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Better Product at Same Cost, Lower Sales and Lower Welfare

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Abstract

We analyze the effect of product quality on the output of a high-quality dominant firm facing a low-quality competitive fringe. Using a standard vertical differentiation model, we show that profit maximizing output decreases with product quality when the dominant firm's marginal cost is lower than that of the fringe, is independent of quality when marginal cost is the same for all firms, and is increasing in quality when the dominant firm's marginal cost is higher than that of the fringe. The driving force behind this result is that an increase in product quality does not cause a parallel shift in the dominant firm's residual demand, but rather causes it to pivot. This, in turn, causes the dominant firm's marginal revenue curve to rotate, rather than shift outwards, resulting in inwards movement around the equilibrium output when the dominant firm's marginal cost is lower than the fringe's. Equally strikingly, higher quality at the original marginal cost may result in all consumers being weakly worse off, with some being strictly worse off. Similar results can be obtained without a competitive fringe, but only under some more restrictive conditions.

JEL Classification Codes: L15, L13.

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1 Introduction

It is now understood that it can be profitable for a firm to take an action that increases the willingness-to-pay of its more likely customers, even at the cost of decreasing the willingness-to-pay of its less likely customers. Such an action effectively rotates the firm's demand curve through an interior point. The firm may be trading off fewer sales with a higher profit margin per sale (Johnson and Myatt 2006). In this paper, we obtain a similar but more striking result: under one quite common competitive environment, and using the canonical model of consumer preferences for vertically differentiated products, we show that an action that increases the willingness-to-pay for all of a firm's consumers, but does not increase its marginal cost, results in a reduction in that firm's sales. Moreover, it is possible that no consumer is made better off.

The competitive environment that we consider includes one single-product dominant firm and a competitive fringe. What makes the firm \dominant" is that it produces a higher quality product

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

$$U_{ij} = V_i + \theta_i g(x_j) - P_j; \qquad (1)$$

where V_i is the willingness of consumers to pay for the product in the absence of the attribute, θ_i is the marginal willingness of consumer i to pay for a unit increase in the attribute, x_j is the value of the attribute for product j, $g(\cdot)$ 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 $H(V)$ on the interval $[V_{MIN}; V_{MAX}]$ (note that in most other papers on vertical differentiation, the value of V_i is the same for all consumers or even set to zero). The parameter θ_i is distributed with marginal distribution $F(\theta)$ with support $[\theta_{MIN}; \theta_{MAX}]$. The value of θ_{MIN} could be as low as 0, while the value of θ_{MAX} could be arbitrarily high. The dispersion in θ could be driven by differences in consumer income or by differences in the direct utility function.[5] The correlation or joint distribution of V_i and θ_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. Consumers have the option of making no purchase and earning a utility of zero.

A dominant firm sells a product of quality x_1, and faces a perfectly competitive fringe which sells products of a lower quality x_0 at a price equal to their (constant) marginal cost c_0.[6] Assumption 1, which is formally stated below, ensures that in equilibruim all consumers with values of θ_i and V_i such that $V_i + \theta_i g(x_0) - c_0 > 0 \Rightarrow \theta_i > \frac{c_0 - V_i}{g(x_0)}$ purchase some version of the product, and all those

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paper, we follow the bulk of the recent literature in simply treating the attribute as something that consumers are willing to pay for, without being explicit about its nature or the way that it affects the product's use.

[5] Much of the early literature on vertical differentiation assumes that consumers have the same preferences but different incomes. However, even in that early literature it was clear that differences in income could be reinterpreted as differences in preferences (Gabszewicz and Thisse 1979, Gabszewics, Shaked, and Sutton, 1986), and that a combination of income and preference differences would generally yield the same results (Shaked and Sutton 1983).

[6] Perfectly competitive pricing follows trivially in our model if firms choose prices, given that the products of the fringe firms are perfect substitutes. More generally, the assumption that small firms are non-strategic is standard in models where a dominant firm faces a competitive fringe, and approximates the solution to a game between a firm that is large (in equilibrium) and many smaller (in equilibrium) rivals. It is straightforward to show this, for example, under Cournot competition between a firm with $MC = q$ and N rivals with $MC = Nq$, where N is large.

with lower values of $_i$ (and V_i) do not. We now analyze the e ect of a change in the dominant rm's quality x_1, holding its cost c_1 constant. This can be thought of temporally, with the dominant rm

$= (P_1 - c_1)[1 - F(\frac{P_1 - c_0}{g(x_1) - g(x_0)})]$.[7] 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 (a brute force proof of our main result that is based on first-order conditions of profit maximization with respect to price was used in earlier versions of the paper and this approach is used in the proof of Proposition 2 below). Solving the (residual) demand function of the dominant firm for P_1 yields the inverse demand function

$$P_1 = c_0 + (g(x_1) - g(x_0))F^{-1}(1 - Q): \qquad (3)$$

Note that the demand intercept is $c_0 + (g(x_1) - g(x_0))_{MAX}$ and is increasing in x_1. We assume that the MR function associated with this demand function is differentiable and monotonically decreasing, i.e., that $F^{-1}(1 - Q) + Q\frac{dF^{-1}(1-Q)}{dQ}$ is monotonically decreasing in Q. An increase in x_1 Mhatiplyn

Note that

$$\frac{dMR(Q)}{dx_1} = g'(x_1)\left[F^{-1}(1-Q) + Q\frac{dF^{-1}(1-Q)}{dQ}\right]. \tag{5}$$

Evaluating at $Q = 0$, we obtain $\frac{dMR(0)}{dx_1} = g'(x_1)\,\theta_{MAX} > 0$, i.e., MR is increasing in x_1 for sufficiently low output levels. Substituting (5) back into (4) gives

$$MR(Q) = c_0 + \frac{g(x_1) - g(x_0)}{g'(x_1)}\frac{dMR(Q)}{dx_1}. \tag{6}$$

Since the quantity at which MR rotates must satisfy $dMR(Q)/dx_1 = 0$, we see that the height of the point about which MR rotates is equal to c_0. Given that the MR curve is assumed to be downward sloping, given that there is a one-to-one relationship between MR and dMR/dx_1 (from equation 6), and given that MR is increasing in x_1 for output $Q = 0$, the MR rotation implies that MR is constant in x_1 for the output level that corresponds to $MR = c_0$, is increasing in x_1 for lower values of Q, and is increasing in x_1 for higher values of Q.

We now turn to the main question of interest. How does the dominant rm's quantity depend on the quality of its product? One might expect that it would go up. This prediction arises from models with horizontal product differentiation and consumers who value quality equally (e.g., Deltas, Harrington and Khanna, 2010). However, in our purely vertical framework, this is not the case if the dominant rm's marginal cost is at or below that of the fringe rms, as our main result below states.

Proposition 1 *Hblig ccstant, he eqbriqatyfbhe dmt nisdecrasig in itpdtqty* x_1 *hen* $c_1 < c_0$, *isiarto* x_1 *hen* $c_1 = c_0$, *ad isiceasig in* x_1 *bein.*

Proof. The dominant rm's pro t maximizing quantity is determined by the intersection of MR and c_1 (the rm's marginal cost). Denote by Q_0 the optimal output level if 23.468 0 Td (and)Tj 89 T93sing in the alternative is to buy (from the fringe) a product of quality x_0 at a price c_0. Any consumer for whom > 0 will have a valuation for the dominant rm's product higher than c_0, but a consumer for whom = 0 will have a valuation equal to c_0. This consumer regards both products as equally good, and so is willing to pay c_0 for the dominant rm's product when the alternative is to buy from the fringe at c_0. An increase in the dominant rm's quality from x_1 to x_1^0 causes the residual inverse demand curve faced by the dominant rm to pivot, not to shift parallel, because the increase in each consumer's willingness-to-pay depends on how much they value quality. De ning Q as the quantity corresponding to a consumer for whom = 0, the increase in quality causes the dominant rm's inverse demand curve to pivot about the point $(Q; c_0)$.[9] This is depicted in Figure 1, in which the distribution of is uniform. Lemma 1 above shows that the height of the rotation point of the marginal revenue curve is also c_0, which is indicated in Figure 1 and leads directly to Proposition 1.

Now we relax the assumption that everyone buys some version of the product and allow for the possibility that consumers with su ciently low and/or V_i do not buy at all. Now there are two notional inverse demand curves that the dominant rm might face: one where consumers' preferred alternative is to buy from the fringe at a price c_0, and one where the alternative is not to buy at all. A quality increase causes the latter inverse demand curve to pivot (and its MR curve to rotate), but about a point whose height is other than c_0. But as long as Assumption 1 is satis ed, the relevant inverse demand curve for the dominant rm is the former one, and so allowing the possibility that consumers buy nothing has no e ect on its conduct. The only change is that now some consumers buy nothing instead of buying from the fringe.

3 Consumer Surplus and Total Welfare

We consider the welfare e ects of an increase in the quality of the dominant rm's product from x_1 to x_1^0 when c_1 c_0, with associated equilibrium prices of P_1 and P_1^0, starting with evaluation of the consumer surplus (the less interesting case of $c_1 > c_0$ can be analyzed in a similar manner). Since each consumer has three possible choices (buy nothing, buy from the fringe, buy from the dominant rm) both before and after the quality increase, there are nine choice pair possibilities. Given our

[9]Note that if zero were not in the support of , *Q* would be obtained from a demand that would result from hypothetically assuming the existence of consumers with = 0 and extrapolating the demand to that value of .

assumptions,   ve of these nine can be ruled out.[10]

The remaining four possible types are illustrated in Figure 2. First are consumers with values of ${}_i$ low enough that $V_i + {}_i$

The e ect of the quality increase on total consumer surplus will depend on whether F ( ) has a fat or a thin tail above $\tilde{\ }_c$. Note that the set of consumers for whom $_i > \tilde{\ }_c$ may be empty. This is because P_1^0 does not depend on the support or the shape of F ( ) above $\frac{P_1^0 \ c \ \ 0}{g(x_1^0) \ g \ \ (x_0)}$, and so $_{MAX}$ could be bigger or smaller than $\tilde{\ }_c$. If $\tilde{\ }_c > \ _{MAX}$

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 (supported, perhaps, 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 Markets without the Competitive Fringe: The Monopoly Case

Suppose the fringe was completely absent and the dominant firm was a pure monopolist. Further suppose that $V = 0$, as in standard vertical differentiation models. Would a similar result obtain? In this case, the pivot point of the demand curve and the rotation point of the marginal revenue curve will both have a height of zero. Clearly Proposition 1 will not hold, as the height of the rotation point

Proof. Since by assumption $V > c_1$, the ratio $(P_1 - c_1)/(P_1 - V)$ is decreasing in P_1. Consider an increase in x_1 accompanied by an increase in P_1 such that π_c remains unchanged. Then, the left hand side of equation (9) would be positive. A positive value of the left hand side of (9) implies that the firm's profit would increase if it further raised its price. Thus, an increase in P_1 that leads to no change in the monopolist's sales is smaller than the profit maximizing increase. Therefore, the profit between V and the marginal cost of the monopolist, and not the shape of the quality function g( ), 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.

4.2 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 introduction of the new one. The analysis in Itoh (1983) is directly relevant to what happens if this is not the case.[16] 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 worthwhile noting that 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. The presence of such costs would make it unprofitable to manufacture, market, and distribute multiple versions of the same product, making the single-product case the salient case. 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, in the non-temporal interpretation of our model, comparing a world with a dominant firm's sole product of a particular quality versus a world where quality is even higher, it is not meaningful to consider the co-existence of both products. Our second assumption is that costs are the same for both versions of the high-quality product. If instead the higher-quality version has higher costs, then our results become stronger: the price of the new product is increasing in the production cost; hence, the dominant firm's market share, consumer surplus and total welfare will all decrease.

[16] 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 an 100% market share for consumers with any value of V_i.

A larger departure from our simple framework involves a simultaneous change in quality of both the dominant rm and the fringe. For example, following the introduction of the new product by the dominant rm, the old product could become generic and be produced by the fringe at its old marginal cost. The e ects of this depend on the relative magnitudes of the di erences $g(x_1) \quad g(x_0)$ and $g(x_1^0) \quad g(x_1)$. If these two di erences are the same, then there is no change in the dominant rm's demand (see equation (3)), and hence in its price and market share. This is not surprising since the dominant rm 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 di erence is larger than the rst, then our \unconventional" results continue to hold with regard to quantities, but not with regard to consumer surplus, since products will be uniformly weakly better for consumers (even after allowing for higher prices). If the second di erence is smaller than the rst, then our results do not hold even for quantities. However, a seeming paradox will remain: even though the quality gap between the dominant rm and the fringe gets smaller, the dominant rm's market share nevertheless goes up.

4.3 The Limits of this Framework

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

$$U_{ij} = V_i + {}_i x_j + x_j^2 \quad P_j; \tag{12}$$

where g(

from the dominant rm and purchasing from the fringe is given by

$$_c x_0 + x_0^2 \quad c_0 = \quad _c x_1 + x_1^2 \quad P_1 \;)$$

in the profit maximizing price that the dominant firm sells fewer units. We also show that the effect of a quality increase on consumer surplus (and on total surplus) is ambiguous, but that it is possible for *all* consumers to be made weakly worse off, with some being strictly worse off.

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, and the standard vertical differentiation model on which we rely is a reasonable approximation of consumer preferences for products that are differentiated by quality, so our model is likely to have reasonably broad applicability. And even in situations where other quantity-increasing effects dominate the quantity-reducing effect analyzed here, 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.

References

Beath, J. and Y. Katsoulacos, *The Economic Theory of Product Differentiation*, Cambridge University Press, Cambridge UK, 1991.

Choi, C. J. and H.S. Shin [1992] "A Comment on a Model of Vertical Product Differentiation," *Journal of Industrial Economics*, vol. 40, pages 229-231.

Deltas, G., D. Harrington, and M. Khanna [2012] "Oligopolies with (Somewhat) Environmentally Conscious Consumers: Market Equilibrium and Regulatory Intervention," *Journal of Economics and Management Strategy*, forthcoming.

Evans, D. S., and M. A. Salinger [2005] "Why Do Firms Bundle and Tie? Evidence from Competitive Markets and Implications for Tying Law, *Yale Journal on Regulation*, vol. 22, pages 37-89.

Evans, D. S., and M. A. Salinger [2008] "The Role of Cost in Determining When Firms Offer Bundles and Ties, *Journal of Industrial Economics*, vol. 56, pages 143-168.

Frascatore, M. R. [1999] "Vertical Product Differentiation when Quality is Scarce: the Case of $n > 2$ Firms," *Australian Economic Papers*, vol. 38, pages 120-130.

Gabszewics, J. J., A. Shaked, and J. Sutton [1986] \Segmenting the Market: The Monopolist's Optimal Product Mix," *Journal of Economic Theory*, vol. 39, pages 273-289.

Gabszewicz, J. J. and J.-F. Thisse [1979] \Price Competition, Quality and Income Disparities," *Journal of Economic Theory*, vol. 20, pages 340-359.

Itoh, M. [1983] \Monopoly, Product Di erentiation and Economic Welfare," *Journal of Economic Theory*, vol. 31, pages 88-104.

Johnson, J.P. and D. P. Myatt [2006] \On the Simple Economics of Advertising, Marketing, and Product Design," *American Economic Review*, vol. 96, pages 756-784.

Lehmann-Grube U. [1997] \Strategic Choice of Quality when Quality is Costly: the Persistence of the High-Quality Advantage," *Rand Journal of Economics*, vol. 28, pages 372-384.

Motta, M. [1993] \Endogenous Quality Choice: Price vs. Quantity Competition," *Journal of Industrial Economics*, vol. 41, pages 113-131.

Noh, Y. H. and G. Moschini [2006] \Vertical Product Di erentiation, Entry-Deterrence Strategies, and Entry Qualities," *Review of Industrial Organization*, vol. 29, pages 227-252.

Shaked, A. and J. Sutton [1983] \Natural Oligopolies," *Econometrica*, vol. 51, pages 1469-1483.