogenous or endogenous, as long as they don’t affect the firm’s marginal cost.\(^9\) Consumers have the option of making no purchase and earning a utility of zero.

A dominant firm sells a product of quality \(x_D\), and faces a perfectly competitive fringe which sells products of a lower quality \(x_F\) at a price equal to their (constant and common) marginal cost \(c_F\).\(^10\) In what follows, we analyze the effect of a change in the dominant firm’s quality \(x_D\), holding its cost \(c_D\) constant. This change can be thought of temporally, with the dominant firm starting at an initial quality level and then improving it, or non-temporally, comparing a dominant firm with a particular quality level to an alternative situation in which its quality is higher. We do not consider simultaneous changes in production costs and the product attribute for the simple reason that the partial effect of increases in the dominant firm’s marginal cost is well understood and always leads to reduced output. By holding production costs fixed and isolating the effect of increased quality on output, we pinpoint the existence of a solely demand-induced effect, and show that the sign of this effect depends on the relationship between \(c_D\) and \(c_F\). We now turn to the derivation of the market equilibrium and the comparative statics.

2.2. The effect of higher dominant firm quality on output

Denote the dominant firm’s price by \(P_D\). Given that the price of the competitive fringe is equal to the marginal cost \(c_F\), the critical value \(\theta_i\) such that the corresponding consumer is indifferent between purchasing from the dominant firm and purchasing from the competitive fringe is

\[
V_i + \theta_i g(x_{ij}) - c_F = V_i + \theta_i g(x_D) - P_D \Rightarrow \theta_i(g(x_D) - g(x_{ij})) = P_D - c_F \Rightarrow \theta_i = \frac{P_D - c_F}{g(x_D) - g(x_{ij})}. \tag{2}
\]

Note that the value of \(V_i\) does not affect which variant of the product is chosen by consumers as long as, for any value of \(V_i\), the consumers for whom \(\theta_i = \theta_i\) strictly prefer purchasing either of the two variants to purchasing neither. A sufficient condition for this is:

**Assumption 1.** The solution \(P_D^*\) to the dominant-firm’s profit maximization problem satisfies the conditions \(\frac{c_D - c_F}{\partial x_D} > \frac{\theta_{\min}}{\theta_{\max}}\) and \(\frac{\theta_{\max}}{\theta_{\min}} > \theta_{\min}\).

Note that if the first inequality in Assumption 1 is satisfied for \(V_i = V_{\min}\) it is also satisfied for all higher values of \(V_i\). Also note that Assumption 1 implies that the fringe has a positive market share for consumers of every value of \(V_i\). Assuming that these conditions are met, the demand function of the dominant firm is equal to

\[
Q_D = 1 - H\left(\frac{\theta_{\max}}{\theta_{\min}}\right), \tag{11}
\]

and the dominant firm chooses \(P_D\) to maximize

\[
\pi = (P_D - c_F)\left(1 - H\left(\frac{\theta_{\max}}{\theta_{\min}}\right)\right). \tag{11}
\]

Rather than solve this maximization problem, we find that it provides more insight to recast the problem as one of optimal choice of output; the two approaches are equivalent since the dominant firm is the only strategic player and there is a one-to-one mapping between its price and the quantity it sells. Solving the (residual) demand function of the dominant firm for \(P_D\) yields the inverse demand function

\[
P_D = c_F + \left(g(x_D) - g(x_F)\right)H^{-1}(1 - Q_D). \tag{3}
\]

Note that the demand intercept is \(c_F + \left(g(x_D) - g(x_F)\right)\theta_{\max}\) and is increasing in \(x_D\). We assume that the marginal revenue \(MR_D\) function associated with this demand function is differentiable and monotonically decreasing, i.e., that \(H^{-1}(1 - Q_D) = \frac{Q_D}{Q_D + \frac{\theta_{\max}}{\theta_{\min}} - \frac{\theta_{\max}}{\theta_{\min}}}\) is monotonically decreasing in \(Q_D\). As discussed in more detail below, an increase in \(x_D\) causes the residual inverse demand curve to pivot clockwise about some point. This pivoting of the inverse demand curve causes the MR\(_D\) curve to rotate clockwise, because the demand intercept increases and

\[
\text{To see that the equilibrium can entail co-existence of a low-cost dominant firm with a high-cost fringe, consider the following example. Suppose } g(\cdot) \text{ is the identity function, } H(\cdot) \text{ is uniform on the } [0, 1] \text{ interval, and } \Psi(\cdot) \text{ is degenerate with } \Psi(0) = 0. \text{ Profit maximization by the dominant firm results in } P_D = (x_D - x_F + c_D + c_F)/2. \text{ The condition that } H^{-1}(1 - Q_D) = \frac{Q_D}{Q_D + \frac{\theta_{\max}}{\theta_{\min}} - \frac{\theta_{\max}}{\theta_{\min}}} \text{ is satisfied if } Q_D < \frac{\theta_{\max}}{\theta_{\min}}. \text{ The value of } H(\cdot) \text{ at which a consumer is indifferent between purchasing from the fringe and not purchasing at all is } \theta_i = c_F/x_F. \text{ If } x_D = 2 \text{ and } x_F = 1, \text{ then } \theta_i > \theta_D, \text{ and thus the fringe has positive output as long as } c_F > (1 + c_F)/3, \text{ i.e., if the cost disadvantage of the fringe is not too high.}
\]
the demand slope gets steeper.\footnote{12} Moreover, the height of the rotation point of the MRD curve is the fringe marginal cost $c_F$.

**Lemma 1.** An increase in the dominant firm’s product quality, $Q_D$, causes a rotation of its marginal revenue curve. The height of the rotation point is equal to $c_F$. Marginal revenue is increasing in $x_D$ for output levels to the left of the rotation point and decreasing in $x_D$ for output levels to the right.

**Proof.** Multiplying the RHS of Eq. (3) by $Q_D$ and differentiating, we obtain marginal revenue

$$MR_D = c_F + \left[ g(x_D) - g(x_F) \right] \left[ H^{-1}(1-Q_D) + Q_D \frac{dH^{-1}(1-Q_D)}{dQ_D} \right]. \tag{4}$$

Note that

$$\frac{\partial MR_D}{\partial Q_D} = g'(x_D) \left[ H^{-1}(1-Q_D) + Q_D \frac{dH^{-1}(1-Q_D)}{dQ_D} \right]. \tag{5}$$

Since $MR_D$ is assumed to be decreasing in $Q_D$, the expression in brackets is decreasing in $Q_D$. Thus $\frac{\partial MR_D}{\partial Q_D}$ is also decreasing in $Q_D$, since $g'(x_D) > 0$. Moreover, $\frac{\partial MR_D}{\partial Q_D}$ is decreasing in $x_D$, by the property of the equality of cross-partial derivatives, $\frac{\partial^2}{\partial x_D \partial Q_D} = \frac{\partial^2}{\partial Q_D \partial x_D}$. Substituting Eq. (5) back into Eq. (4) gives

$$MR_D = c_F + \frac{g'(x_D) - g'(x_F)}{g'(x_D)} \frac{\partial MR_D}{\partial Q_D}. \tag{6}$$

Since the quantity at which $MR_D$ rotates satisfies $\frac{\partial}{\partial Q_D} = 0$, we see that the height of the point about which $MR_D$ rotates is equal to $c_F$. Since $\frac{\partial}{\partial Q_D} = 1$ at the output level that corresponds to $MR_D = c_F$ and since $\frac{\partial}{\partial Q_D}$ is decreasing in $Q_D$, $MR_D$ is constant in $x_D$ for the output level that corresponds to $MR_D = c_F$, is increasing in $x_D$ for lower values of $Q_D$, and is decreasing in $x_D$ for higher values of $Q_D$. \(\square\)

We now turn to the main question of interest. How does the dominant firm’s quantity depend on the quality of its product? One might expect that it would go up. This is indeed the result obtained in models with horizontal product differentiation and consumers who value quality equally (e.g., Deltas et al., 2013). But in our framework, this result does not necessarily hold. Rather the effect depends on the relationship between the dominant firm’s marginal cost and that of the fringe firms, as our main result below states.

**Proposition 1.** Holding costs constant, the equilibrium output of the dominant firm is decreasing in its product quality, $x_D$, when $c_D < c_F$, is invariant to $x_D$ when $c_D = c_F$, and is increasing in $x_D$ when $c_D > c_F$.

**Proof.** The dominant firm’s profit-maximizing quantity, $Q_D^*$, is determined by the intersection of $MR_D$ and $c_F$ (its marginal cost). Denote by $Q_D$ the output that corresponds to the intersection of $MR_D$ with $c_F$ (the fringe firms’ marginal cost). Given that $MR_D$ is downward sloping, both $Q_D$ and $Q_D^*$ define unique output levels. Lemma 1 shows that $Q_D$ is invariant to $x_D$. When $c_D = c_F$, $Q_D = Q_D^*$, and thus $Q_D^*$ is also invariant to $x_D$. Since $MR_D$ is assumed to be decreasing in $Q_D$, $c_D < c_F$ implies that $Q_D^* > Q_D$. Lemma 1 shows that to the right of $Q_D$, $MR_D$ is increasing in $x_D$, which implies that its intersection with $c_D$ must move to the left when $x_D$ increases, decreasing $Q_D^*$. Analogous reasoning for the case where $c_D > c_F$ shows that, in that case, when $x_D$ increases, $Q_D^*$ also increases.\footnote{13} \(\square\)

A simple way to see the intuition behind our main result is as follows. Suppose for the moment that $\theta_{MIN} > 0$ and $\theta_{MIN} = 0$, so that there is some consumer who does not value quality at all and every consumer buys some version of the product. In this case the residual inverse demand faced by the dominant firm is determined by how much consumers value a product of quality $Q_D$ when the alternative is to buy (from the fringe) a product of quality $x_F$ at a price $c_F$. Any consumer for whom $\theta > 0$ will have a willingness-to-pay for the dominant firm’s product higher than $c_F$, but a consumer for whom $\theta = 0$ will have a willingness-to-pay equal to $c_F$. This consumer regards both products as equally good, and so is willing to pay $c_F$ for the dominant firm’s product when the alternative is to buy from the fringe at $c_F$. An increase in the dominant firm’s quality from $x_D$ to $x_F$ causes the residual inverse demand curve faced by the dominant firm to pivot, not to shift parallel, because the increase in each consumer’s willingness-to-pay depends on how much they value quality. Defining $Q$ as the quantity corresponding to a consumer for whom $\theta = 0$, the increase in quality causes the dominant firm’s inverse demand curve to pivot about the point $(Q, c_F)$.\footnote{14} This is depicted in Fig. 1, in which the distribution of $\theta$ is uniform. Lemma 1 above shows that the height of the rotation point of the $MR_D$ curve is also $c_F$, which is indicated in Fig. 1 and leads directly to the result in Proposition 1.

As discussed above, the demand curves in Fig. 1 represent consumers’ willingness-to-pay for the dominant firm’s product when the alternative is to buy from the fringe at a price of $c_F$. That is, they implicitly assume that all consumers buy some version of the product. But this depiction is merely to make the figure easier to interpret. The actual assumption made in Assumption 1 only guarantees that all consumers who are relevant to the dominant firm’s problem buy some version of the product. At some quantity greater than the profit-maximizing quantity, the correct demand may be one that represents the willingness-to-pay for the dominant firm’s product when the alternative faced by some of the firm’s marginal consumers (or, when $V_i = V$ for every $i$, by the marginal consumer) is to not buy the product at all. In that case, beyond the quantity level where the no purchase option becomes relevant, the true demand curve is lower than the “notional” demand curve (where all consumers buy a version of the product). The figure simply ignores the possibility of not buying either product, because including this would add clutter without aiding intuition, given that any reduction of the demand at quantity levels to the right of the profit-maximizing output is irrelevant to the dominant firm’s problem.

2.3. Relating the results to elasticity changes: A recast in terms of demand for quality

Ultimately, changes in price markups and associated changes in quantity are always related to changes in elasticities. In our setting, when a dominant firm competes with a fringe, an increase in the quality of the dominant firm’s product causes demand to pivot and decreases the demand elasticity (makes demand more inelastic), thus increasing the optimal markup. When the marginal cost of the dominant firm is below that of the fringe, the increase in the optimal markup is so high that equilibrium output falls. In this section, we

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\footnote{12} We use the term “pivot” to describe the effect on demand, and the term “rotate” to describe the effect on $MR_D$. Though both terms describe a clockwise rotational movement, the former refers to a movement in which all price-quantity points move outward (or stay fixed), while the latter refers to a movement in which some price-quantity points move outward while others move inwards (with one point remaining fixed). The relationship between the demand pivot point and the $MR_D$ rotation point will prove important in what follows.

\footnote{13} A brute force proof of this result based on the first-order condition of profit maximization with respect to price was used in earlier versions of the paper. To show how this approach works, we use it in the proof of Proposition 3.

\footnote{14} Given our assumption that the mass of consumers is normalized to 1, if $\theta_{MIN} = 0$ then $Q_D = Q_D^*$ – 1. Note that if zero were not in the support of $\theta$, $Q_D^*$ would be obtained from a demand that would result from hypothetically assuming the existence of consumers with $\theta = 0$ and extrapolating the demand to that value of $\theta$. We emphasize that the model does not assume the existence of a consumer who does not care about quality. Hypothesizing such a consumer is merely a pedagogical device to illustrate the idea that the demand curve pivots rather than shifts.
describe our main results in terms of demand elasticity, by recasting the demand in terms of (incremental) product quality. In this formulation, the difference between the price of the dominant firm and that of the fringe is the “price” of quality, and the difference in the two marginal costs is the “cost” of quality. Unlike in the standard monopoly case where the monopolist sells to consumers whose outside option is to get nothing and pay nothing, here the dominant firm is viewed as a monopolist selling to consumers whose outside option is to get a base product at a price equal to marginal cost. We are indebted to a referee for pointing out that the problem can be viewed in this way, and that additional insight can be gained by doing so.

As a starting point, we begin with the dominant firm’s MR = MC condition, \(\partial P_D / \partial Q_D = \partial P_F / \partial Q_F\); by subtracting \(c_F\) from both sides and recalling that \(P_F = c_F\), this condition becomes \(\partial P_D / \partial Q_D = \partial P_F / \partial Q_F = c_F - c_F = \partial Q_D / \partial P_D\). Define \(\Delta P = P_D - P_F\) as the “quality premium” charged by the dominant firm and \(\Delta c = c_F - c_F\) as the marginal cost of producing quality. We then have \(\epsilon_{Q_D} \Delta P + \Delta P = \Delta c\) which can be written as

\[
\Delta P \left(1 + \frac{1}{\epsilon_{Q_D} \Delta P}\right) = \Delta c, \tag{7}
\]

where \(\epsilon_{Q_D} \Delta P = \partial Q_D / \partial P_D\) is the elasticity of demand for quality, i.e., the elasticity of demand for the high-quality good with respect to the quality premium. It will prove relevant that, for a given dominant firm quantity, the elasticity \(\epsilon_{Q_D} \Delta P\) is independent of \(x_D\). We show this next. In the proof of Lemma 1 above we showed that

\[
P_D = P_F + [g(x_D) - g(x_F)]H^{-1}(1 - Q_D), \tag{8}
\]

which with some limited manipulation yields

\[
\Delta P = [g(x_D) - g(x_F)]H^{-1}(1 - Q_D) \rightarrow \Delta c, \tag{9}
\]

\[
Q_D = 1 - H \left(\frac{\Delta P}{g(x_D) - g(x_F)}\right) \tag{10}
\]

The derivative of \(Q_D\) with respect to \(\Delta P\) is given by

\[
\frac{\partial Q_D}{\partial \Delta P} = -f \left(\frac{g(x_F)}{g(x_D) - g(x_F)}\right) \tag{11}
\]

Multiplying by \(\Delta P\), substituting using the expression in Eq. (9), and dividing by \(Q_D\), we obtain the elasticity of demand for quality \(\epsilon_{Q_D} \Delta P\) as

\[
\epsilon_{Q_D} \Delta P = \frac{-f \left(\frac{g(x_F)}{g(x_D) - g(x_F)}\right) H^{-1}(1 - Q_D)}{Q_D} \tag{12}
\]

\[
= -\frac{h(\theta_1)H^{-1}(1 - Q_D)}{Q_D} \tag{13}
\]

\[
= \frac{h(H^{-1}(1 - Q_D))^{-1}}{Q_D} \tag{14}
\]

This expression depends on \(x_D\) only indirectly, through the effect of \(x_D\) on \(Q_D\). Moreover, given that the dominant firm’s profit function is assumed to have a unique local maximum, \(\epsilon_{Q_D} \Delta P\) is increasing in \(Q_D\), i.e., Eq. (14) is invertible and each value of \(\epsilon_{Q_D} \Delta P\) corresponds to a unique value of \(Q_D\).

Using these results, our main finding can be seen by examining the expression in Eq. (7). If \(\Delta c = 0\), then for any value of \(x_D\), the dominant firm chooses its quantity such that \(\epsilon_{Q_D} \Delta P = -1\). Eq. (14) above shows that this quantity is the same for any level of quality. When \(\Delta c > 0\), the expression inside the parentheses in Eq. (7) is negative (i.e., \(\epsilon_{Q_D} \Delta P > -1\)), since by assumption \(\Delta P > 0\). An increase in quality at the original quantity leads to an increase in the dominant firm’s price, i.e., \(\Delta P\) goes up. The left-hand side of Eq. (7) now becomes smaller than the right-hand side (recall both sides are negative). A decrease in elasticity (away from zero) will be required so that the product on the left-hand side stays equal to \(\Delta c\), which means quantity must fall. The same idea works in the opposite direction when \(\Delta c > 0\).

3. Consumer surplus and total welfare

Typically, quality increases are good for consumers and for total welfare. In our model, however, the welfare effect depends on the relationship between \(c_F\) and \(c_F\) for reasons closely related to those discussed above. Specifically, as we show below, higher quality makes all consumers better off when the dominant firm’s marginal cost is equal to or higher than that of the fringe. But when the marginal cost of the dominant firm is lower than that of the fringe, the opposite may, surprisingly, be true. We first analyze this “paradoxical” case, before turning to the “normal” case. In particular, we consider the welfare effects of an increase in the quality of the dominant firm’s product from \(x_D\) to \(x_D’\) when \(c_F < c_F\) with associated equilibrium prices of \(P_D\) and \(P_F\), starting with evaluation of the consumer surplus. Since each consumer has three possible choices (buy nothing, buy from the fringe, buy from the dominant firm) both before and after the quality increase, there are nine choice pair possibilities. Given our assumptions, five of these nine can be ruled out.\(^{16}\)

16 There are no consumers who don’t buy at all before the quality increase and buy from the fringe after, or the reverse, because the increase in the quality of the dominant firm’s product does not affect the utility of either of these choices. There are also no consumers who don’t buy at all before and buy from the dominant firm after, or who buy from the fringe before and from the dominant firm after, because our main result shows that the quality increase causes quantity to (weakly) decrease. Finally, there are no consumers who buy from the dominant firm before and don’t buy at all after, because under Assumption 1 those who purchase from the dominant firm prefer the fringe’s product to not buying at all.
is unchanged. Second are consumers with values of \( \theta \) such that \( \theta_i \leq \frac{c_{fi} - c_{QD}}{g(x_{QD}) - g(x_f)} \). These consumers buy the product from the fringe both before and after the increase in the quality of the dominant firm’s product. Since the fringe’s price and quality are unaffected by the dominant firm’s quality increase, the welfare of these consumers is unaffected as well. Third are consumers with values of \( \theta_i \in \left( \frac{c_{fi} - c_{QD}}{g(x_{QD}) - g(x_f)}, \frac{c_{fi} - c_{QD}}{g(x_{QD})} \right) \). These consumers buy from the dominant firm before the quality increase, but switch to the fringe after it. Since the utility of consuming the fringe’s product did not change, by revealed preference these consumers must be worse off following the quality improvement. Fourth are consumers for whom \( \theta_i > \frac{c_{fi} - c_{QD}}{g(x_{QD})} \). These consumers buy the high-quality product both before and after the quality improvement. They can be divided into two sub-types. The first sub-type consists of consumers with values of \( \theta_i \) such that \( \frac{c_{fi} - c_{QD}}{g(x_{QD})} > \theta_i > \frac{c_{fi} - c_{QD}}{g(x_{QD})} - \frac{b_{fi}}{g(x_{QD}) - g(x_f)} \) (where \( \hat{b}_{fi} \) satisfies \( \hat{b}_{fi}g(x_{QD}) - P_{fi} = \theta_i g(x_f) - P_{fi} \) and represents the consumer who values quality just enough to be equally well off before and after the quality increase), i.e., \( \theta_i \in \left( \frac{c_{fi} - c_{QD}}{g(x_{QD})} - \frac{b_{fi}}{g(x_{QD}) - g(x_f)}, \frac{c_{fi} - c_{QD}}{g(x_{QD})} \right) \). These consumers suffer a reduction in their utility as they value the quality improvement less than the price increase. The second sub-type consists of individuals for whom \( \theta_i > \frac{c_{fi} - c_{QD}}{g(x_{QD})} \), i.e., \( \theta_i \in \left( \frac{c_{fi} - c_{QD}}{g(x_{QD})}, \theta_{\text{MAX}} \right) \). These consumers are made better off by the quality improvement.\(^{18}\)

Therefore, the effect of the quality increase on total consumer surplus when \( c_{QD} < c_f \) is ambiguous: the gains to consumers with the highest values of \( \theta_i \) may be larger or smaller than the losses to those with lower values.\(^{19}\) The effect of the quality increase on total consumer surplus will depend on whether \( H(\cdot) \) has a fat or a thin tail above \( \theta_i \). Note that the set of consumers for whom \( \theta_i > \theta_i \) may be empty. This is because \( P_{fi} \) does not depend on the support of the shape of \( H(\cdot) \) above \( \frac{c_{fi} - c_{QD}}{g(x_{QD})} \), and so \( \theta_{\text{MAX}} \) could be bigger or smaller than \( \hat{b}_{fi} \). If \( \theta_i > \theta_{\text{MAX}} \), then all consumers are made weakly worse off by the quality increase.

Now consider the case where \( c_{QD} = c_f \), under which there is no change in equilibrium quantity. A consumer purchases the dominant firm’s product at the new quality and price if and only if he or she would purchase it at the old quality and price. For the marginal consumer at the initial price and quality, the effect of the higher price and higher quality cancel out. Thus, the marginal consumer is not only indifferent between buying from the fringe or the dominant firm, but also experiences no utility change from the quality increase, i.e., \( \hat{\theta}_i = \theta_i = \theta_i \). All inframarginal consumers are better off, since they are subject to the same price change but value the quality increase by more. Similarly, when \( c_{QD} > c_f \), the quantity sold by the dominant firm goes up at the expense of the quantity sold by the fringe. Following the reasoning above, it is easy to see that all consumers who are purchasing from the dominant firm following the change in quality become better off, while the welfare of all the other consumers is unchanged.

The quality increase has no effect on fringe producers, as they earn zero profits both before and after it. It increases the profits of the dominant firm: that firm could have kept the price unchanged, leading to increased profits since at the original price its quantity would increase (recall that marginal cost is the same). But the dominant firm chooses to raise the price, which means that a price increase leads to a further increase in its profits. In sum, the effect on total welfare is ambiguous when \( c_{QD} < c_f \), and is definitely positive when \( c_{QD} \geq c_f \).

At this point, it is instructive to briefly contrast these results with the effects of an exogenous and costless improvement in the quality of the fringe firms’ product. Such a quality improvement raises the surplus of every consumer, because: (i) it increases the value of the fringe product without increasing its price, since that price is equal to marginal cost; and (ii) it decreases the price of the dominant firm’s product without decreasing its value, since its residual demand shift in and becomes flatter.\(^{20}\) Thus, both options that consumers face result in higher surplus to them.\(^{21}\)

4. Discussion and extensions

The most natural extension to our model would be to allow all firms to be strategic, rather than assuming a non-strategic competitive fringe. We did not pursue this extension because a small amount of strategic interaction (e.g., supported by a small amount of differentiation among the fringe firms) will not materially affect our results. In what follows, we take up other more meaningful extensions.

4.1. Increasing marginal cost

The baseline version of the model assumes that all firms have constant marginal costs. This is an analytically convenient assumption and makes it easier to compare the dominant firm’s marginal cost with that of the fringe. However, our results do not hinge on it. In this section, we allow the (differentiable) marginal cost functions of the dominant firm, \( c_{fi}(Q_{fi}) \), and of the fringe, \( c_{fi}(Q_{fi}) \), to be weakly increasing in output. Note that Assumption 1 guarantees that any change in the output of the dominant firm is offset one-for-one by a change in the output of the fringe. Thus, changes in \( Q_{fi} \) do not affect total industry output \( Q \). In this setting, an increase in the dominant firm’s quality still causes its residual demand to pivot and its MRD function to rotate. But now

\[^{18}\text{Our assumptions, including the assumption that } c_{QD} < c_f \text{, ensure that these thresholds are ranked as in Fig. 2.}\]

\[^{19}\text{For example, assume } \theta \text{ has a density of 1 on } [0,u] \text{ where } u \leq 1 \text{ and there is a mass point with mass } 1-u \text{ at } \theta = u. \text{ One can show that in this case the effects on consumer surplus can be of either sign depending on } u. \text{ For } u \text{ low enough, no consumer is better off from the quality increase. Note that if } u = 1 \text{ the distribution becomes } U[0,1], \text{ in which case total consumer surplus unambiguously increases.}\]

\[^{20}\text{The quality improvement of the fringe’s product from } x_f \text{ to } x_{QD} \text{ increases the willingness of consumers to pay for it by } \left( g(x_{QD}) - g(x_f) \right). \text{ The residual demand of the dominant firm is shifted downwards by this same amount, and thus becomes flatter since high } \theta \text{ consumers are those with the highest willingness-to-pay for the dominant firm’s product.}\]

\[^{21}\text{These observations are not sufficient to sign the total welfare effects of a quality improvement to the fringe’s product. Consumers who switch from the dominant firm’s product to the fringe’s product gain in consumer surplus, but their switch to the fringe reduces the dominant firm’s profits (recall that fringe firms have zero profit since they price at marginal cost). Indeed, the utility of the marginal consumer who switches to the fringe will increase by a very small amount, but the dominant firm’s profits from selling to that consumer fall by a discrete amount.}\]
instead of the height of the MR\textsubscript{D} rotation point being equal to the fringe firms’ marginal cost, it is strictly below it if \(c_f(\cdot)\) is strictly increasing, as Lemma 2 shows.

**Lemma 2.** When the marginal cost functions are increasing, an increase in the product quality of the dominant firm, \(x_D\), causes a rotation of the marginal revenue curve, with the height of the rotation point equal to \(c_f(Q_f) - Q_f c'_f(Q_f) < c_f(Q_d)\). Marginal revenue is increasing in \(x_D\) for output levels to the left of the rotation point and decreasing in \(x_D\) for output levels to the right.

**Proof.** Following derivations made prior to Lemma 1, it is straightforward to show that when marginal costs are increasing, Eq. (3) becomes

\[
P_D = c_f(Q_f) + (g(x_D) - g(x_D))H^{-1}(1 - Q_D).
\]

Using the fact that \(Q_f = Q - Q_f\), multiplying both sides by \(Q_f\), and differentiating with respect to \(Q_f\), we obtain the marginal revenue function of the dominant firm

\[
MR_D = c_f(Q - Q_f) - Q_f c'_f(Q - Q_f)
\]

\[
+ [g(x_f) - g(x_f)] \left[ H^{-1}(1 - Q_f) + Q_f \frac{dH^{-1}(1 - Q_f)}{dQ_f} \right].
\]

Note that, as the marginal cost of the fringe increases, the slope of \(MR_D\) decreases, i.e., the decline of \(MR_D\) becomes steeper. Also note that

\[
\frac{dMR_D}{dQ_f} = g(x_f) \left[ H^{-1}(1 - Q_f) + Q_f \frac{dH^{-1}(1 - Q_f)}{dQ_f} \right].
\]

Note that the rotation rate of \(MR_D\) does not depend on the fringe's or the dominant firm’s cost structure. Substituting back into Eq. (16) gives

\[
MR_D = c_f(Q - Q_f) - Q_f c'_f(Q - Q_f) + \frac{g(x_f) - g(x_f)}{g(x_f)} \frac{dMR_D}{dQ_f}.
\]

Since the quantity at which \(MR_D\) rotates must satisfy \(dMR_D/dQ_f = 0\), we see that the height of the point of which \(MR_D\) rotates is equal to \(c_f(Q - Q_f) - Q_f c'_f(Q - Q_f)\). The last statement of the Lemma follows from the same arguments used in the proof of Lemma 1. \(\blacksquare\)

It is clear from Lemma 2 that the \(MR_D\) rotation point is below \(c_f(Q_f)\), and that its location is not affected by \(c_g(\cdot)\). If at an initial equilibrium the fringe and the dominant firm have the same marginal cost, then a rotation of \(MR_D\) induced by an increase in \(x_f\) increases the dominant firm’s output. The dominant firm’s output decreases with an increase in \(x_D\) only if the marginal cost of the dominant firm is sufficiently lower than the marginal cost of the fringe at the initial equilibrium, as the following proposition states.

**Proposition 2.** When marginal costs are increasing in output, the equilibrium quantity of the dominant firm is decreasing in its product quality \(x_D\) when \(c_f(Q_f) < c_f(Q_f') - Q_f c'_f(Q_f')\), is invariant to \(x_D\) when \(c_f(Q_f) = c_f(Q_f') - Q_f c'_f(Q_f')\), and is increasing in \(x_D\) otherwise.

This is stated without proof, given that the formal proof follows the steps in the proof of Proposition 1. The shape of \(c_f(\cdot)\) does not affect \(MR_D\), its point of rotation, or the rate of rotation as \(x_D\) increases. Thus, the slope of \(c_f(\cdot)\) at the initial equilibrium has no effect on the sign of the change of \(Q_f\), but it attenuates its magnitude. For any given rotation of \(MR_D\), the steeper the marginal cost function of the dominant firm, the smaller the change in its output (either positive or negative). In the remainder of the paper we return to the assumption of constant marginal costs.

### 4.2. Removing the competitive fringe: The pure monopoly case

Suppose the fringe was completely absent and the dominant firm was a pure monopolist. Further suppose that \(V = 0\), as in the more basic models of vertical differentiation. Would a similar result obtain? In that case, one can show that the pivot point of the demand curve and the rotation point of the \(MR_D\) curve will both have a height of zero. Following the insights of Proposition 1, one can clearly see that an increase in quality raises output, as the height of the rotation point is below \(c_f\). Note that with the presence of a competitive fringe, in our general formulation of the vertical differentiation model, the distribution of \(V_f\) was not important (as long as Assumption 1 was satisfied), and in particular, the findings of Proposition 1 would hold even when \(V_f = 0\) for all \(i\). In the absence of competitive fringe, that would no longer be the case. Thus, in the basic model of preferences under vertical differentiation, the competitive fringe is essential for obtaining our results.

But even in the pure monopoly case, we can still obtain a result like the one in Proposition 1, though only under more restrictive conditions. A sufficient condition for this is that \(V_{\min} > c_f\). To most easily demonstrate this, suppose that \(V_i = V > c_f\) for all \(i\). In this case, the value of \(\theta\) for the consumer who is indifferent between purchasing and not purchasing the good is given by

\[
\theta_c = \frac{P_D - V}{g(x_f)}.
\]

The monopolist’s profit function is \(\pi = (P_D - c_f) \left[ 1 - H\left(\frac{\theta_c}{\theta}\right) \right]\) and the first-order condition of profit maximization with respect to \(P_D\) is given by

\[
\frac{\partial \pi}{\partial P_D} = 1 - H\left(\frac{P_D - V}{g(x_f)}\right) - (P_D - c_f) h\left(\frac{P_D - V}{g(x_f)}\right) \frac{1}{g(x_f)} = 0,
\]

which in turn can be rewritten as

\[
1 - H'(\theta_c) \frac{P_D - c_f}{P_D - V} h(\theta_c) \theta_c = 0.
\]

In this environment, increases in product quality lead to decreases in quantity, as Proposition 3 states.\(^{22}\)

**Proposition 3.** Suppose there is no competitive fringe. Then an increase in \(x_D\), holding \(c_f\) constant, leads to a reduction in the monopolist’s output if \(V > c_f\), leads to no change in output if \(V = c_f\), and leads to an increase in output if \(V < c_f\).

**Proof.** Since by assumption \(V > c_f\), the ratio \((P_D^* - c_f) / (P_D^* - V)\) is decreasing in \(P_D^*\). Consider an increase in \(x_D\) accompanied by an increase in \(P_D\) such that \(\theta_c\) remains unchanged. Then, the left-hand side of Eq. (19) would be positive. A positive value of the left-hand side of Eq. (19) implies that the firm’s profit would increase if it further raised its price. Thus, an increase in \(P_D\) that leads to no change in the monopolist’s output is smaller than the profit-maximizing increase. Therefore, the profit-maximizing price increase will reduce the firm’s output. The proof of the converse follows by reversing the signs in the above exposition.\(^{23}\) \(\blacksquare\)

We now show that the model with the competitive fringe and the monopoly model fits into a unified framework, in which the former is equivalent to the latter when \(V = c_f\). Since the competitive fringe is

\(^{22}\) This example fits the Johnson and Myatt (2006) framework of demand rotation, albeit as a boundary case, with the rotation at the edge of the support of consumer willingness-to-pay.

\(^{23}\) This proposition could also have been proven using steps analogous to those used in Proposition 1, but where the rotation point of the MR\textsubscript{D} curve is at a height of \(V\) rather than \(c_f\).
non-strategic, the dominant firm can be thought of as a monopolist, albeit one facing the residual demand rather than market demand. The net willingness-to-pay for the dominant firm’s product for consumers whose best alternative is purchasing from the fringe is

\[
W_i = U_{\text{dominant}}^i - U_{\text{fringe}}^i = (V_i + \theta_i g(x_{i0}) - P_D) - (V_i + \theta_i g(x_{iF}) - c_F).
\]

Since \(g(\cdot)\) can be any increasing function, we can reparametrize it as \(\gamma(x_0) = g(x_0) - g(x_F)\), and write

\[
W_i = c_F + \theta_i \gamma(x_0) - P_D. \tag{20}
\]

Note that Eq. (21) is of the same form as Eq. (1) but with \(V_i\) being replaced by the marginal cost of the fringe. The price of the outside option \(c_F\) takes the place of the value of the good in the absence of the attribute \(V_i\). Since we have shown in the preceding section that the only factor that determines whether the monopoly output will decline with an increase in quality is the relationship between \(V_i\) and the marginal cost of the monopolist, and not the shape of the quality function \(g(\cdot)\), it follows that in the presence of the competitive fringe the only relevant factor is the comparison between the marginal cost of the fringe and that of the dominant firm.

4.3. Multi-product firms and cost changes

Our stylized model makes two assumptions regarding the environment following the introduction of the new high-quality product. The first is that the old high-quality product is discontinued upon the introduction of the new one. The analysis in Itoh (1983) is directly relevant to what happens if this is not the case.\(^{24}\) If the dominant firm retains both products, then following Itoh’s Proposition 1, the optimal price of the original high-quality product remains unchanged, and so the market share of the dominant firm also remains unchanged. Consumer surplus goes up, as consumers either consume the product they used to and pay the same price, or they consume a better product at a higher price, which by revealed preference makes them better off. Welfare also goes up, since both consumer surplus and profits go up as long as all products have positive market share, as ensured by Assumption 1.

It is worth noting that, while it is possible for the dominant firm to continue to offer both products, in many cases the introduction of a new product (e.g., the iPad or other electronics) is accompanied by the discontinuation of the older product, as we assume in the main body of the paper. An explanation for this is the presence of substantial fixed costs at the product level. Such costs often make it unprofitable to manufacture, market, and distribute multiple versions of the same product, making the single-product case the salient one. Evans and Salinger (2005, 2008) present empirical evidence of the importance of fixed costs at the product level and develop a theoretical model of the relevance of such fixed costs in evaluating tying and bundling conduct. Moreover, the idea of offering both versions of the product only applies to the “temporal” interpretation of our model, in which the product exists and is not purchasing at all, and since the dominant firm does not have a 100% market share for consumers with any value of \(V_i\), where the quality of that product is higher; in that case it is not meaningful to consider the co-existence of both products.\(^{25}\)

Our second assumption is that costs are the same for both versions of the dominant firm’s product. Allowing the higher-quality version to have higher marginal costs would, all else equal, lead to a higher price and a lower quantity for the new product, and would also lower consumer surplus and total welfare.

A larger departure from our simple framework involves a simultaneous change in quality of both the dominant firm and the fringe. For example, following the introduction of the new product by the dominant firm, the old product could become generic and be produced by the fringe at its old marginal cost. The effects of this depend on the relative magnitudes of the differences \(g(x_0) - g(x_F)\) and \(g(x_{i0}) - g(x_{iF})\). If these two differences are the same, then there is no change in the dominant firm’s demand (see Eq. (3)), and hence in its price and market share. This is not surprising since the dominant firm has a better product, but not better relative to the new product of the fringe. Consumer surplus goes up, however, since consumers will purchase uniformly better products at the old prices. If the second difference is larger than the first, then our baseline results continue to hold with regard to quantity (i.e., quantity falls if \(c_D < c_F\)), but not with regard to consumer surplus (i.e., consumer surplus now unambiguously increases even when \(c_D < c_F\)).

4.4. The limits of this framework

The results outlined so far depend upon the standard (and reasonable) assumption in vertical differentiation models that willingness-to-pay for the product is a linear function of a monotonic transformation \(g(\cdot)\) of the product attribute. We now consider a modification of the model that departs from this linear assumption by allowing utility to be quadratic in the attribute

\[
U_y = V_i + \theta_i x_i + \xi x_i^2 - P_i, \tag{22}
\]

where \(g(\cdot)\) has been replaced by the identity function and \(\bar{\theta}\) is a parameter common to all consumers. A possible example in which willingness-to-pay could be quadratic is one where product quality takes the form of the customers’ travel time to reach the firm’s location. A higher value of \(x_i\) means lower travel time, possibly because of lower traffic on the road leading to the firm (so \(\theta_i\) and \(\bar{\theta}\) would both be negative). Now \(\theta_i\) could represent the monetary loss from forgoing paid work to travel to the firm, or the monetary cost of the fuel required to drive there. Since wages and fuel efficiency vary across potential consumers and their vehicles, the parameter \(\theta_i\) could differ across individuals. The term \(\xi x_i^2\) would represent the pure disutility of travel and would be convex in the required travel time. Though this could also differ across consumers, for simplicity it is assumed not to.

Under these preferences, the value of \(\theta_i\) for the consumer who is indifferent between purchasing from the dominant firm and purchasing from the fringe is given by

\[
\begin{align*}
\theta_i x_i + \xi x_i^2 - c_F &= \theta_i x_0 + \xi x_0^2 - P_D \\
\theta_i(x_0 - x_i) &= P_D - c_F - \bar{\theta}(x_0^2 - x_i^2) \\
\theta_i &= \frac{P_D - c_F}{x_0 - x_i} - \bar{\theta}(x_0 + x_i).
\end{align*}
\]

\(^{24}\) The competitive fringe in our model is equivalent to the outside option in Itoh, since no consumer is indifferent between purchasing from the dominant firm and not purchasing at all, and since the dominant firm does not have a 100% market share for consumers with any value of \(V_i\).

\(^{25}\) For example if “quality” is a desirable location for a retailer, then quality can change, but there cannot be two different qualities offered at the same time.
For simplicity from now on we assume that \( \theta_i \) is distributed U[0, 1].

The residual demand for the dominant firm's product is

\[
Q_D = 1 - \frac{P_D - C_D}{x_D - x_f} + \delta (x_D - x_f),
\]

(24)

in which solving for price yields

\[
P_D = C_D + (x_D - x_f) + \delta (x_D^2 - x_F^2) - (x_D - x_f)Q_D.
\]

(25)

Notice the pivoting component, which pushes the y-axis intercept upwards and decreases the slope one-for-one for an increase in the value of \( x_D \) and an additional parallel shift component that pushes out the demand at a rate of 2\( x_D \) as \( x_D \) increases. The optimal output level of the dominant firm is obtained by equating the MR with marginal cost

\[
Q_D^*= \frac{1}{2} + \frac{1}{2} \frac{C_D - C_F}{x_D - x_F} + \frac{\delta}{2} (x_D + x_f).
\]

(26)

This preference structure not only leads the demand curve to pivot in response to a quality increase, but also causes it to translate outward. Notice that \( \delta = 0 \) yields our original model and \( Q_D^* \) is invariant to quality when \( C_D = C_F \) and decreasing in \( x_D \) when \( C_D < C_F \). But if \( \delta > 0 \) then there is an additional, strictly positive term that does not depend on the relationship between the two marginal costs. This means that \( Q_D^* \) unambiguously increases when \( C_D \geq C_F \) and can increase or decrease when \( C_D < C_F \) depending on which effect dominates.

5. Concluding remarks

In this paper we identify a mechanism through which quality improvements that increase willingness-to-pay for a product can lead to reduced equilibrium output of that product. The result does not come from any trivial source such as reduced long run sales of a product whose durability increases. Rather, it comes from the fact that an increase in the quality of a dominant firm's product causes a reduction in the elasticity of the dominant firm's residual demand curve. This elasticity effect can lead to such a large increase in the profit-maximizing price that the dominant firm sells fewer units. Interestingly, this happens when (and only when) the dominant firm's marginal cost is lower than that of a competitive fringe. We also show that when this is the case, an increase in quality can decrease consumer surplus (and total surplus), and even possibly make all consumers weakly worse off. However, when the marginal cost of the dominant firm is equal to or higher than that of the competitive fringe, consumer surplus unambiguously increases.

As discussed above, our most “surprising” results come from the case where the dominant firm's costs are lower than the fringe's. While we do not claim that this is the typical case, we note that a number of markets can (to a first approximation) be described as consisting of a dominant firm competing against a number of much smaller and less efficient rivals. In addition, the standard vertical differentiation model on which we rely is a reasonable approximation of consumer preferences for products that are differentiated by quality. Thus, our model is likely to have reasonably broad applicability. Even in situations where other quantity-increasing effects dominate the quantity-reducing effect analyzed here, the quantity-reducing mechanism will still be present, and its presence will tend to make the quantity increase smaller than it otherwise would be. At the very least we have shown that a quality improvement in the product of a dominant firm facing a competitive fringe has an effect of indeterminate sign on that firm's output, and that in an important special case, it is guaranteed to have a negative effect.

In Section 3 we briefly discussed the consumer surplus and total welfare effects of quality improvement in the dominant firm's product compared to an improvement in the fringe firms' product. Those results suggest that there may be instances where the latter is more valuable. It may also be less costly to improve the technology of the laggards rather than improve that of the leaders, e.g., the dissemination of open-source alternatives to dominant-firm technology may be achievable at relatively low cost compared to R&D to advance the technology frontier. Thus, innovations that improve quality of the fringe firms, rather than of the dominant firm, may be more effective from the cost side as well as from the demand side. This observation may have policy implications, as current policy is based almost entirely on encouraging innovation at the frontier.

References


