Better Product at Same Cost: Leader Innovation vs Generic Product Improvement

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Chapter 4

Better Product at Same Cost: Leader Innovation vs. Generic Product Improvement*

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Abstract
We develop a parametric model in which a high-quality dominant firm faces a low-quality competitive fringe. We show that in this model, an increase in the dominant firm’s product quality increases total welfare and consumer surplus. An increase in fringe firm quality has an ambiguous effect on total welfare, but always increases consumer surplus. Moreover, an increase in fringe quality always leads to a bigger increase in consumer surplus than does an increase in dominant firm quality, but the analogous comparison for total welfare is ambiguous. Finally, we show that an increase in dominant firm quality always increases total welfare by more than it increases consumer surplus, whereas for an increase in fringe firm quality, the opposite is true. The first of these findings relies on our parametric assumptions, but the others appear not to. We discuss the relevance of these results to public policy.

Keywords: Product innovation, dominant firm, competitive fringe, vertical differentiation.

JEL Classification Codes: L15, L13, J60, O31.

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1. **Introduction**

A product innovation can make it possible to produce a higher-quality version of an existing product, sometimes at the old production cost. All else equal, such an improvement tends to increase welfare, at least net of any R&D costs incurred. But if the higher-quality product is introduced into a market characterized by distortions due to market power, then the welfare effect will also depend on whether it makes those distortions bigger or smaller. In this chapter, we consider a market structure that does contain such a distortion, namely that of a high-quality dominant firm competing with a low-quality competitive fringe. Within this framework, we derive the total welfare and consumer surplus effects of a quality increase in the dominant firm’s product and in the fringe’s product, and we also derive several results on how these welfare effects compare with each other. Our results have a direct bearing on the question of what kind of innovation is more valuable, a pushing out of the quality frontier (i.e., an increase in the quality of the dominant firm’s product, also referred to as the “branded” product), or catchup innovation by the fringe (i.e., an increase in the quality of the “generic” product). Most analyses of innovation focus on the former, but we show that, somewhat surprisingly, the latter can be more valuable.

A major theme of our results is that the comparison of the two types of quality increase depends on the welfare standard adopted, i.e., innovation has redistributive effects, and the nature of the redistribution depends on which product’s quality is improved.

Our framework can be applied to a number of settings, such as in consumer electronics, where there is often a clear quality leader (e.g., the iPad), competing with a number of sellers of lower-quality products that compete mainly on price (e.g., other tablet computers). Another such setting is the competition between branded drugs under patent protection and older generic drugs that are less effective but also much cheaper. Yet another might be CT scans vs. MRI scans. For some purposes, these two technologies are substitutes for each other, meaning that either could potentially be appropriate for a particular diagnostic purpose (see Borgen et al., 2006 for an example). A major disadvantage of CT scans is that they expose the patient to radiation, while MRI scans do not. In the framework of
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our model, an improvement to CT technology, for example a reduction in patient radiation exposure, could be thought of as a quality improvement of a trailing product relative to a frontier product. Notice that in the last two examples, the trailing technology is not simply a lower-quality version of the frontier technology, but is technologically distinct. Our model applies to these cases as well; all that is required is that the trailing product be a lower-quality substitute in demand.

Our findings have implications for public policy. Given that governments have finite resources with which to encourage innovation, there exists a trade-off between encouraging innovation of new or frontier products and encouraging improvements in existing generic technologies that may be less advanced. For example, support for basic science and university research can help foster frontier innovations, but is unlikely to lead to improvements in well-established technologies. Support for corporate R&D, whether direct or through tax incentives, can lead to improvement in either type of product. In contrast, a broader tax incentive, such as accelerated depreciation of all investments including product redesign, will likely have a relatively larger effect at the trailing edge. As a specific example, the U.S. government faces such a trade-off with respect to investments in improving healthcare. The Agency for Healthcare Research and Quality (AHRQ) conducts and funds a variety of research activities to develop new methods of measuring and improving the quality of patient medical care; these activities improve the “frontier” of care. At the same time, the U.S. government also funds and operates, through the Centers for Medicare and Medicaid Services (CMS), the Electronic Health Record (EHR) Incentive Programs for Medicare and Medicaid, which establish incentives for providers who participate in those programs to adopt existing EHR technologies; these activities improve quality of care by bringing providers closer to the existing frontier. Our results are also relevant to public policies that do not involve expenditures or taxation, such as those related to intellectual property (IP) protection. For example, a stricter IP policy, such as stronger patents, might provide stronger incentives for investment in frontier innovation, but at the expense of technology diffusion or imitation, resulting in higher quality at the frontier and lower
quality inside it. Our model speaks to the welfare implications of such
differences.

We use a standard model of vertical differentiation, and also adopt
the common parametric assumption that the distribution of consumer
ingenuity-to-pay for quality is distributed uniformly. This assumption
yields linear demand structures and closed form expressions for our
comparative statics results. Though these results, being derived from a
parametric model, may not always generalize, they do yield a number of
insights. In our parametric model, an increase in the quality of the dominant
firm’s product leads to an increase in total welfare. The basic analytics
behind this result are as follows. A quality increase of the dominant firm’s
product provides infra-marginal consumers of that product with higher
quality at the same social cost of production, which tends to increase total
welfare. In the special case where quality changes have no effect on who
buys which product (which in our model occurs when the two marginal
costs are equal), the analysis described above is complete. But if the two
costs are not equal, then changes in quality cause some customers to switch
products. When consumers switch from the generic (fringe) product to the
branded (dominant firm’s) product, they consume a product of higher value.
This product is also more expensive to produce, but the net effect of the
switches on total welfare is positive. When consumers switch from the
branded product to the generic, these effects are reversed and the net effect
of the switches is negative; however, the aggregate effect is positive in this
case as well.

In contrast, an increase in the quality of the fringe firms’ product has
an ambiguous effect on total welfare. As in the case of the dominant firm, a
quality increase to the fringe firms’ product benefits infra-marginal fringe
firm consumers. But all else equal, consumers who buy the fringe firms’
product value quality by less than do those who buy the dominant firm’s
product, so the welfare benefit per infra-marginal consumer is smaller. The
total effect across all infra-marginal consumers is also smaller than for an
increase in the dominant firm’s quality, unless the number of infra-marginal
consumers of the fringe firms’ product is sufficiently greater than the number
of infra-marginal consumers of the dominant firm’s product. The effects
due to switches are exactly the same as what they are in the case of the
dominant firm. There is an additional positive effect of an increase in fringe
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firm quality that is not present for an increase in dominant firm quality, because an increase in fringe product quality causes some consumers to buy from the fringe instead of not buying at all. The aggregate effect is ambiguous, as stated at the outset. Consumer surplus is increasing in the quality of either product. The analysis is similar to that for total welfare, except that the effects of quality changes on dominant firm profits are given zero weight.

Regarding the comparison between the effects of an increase in dominant firm quality vs. fringe firm quality, we show that under a consumer surplus standard, the latter is unambiguously more valuable than the former. This is because higher fringe firm quality increases the value of the fringe firms’ product without increasing its price, and it also, by narrowing the quality gap, reduces the dominant firm’s price and profits, leading to a transfer from the dominant firm to consumers. This reduction in profits also has the effect of making consumer surplus more responsive than total welfare to an increase in fringe product quality. In contrast, under a total welfare standard, it is possible that welfare increases by more from an increase in dominant firm quality than from an increase in fringe firm quality. Relatedly, total welfare is more responsive than consumer surplus to an increase in dominant firm quality.

The model in this chapter is based on the framework in Balan and Deltas (2013). However, the questions addressed in that paper are quite different from those addressed here; that paper deals with the quantity and welfare effects of changes in the dominant firm’s quality, and touches only tangentially on the effects of changes in fringe firm quality. However, one result from that paper plays a significant role in the results derived in this one. Specifically, that paper shows that the effect of an increase in the dominant firm’s quality on its equilibrium quantity depends on how its marginal cost compares to the (common) marginal cost of the fringe firms. Higher quality has no effect on the dominant firm’s quantity when the two costs are equal, increases quantity when the dominant firm’s costs are higher, and decreases quantity when they are lower. In this chapter, we derive closely related results on the effect of fringe product quality on the quantity of either product, as a function of relative marginal costs.

As far as we are aware, there are no other papers that explicitly compare the welfare effects of changes in product quality at the frontier vs. inside the
frontier, and certainly not in the case of a dominant firm facing a competitive fringe. But there is a substantial theoretical literature on issues related to ones discussed in this chapter, particularly regarding the effect of market structure on incentives to invest in R&D. We make no attempt to summarize this broad literature, but we mention here a few tangentially relevant papers. Early contributions by Benoit (1985) and Pepall and Richards (1994) analyze the effect of imitation costs on a firm’s incentive to invest in developing new products. Greenstein and Ramey (1998) use a vertical differentiation framework similar to ours to analyze the effect of market structure for an existing product on the incentive to invest in developing a new product. Chen and Schwartz (2013) use a similar model to compare the innovation incentives of a monopolist facing no competition with those of a firm that is one of many producers of an older product, which may remain available post-innovation. Finally, Matsushima and Liu (2012) use a model with two dominant firms facing a competitive fringe, and analyze the effect of changes in the fringe firms’ cost or quality on R&D investment levels.

2. The Model and Market Equilibrium

Our basic framework follows Balan and Deltas (2013). This framework modifies the standard vertical differentiation duopoly model of Mussa and Rosen (1978) by assuming that a high quality dominant firm competes against a low quality competitive fringe.\(^1\) There is a unit mass of consumers, who differ in their marginal willingness-to-pay for quality. The indirect utility of consumer \(i\) for product \(j\) is given by

\[
U_{ij} = \theta_i s_j, \tag{1}
\]

where \(\theta_i\) is the marginal willingness of consumer \(i\) to pay for a unit increase in quality, and \(s_j\) is the quality of product \(j\). The parameter \(\theta_i\) is distributed uniformly on the \([0, 1]\) interval. Fixing the upper and lower bounds of the distribution does not result in any loss of generality, given that the units of

\(^1\) See Beath and Katsoulacos (1991) for a detailed discussion of the foundations of the vertical differentiation literature.
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product quality can be arbitrarily rescaled. The value of $\theta_i$ can depend on the consumer’s intrinsic preferences and also on his or her income.\(^2\) The dominant firm’s quality and price are denoted by $s_D$ and $P_D$, respectively. Those of the fringe are denoted by $s_F$ and $P_F$.\(^3\) We will sometimes refer to the dominant firm’s product as the “branded product,” since often (as in pharmaceuticals) it will be a branded product. The fringe’s product will sometimes be referred to as the “generic product,” since brand is of no importance given that the product is sold by many firms. We assume that $s_D > s_F$ but make no assumptions about the relative values of marginal costs; the dominant firm’s marginal cost, $c_D$, can be greater than, equal to, or less than the (common) fringe firm marginal cost, $c_F$. That is, the dominant firm’s higher quality need not come exclusively from using more expensive inputs, but instead may come from superior technology or some other advantage over the fringe firms.\(^4\) The dominant firm chooses its price to maximize its profits, given its marginal cost. The price of the competitive fringe is equal to $c_F$. Consumers choose the product that maximizes their utility, net of the product price. Consumers have the option of making no purchase and earning a utility of zero.

In what follows, we assume that both the dominant firm and the competitive fringe have positive market shares in equilibrium and that some consumers choose to purchase neither version of the product. This assumption is equivalent to the set of inequalities given below (Assumption 1), to which we will refer on a number of occasions.

\[ \frac{1}{2} > \frac{1}{2} \frac{c_D - c_F}{s_D - s_F} > \frac{c_F}{s_F} > 0. \]

We now proceed to the derivation of market shares. The critical value $\theta_D$ such that a consumer is indifferent between purchasing from the dominant

\(^2\)The early literature (Gabszewicz and Thisse, 1979; Gabszewics et al., 1986) emphasized differences in income, but the source of the variation in $\theta$ is not important for this chapter. See also Shaked and Sutton (1983).

\(^3\)The modeling environment is somewhat simplified relative to that in Balan and Deltas (2013), but with limited loss of generality. The simplifications result in more transparent analytics and closed form solutions. There is also a minor change in notation.

\(^4\)There are alternative ways to define a firm as dominant, for example, based on equilibrium market shares or based on the ratio of quality over production cost. Our definition is the easiest one to use.
firm and purchasing from the fringe is
\[ \theta_{DsF} - P_F = \theta_{DsD} - P_D \implies (using \ P_F = c_F) \]
\[ \theta_D = \frac{P_D - c_F}{s_D - s_F}. \quad (2) \]

Every consumer with \( \theta_i > \theta_D \) will purchase from the dominant firm. Thus, the demand function of the dominant firm is equal to \( Q_D = 1 - \frac{P_D - c_F}{s_D - s_F} \), and the dominant firm chooses \( P_D \) to maximize \( \pi_D = (P_D - c_D) \left( 1 - \frac{P_D - c_F}{s_D - s_F} \right) \), yielding an optimal price of
\[ P^*_D = \frac{s_D - s_F + c_D + c_F}{2}. \quad (3) \]

Substituting into the demand function, we obtain the equilibrium sales volume of the dominant firm
\[ Q^*_D = \frac{1}{2} - \frac{1}{2} \frac{c_D - c_F}{s_D - s_F}. \quad (4) \]

Substituting \( P^*_D \) into (2), we get \( \theta^*_D = \frac{1}{2} + \frac{1}{2} \frac{c_D - c_F}{s_D - s_F} \), which Assumption 1 ensures is below 1 (the upper bound of the support of \( \theta \)). We now turn to comparative statics on the dominant firm’s equilibrium price and quantity in (3) and (4). The dominant firm’s price is increasing in the quality difference between the branded and the generic product, and also increasing in the production cost of either product. The comparative statics of the dominant firm’s sales volume are more interesting. Though sales volume goes up with \( c_F \) and down with \( c_D \), as expected, a change in \( s_D \) or in \( s_F \) has an effect of indeterminate sign. When the dominant firm’s cost exceeds that of the fringe, then the expected sign prevails; \( Q^*_D \) goes up with \( s_D \) and down with \( s_F \). But when the dominant firm’s cost is lower than that of the fringe, then its optimal output decreases with its own quality and increases with the quality of the fringe. When the marginal costs of the firms are equal to each other, the dominant firm’s sales volume is independent of either firm’s quality.

This surprising result is explained in detail and in a more general framework in Balan and Deltas (2013). The basic intuition is that higher quality of the dominant firm’s product causes an outward pivot, rather than a parallel shift, of its residual demand curve. This pivoting of demand causes
the marginal revenue curve to rotate clockwise about a point whose height is equal to the fringe firms’ (common) marginal cost. When the dominant firm’s marginal cost is higher than that of the fringe, the intersection point of its marginal cost and marginal revenue curves moves to the right, and output increases. Similarly, when the dominant firm’s marginal cost is lower than that of the fringe, the intersection point moves to the left and quantity falls. When the two marginal costs are equal, the intersection point does not change, and so quantity does not change either.\footnote{In models with horizontal product differentiation and consumers who value quality equally, an increase in a firm’s product quality leads to an increase in that firm’s equilibrium sales regardless of relative costs. See, for example, Deltas \textit{et al.} (2013).}

As for the fringe, perfect competition drives its price to its marginal cost. Thus, the willingness-to-pay for quality, $\theta_F$, of the consumer who is indifferent between purchasing from the fringe and not purchasing at all satisfies

$$\theta_F s_F - P_F = 0 \Rightarrow \theta_F^* = \frac{c_F}{s_F},$$

(5)

Every consumer with a value of $\theta_i$ in the interval $[\theta_F^*, \theta_D^*]$ purchases from the fringe. Note that Assumption 1 ensures that this interval has positive length. Given that $\theta_i$ has a standard uniform distribution, the sales volume of the fringe is given by

$$Q_F = \frac{P_D - c_F}{s_D - s_F} - c_F s_F.$$

Substituting in $P_D^*$ and simplifying we obtain

$$Q_F^* = \frac{1}{2} + \frac{1}{2} - \frac{c_F}{s_D - s_F} - \frac{c_F}{s_F}.\phantom{\text{(5)}}$$

(6)

It can be easily seen from equation (6) that an increase in the marginal cost of the fringe decreases its sales volume, while an increase in the marginal cost of the dominant firm increases the fringe’s sales volume. The comparative statics effect of a change in $s_D$ on $Q_F^*$ is exactly the reverse of its effect on the dominant firm’s quantity, since every sale lost by the dominant firm is gained by the fringe (and vice-versa). The effect of a change in $s_F$ is slightly more complicated because a second margin is present, namely the margin between buying from the fringe and not buying at all. On this second margin,
an increase in $s_F$ unambiguously increases sales, as some consumers who initially did not buy either product will purchase from the fringe at the higher quality. The net effect can be negative, meaning that an increase in the quality of the fringe firms’ product can result in a decrease in its sales, as we show next. The derivative of the generic product sales volume with respect to $s_F$ is

$$\frac{\partial Q^*_{F}}{\partial s_F} = \frac{1}{2} \frac{c_D - c_F}{(s_D - s_F)^2} + \frac{c_F}{s_F^2}. \quad (7)$$

This is negative if

$$\frac{c_F}{s_F^2} < \frac{1}{2} \frac{c_D - c_F}{(s_D - s_F)^2} \Rightarrow c_F < \frac{s_F^2}{2} \frac{c_F - c_D}{(s_D - s_F)^2}. \quad (8)$$

Notice that the order of marginal costs in the numerator on the right-hand side has been flipped in the last step. This condition could be satisfied if $c_F = \epsilon$, where $\epsilon$ is a small positive number that exceeds $c_D$. Indeed, there are parameter values that can satisfy condition (8) and also Assumption 1. We summarize the above discussion on equilibrium sales volumes in Proposition 1.

**Proposition 1** The dominant firm’s sales volume is increasing in $s_D$ and decreasing in $s_F$ if $c_D > c_F$, decreasing in $s_D$ and increasing in $s_F$ if $c_D < c_F$, and invariant to either quality if $c_D = c_F$. These results are reversed for the comparative statics of the fringe’s sales volume with respect to $s_D$. The sales volume of the fringe decreases in $s_F$ only if $c_D$ and $c_F$ are sufficiently small and $c_F > c_D$.

An examination of this proposition shows that neither the dominant firm’s nor the fringe’s sales volume is guaranteed to increase in its own quality. However, if an increase in the fringe’s quality reduces its sales volume, then it must be the case that an increase in the dominant firm’s quality decreases its sales volume as well, but the reverse does not

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6For example, when $c_F = \frac{1}{3}$, $c_D = \frac{1}{100}$, $s_F = \frac{4}{5}$, and $s_D = 1$, both Assumption 1 and inequality (8) are satisfied. Moreover, $Q_D = \frac{21}{40}$, $Q_F = \frac{9}{20}$, and $P_D = \frac{23}{40}$. 
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necessarily hold. We next turn to the welfare effects of changes in the dominant firm or fringe firm quality.

3. Consumer Surplus and Total Welfare

In this section, we evaluate the total welfare, \( W \), and consumer surplus, \( CS \), and we derive their comparative statics with respect to the quality of the two products. Suppressing the stars in the critical values of \( \theta \), total welfare is given by

\[
W = \int_{\theta_D}^{1} \theta s_D - c_D d\theta + \int_{\theta_F}^{\theta_D} \theta s_F - c_F d\theta
\]

\[
= \left( \frac{1}{2} s_D \theta^2 - c_D \theta \right) \bigg|_{\theta = \theta_D}^{\theta = 1} + \left( \frac{1}{2} s_F \theta^2 - c_F \theta \right) \bigg|_{\theta = \theta_F}^{\theta = \theta_D}
\]

\[
= \frac{s_D}{2} - c_D - \left( \frac{s_D}{2} \theta_D^2 - c_D \theta_D \right) + \frac{s_F}{2} \theta_D^2 - c_F \theta_D - \left( \frac{s_F}{2} \theta_F^2 - c_F \theta_F \right)
\]

\[
= \frac{s_D}{2} - \frac{s_D}{2} \theta_D^2 + \frac{s_F}{2} \theta_D^2 - \frac{s_F}{2} \theta_F^2 - c_D(1 - \theta_D) - c_F(\theta_D - \theta_F)
\]

\[
= \frac{s_D}{2} - \frac{s_D - s_F}{2} (1 - Q_D)^2 - \frac{s_F}{2} (1 - Q_F - Q_D)^2 - c_D Q_D - c_F Q_F,
\]

where the last line replaces \( \theta_D \) and \( \theta_F \) with the corresponding functions of \( Q_D \) and \( Q_F \). Substituting in the equilibrium values of \( Q_F^* \) and \( Q_D^* \) and simplifying we get

\[
W = \frac{1}{8} \left( 3s_D + s_F - 6c_D - 2c_F + \frac{3(c_D - c_F)^2}{s_D - s_F} + \frac{4c_F^2}{s_F} \right).
\]

Consumer surplus is given by

\[
CS = \int_{\theta_D}^{1} \theta s_D - P_D d\theta + \int_{\theta_F}^{\theta_D} \theta s_F - P_F d\theta
\]

\[
= \left( \frac{1}{2} s_D \theta^2 - P_D \theta \right) \bigg|_{\theta = \theta_D}^{\theta = 1} + \left( \frac{1}{2} s_F \theta^2 - P_F \theta \right) \bigg|_{\theta = \theta_F}^{\theta = \theta_D}
\]

\[
= \frac{s_D}{2} - P_D - \left( \frac{s_D}{2} \theta_D^2 - P_D \theta_D \right) + \frac{s_F}{2} \theta_D^2 - P_F \theta_D - \left( \frac{s_F}{2} \theta_F^2 - P_F \theta_F \right)
\]
\[
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\]

\[\begin{align}
    & = \frac{s_D}{2} - \frac{s_D}{2} \theta_D^2 + \frac{s_F}{2} \theta_D^2 - \frac{s_F}{2} \theta_F^2 - P_D(1 - \theta_D) - P_F(\theta_D - \theta_F) \\
    & = \frac{s_D}{2} - \frac{s_D - s_F}{2} (1 - Q_D)^2 - \frac{s_F}{2} (1 - Q_F - Q_D)^2 - P_D Q_D - P_F Q_F,
\end{align}\]

where, as above, the last line replaces \( \theta_D \) and \( \theta_F \) with the corresponding functions of \( Q_D \) and \( Q_F \). Substituting in the equilibrium values of \( Q^*_F \) and \( Q^*_D \) and simplifying we get

\[CS = \frac{1}{8} \left( s_D - 3s_F - 2c_D - 6c_F + \frac{(c_D - c_F)^2}{s_D - s_F} + \frac{4c_F^2}{s_F} \right).\]

We now derive the comparative statics of total welfare and consumer surplus with respect to changes in product quality.\(^7\) We do not consider simultaneous changes in production costs and product quality because the partial effect of increases in marginal costs are known. We start with the comparative statics of total welfare with respect to the quality of the branded good, whose derivation is immediate. They are stated in Proposition 2.

**Proposition 2** When consumer willingness-to-pay for quality, \( \theta \), is distributed \( U[0, 1] \), an increase in \( s_D \) increases welfare. In particular,

\[\frac{\partial W}{\partial s_D} = \frac{1}{8} \left( 3 - \frac{3(c_D - c_F)^2}{(s_D - s_F)^2} \right).\]

This is positive if \( \frac{c_D - c_F}{s_D - s_F} < 1 \), which is directly implied by Assumption 1.

We now examine more closely the expression in Proposition 2, starting with the case where \( c_D = c_F \). Recall that when the dominant and the fringe firms have the same marginal cost, a change in \( s_D \) does not change the dominant firm’s output. It is easy to see that in this case, the effect of an increase in the dominant firm’s quality must increase total welfare; the number of consumers who buy the dominant firm’s product does not change,

\(^7\)Strictly speaking, the comparative statics approach implies that quality changes are “exogenous,” for example, being different realizations of a stochastic process, such as an R&D project with an uncertain outcome. However, even if quality changes are the result of deterministic profit-maximizing firm decisions, the effect of quality changes on \( W \) and \( CS \) would still be as derived here.
and they enjoy a higher-quality product with no change in production costs. When $c_D \neq c_F$, an increase in $s_D$ affects the dominant firm’s quantity, which introduces an additional welfare effect. As in the $c_D = c_F$ case, infra-margin consumers enjoy higher quality at the same production cost, which tends to increase welfare. When $c_D > c_F$, an increase in $s_D$ also causes some consumers to switch from the fringe to the dominant firm. These consumers get a higher-quality product but at a higher production cost. Since $\theta_D(s_D - s_F) = P_D - c_F > c_D - c_F$ (see equation 2), the net contribution of these switches to welfare is positive, and thus the aggregate effect is also positive. When $c_D < c_F$, higher $s_D$ causes some consumers to switch from the dominant firm to the fringe, getting a lower-quality product but at a lower production cost. Under Assumption 1, the net contribution of these switches to welfare is negative, but not by enough to reverse the sign of the derivative when $\theta$ is distributed uniformly (as assumed here).\(^8\)

Also note that marginal costs enter in (13) only though the absolute value of their difference, which has a negative sign. When $c_D$ is much greater than $c_F$, there are very few consumers of the dominant firm’s product, so the welfare gain from an increase in $s_D$ is small. When $c_D$ is much smaller than $c_F$, an increase in $s_D$ causes many consumers to switch from the dominant firm to the fringe, which also causes the welfare gain to be small.

We next derive the comparative statics of welfare with respect to the generic product, which are reported in Proposition 3.

**Proposition 3** When consumer willingness-to-pay for quality, $\theta$, is distributed $U[0, 1]$, an increase in $s_F$ is not guaranteed to increase welfare. In particular,

$$
\frac{\partial W}{\partial s_F} = \frac{1}{8} \left( 1 + \frac{3(c_D - c_F)^2}{(s_D - s_F)^2} - \frac{4c_F^2}{s_F^2} \right),
$$

(14)

which under Assumption 1 is positive when $c_D \leq c_F$, but is of ambiguous sign when $c_D > c_F$.

**Proof.** Notice that $c_D$ enters only in the second term inside the bracket of Equation (14), and that this non-negative term is minimized (and becomes

\(^8\)As discussed in Balan and Deltas (2013), this result is not guaranteed to hold for non-uniformly distributed $\theta$.\)
zero) when setting $c_D = c_F$. Therefore, a starting point is to consider this case. Notice that under the condition $c_D = c_F$, Assumption 1 becomes 

$$\frac{c_F}{s_F} < \frac{1}{2} \Rightarrow \frac{4c_F^2}{s_F} < 1.$$ 

This demonstrates that $\frac{\partial W}{\partial s_F} > 0$ when $c_D = c_F$. This might appear to guarantee that the derivative is also positive when $c_D \neq c_F$, since the derivative is increasing in the absolute value of the difference between the two marginal costs. However, this is not the case. Recall that under Assumption 1, 

$$\frac{c_F}{s_F} < \frac{1}{2} + \frac{c_D - c_F}{s_D - s_F},$$

the right-hand side of which is increasing in $c_D - c_F$. Therefore, when $c_D > c_F$, $\frac{c_F}{s_F}$ can take on larger values. Since an increase in this term reduces $\frac{\partial W}{\partial s_F}$, sufficiently high values of $\frac{c_F}{s_F}$ can make the derivative turn negative. This is demonstrated in Figure 1 which plots $\frac{\partial W}{\partial s_F}$ as a function of $c_F$ for specific values of the remaining parameters (in particular, $c_D = \frac{9}{32}$, $s_D = 1$, and $s_F = \frac{1}{4}$).

![Figure 1](image_url)

Figure 1. Total welfare effect of fringe quality increase (left axis) and associated firm outputs (right axis) as a function of fringe marginal cost, $c_F$, with $c_D = \frac{9}{32}$, $s_D = 1$, and $s_F = \frac{1}{4}$.

9 Figure 1 also plots the equilibrium quantities for the dominant firm and the fringe, showing that both are indeed positive throughout the plotted range. Note that an increase in $s_F$ decreases total welfare when the market share of the fringe is very small. In this case, the negative effect on welfare from consumers switching from the dominant firm to the fringe outweighs the positive effect on welfare from the increased utility of the continuing consumers of the fringe (in Figure 1 $c_D > c_F$, so a narrowing of the quality gap leads to consumer switching from the dominant firm to the fringe).
For values of $c_F$ that are sufficiently high, but are still low enough for the fringe market share to be positive, total welfare decreases with $s_F$. By contrast, when $c_D < c_F$, the constraint in Assumption 1 becomes more binding, and thus $\frac{\partial W}{\partial s_F}$ is guaranteed to be positive. □

We now turn to the intuition behind Proposition 3. As above, we begin with the case where $c_D = c_F$. Once again, an increase in $s_F$ does not cause any consumers to switch from the dominant firm to the fringe, or vice-versa; the welfare change attributed to the continuing consumers of the fringe product from an increase in $s_F$ is positive. An increase in $s_F$ does cause some consumers to switch from not buying at all to buying from the fringe, which by revealed preference also increases welfare. When $c_D \neq c_F$, these effects are still present (and still tend to increase welfare), but now there is also an effect due to switching from the dominant firm to the fringe, or vice-versa. This latter effect is exactly the same as in the comparative statics on $s_D$ described above, but in the opposite direction, which is why the right-hand side of expressions (13) and (14) have a common term, but with opposite signs. As the proof of Proposition 3 demonstrates, it is possible that the net welfare effect can be negative.

We now show that not only is the effect of an increase in $s_F$ on welfare of ambiguous sign, but so is the difference between $\frac{\partial W}{\partial s_D}$ and $\frac{\partial W}{\partial s_F}$, even under the assumption of uniformly distributed $\theta$. This fact, which is relevant for the appropriate targeting of potentially scarce public resources to encourage R&D, is stated in Corollary 1.

**Corollary 1** The difference between $\frac{\partial W}{\partial s_D}$ and $\frac{\partial W}{\partial s_F}$ can be written as

$$\frac{\partial W}{\partial s_D} - \frac{\partial W}{\partial s_F} = \frac{1}{8} \left( 2 - \frac{6(c_D - c_F)^2}{(s_D - s_F)^2} + \frac{4c_F^2}{s_F^2} \right).$$

This is positive when $c_D$ is not too different from $c_F$, but is of ambiguous sign otherwise.

As can be seen in (4) and (6) above, when $c_D = c_F$, then $Q^*_D = \frac{1}{2}$, and when (in the limit) $c_F \approx 0$, then $Q^*_F \approx \frac{1}{2}$ as well. In this special case, an increase in $s_D$ or in $s_F$ each affect half of all consumers. However, the consumers who buy from the dominant firm have higher values of $\theta$ (they value the quality increase more), so the difference between the two derivatives is positive. Under an alternative assumption regarding the
distribution of $\theta$, this effect can be reversed only if the initial number of fringe firm customers is sufficiently greater than dominant firm customers, or if the distribution of $\theta$ above the median has a sufficiently short-tail.

Higher values of $c_F$ lead more consumers to not buy the product at all, and therefore to more consumers who do not benefit from an improvement in fringe quality. This tends to increase the difference between the two derivatives. The difference between the derivatives is decreasing in the absolute value of the cost difference, $|c_D - c_F|$. When this difference is large enough, it is possible that $\frac{\partial W}{\partial s_D} - \frac{\partial W}{\partial s_F} < 0$, i.e., that welfare is more responsive to an increase in the quality of the generic product than to an increase in the quality of the branded product. This is illustrated in Figure 2, which plots $\frac{\partial W}{\partial s_D} - \frac{\partial W}{\partial s_F}$ as a function of $c_F$ for specific values of the remaining parameters (in particular, for $c_D = \frac{155}{256}$, $s_D = 1$, and $s_F = \frac{1}{16}$). For low values of $c_F$, when the difference $c_D - c_F$ is large, the difference in the derivatives is negative (an increase in $s_F$ has a bigger effect on welfare than an increase in $s_D$), while the converse is true for high values of $c_F$. Figure 2 also plots the equilibrium quantities for the dominant firm and the fringe firm.

**Figure 2.** Difference in total welfare effects of dominant firm vs. fringe firm quality increases (left axis) and associated firm outputs (right axis) as a function of fringe marginal cost, $c_F$, with $c_D = \frac{155}{256}$, $s_D = 1$, and $s_F = \frac{1}{16}$.
fringe, showing that they are indeed positive throughout the plotted range. Note that when total welfare is more responsive to fringe quality than to dominant firm quality, the market share of the fringe greatly exceeds that of the dominant firm, which is consistent with the intuition conveyed earlier in this section.

We now turn our attention to the comparative statics on consumer surplus, which are derived in Proposition 4.

**Proposition 4** When consumer willingness-to-pay for quality, \( \theta \), is distributed \( U[0, 1] \), an increase in either \( s_D \) or \( s_F \) increases consumer surplus. In particular,

\[
\frac{\partial CS}{\partial s_D} = \frac{1}{8} \left( 1 - \frac{(c_D - c_F)^2}{(s_D - s_F)^2} \right),
\]

and

\[
\frac{\partial CS}{\partial s_F} = \frac{1}{8} \left( 3 + \frac{(c_D - c_F)^2}{(s_D - s_F)^2} - \frac{4c_F^2}{s_F^2} \right)
\]

which are both positive under Assumption 1.

**Proof.** The derivative of \( CS \) with respect to \( s_D \) can easily be shown to be positive following the first inequality of Assumption 1, which implies that \( \frac{c_D - c_F}{s_D - s_F} < 1 \). Now consider the derivative of \( CS \) with respect to \( s_F \). From the second inequality of Assumption 1, we have \( 1 + \frac{c_D - c_F}{s_D - s_F} > \frac{2c_F}{s_F} \). Given that both sides are positive, squaring yields \( 1 + \frac{(c_D - c_F)^2}{(s_D - s_F)^2} + 2 \frac{c_D - c_F}{s_D - s_F} > \frac{4c_F^2}{s_F^2} \). Since from Assumption 1 we know that \( \frac{c_D - c_F}{s_D - s_F} < 1 \), replacing \( \frac{c_D - c_F}{s_D - s_F} \) by 1 in the previous inequality implies that \( 1 + \frac{(c_D - c_F)^2}{(s_D - s_F)^2} + 2 \frac{c_D - c_F}{s_D - s_F} > \frac{4c_F^2}{s_F^2} \), which finally implies that the bracketed expression in equation (17) is positive. \( \square \)

Proposition 4 states that consumer surplus is unambiguously increasing in \( s_D \). We should note that this result does not necessary hold for a general distribution of \( \theta \), as was discussed in Balan and Deltas (2013). Proposition 4 also states that consumer surplus is unambiguously increasing in \( s_F \). This is in contrast to Proposition 3, which showed that \( \frac{\partial W}{\partial s_F} \) is of ambiguous sign. The reason is that part of the effect of higher \( s_F \) is to lower dominant firm
price and profit, which tends to decrease welfare but increase consumer surplus.

Though, as Proposition 4 states, consumer welfare surplus increases in both $s_D$ and $s_F$, one can show that it is more responsive to changes in $s_F$. This is important from a policy standpoint if the government has limited resources to spend on encouraging R&D. Comparing expressions (16) and (17), it is easy to see that when $c_D = c_F$ and $c_F = 0$, the increase in consumer surplus is larger when $s_F$ goes up than when $s_D$ goes up (3 instead of 1). Corollary 2, the proof of which parallels arguments in the proof of Proposition 4, shows that this ranking holds more generally.

**Corollary 2** The difference between $\frac{\partial CS}{\partial s_D}$ and $\frac{\partial CS}{\partial s_F}$ is given by

$$\frac{\partial CS}{\partial s_D} - \frac{\partial CS}{\partial s_F} = \frac{1}{8} \left( -2 - \frac{2(c_D - c_F)^2}{(s_D - s_F)^2} + \frac{4c_F^2}{s_F^2} \right) < 0.$$

This expression is always negative, i.e., consumers always benefit from an improvement in the fringe firm’s quality by more than from an increase in the dominant firm’s quality. One reason for this is that an increase in $s_F$ benefits not only the consumers of the generic product, but also the consumers of the branded product by forcing the dominant firm to reduce prices. That is, an increase in $s_F$ also has a redistributive effect by shifting surplus from the dominant firm to its consumers.\(^\text{10}\)

We conclude this section with a discussion of the distribution of gains from innovation, i.e., we pose the question of who benefits from innovation: the consumers or the firms? Let us first examine the expression (16) and compare it with that in Proposition 2. It is easy to see that when $c_D = c_F$, consumer surplus is less responsive than total welfare to an increase in $s_D$ (1 instead of 3), because some of the welfare increase is captured by the dominant firm in the form of higher prices. It is possible to show that $\frac{\partial W}{\partial s_D} > \frac{\partial CS}{\partial s_D}$ even when the costs are different, and for the same reason. In other words, an innovation by the dominant firm benefits society by more than it benefits consumers, since only part of the welfare gain is reflected in consumer surplus and the rest contributes to increased profits. Let us now

\(^{10}\)It is also easily shown that $\frac{\partial CS}{\partial s_D} - \frac{\partial CS}{\partial s_F} < \frac{\partial W}{\partial s_D} - \frac{\partial W}{\partial s_F}$, i.e., the difference in the responsiveness of total welfare to changes in $s_D$ and $s_F$ always exceeds that of consumer surplus.
examine the expression (14) and compare it with (17). It is easy to see that when \( c_D = c_F \), consumer surplus is more responsive than total welfare to an increase in \( s_F \). In fact, \( \frac{\partial W}{\partial s_F} < \frac{\partial CS}{\partial s_F} \) even when the costs are different, and for the same reasons as those described in the discussion following the proof of Proposition 4. Intuitively, an increase in fringe quality does not increase fringe profits, since fringe firms are perfectly competitive with constant marginal cost. The increase in fringe quality always reduces the profits of the dominant firm, by making the generic product a closer substitute to the branded product. Thus, aggregate profits go down, which directly implies that consumer surplus goes up by more than total welfare.

4. Concluding Remarks

In this chapter, we examine the effects of increases in product quality on total welfare and on consumer surplus. We show that these effects differ depending on whether the quality increase is to the product of a dominant branded firm at the technological frontier, or to the products of generic fringe firms inside the frontier. We show that these effects are not always positive, and that the welfare and consumer surplus effects of a quality improvement to the branded product vs. the generic products cannot always be unambiguously ranked.

Our framework abstracts from the incentives of firms to undertake costly investments in increasing the quality of their products, and also from the fact that the cost of a given quality increase is likely different for branded firms than for generic firms. Our results, then, are best viewed as comparative statics on the continuation payoffs of a given quality increase abstracting from any up-front costs. Endogenizing R&D for the fringe would require a somewhat different cost structure than the one used in this chapter, so that fringe firms earn some quasi-rents, or alternatively an assumption that firms compete in quantities rather than in prices.\(^{11}\) Either assumption would increase the complexity of the modeling. Moreover, our results should not be taken to the limit: even under the conditions where marginal improvements to fringe product quality are more valuable than are marginal improvements to branded product quality, eventually significant

\(^{11}\)See Motta (1993) for some related discussion.
increases in total welfare and consumer surplus cannot be achieved with improvements in fringe firm quality but rather require improvements at the technological frontier.

The results of this chapter can be thought of as illustrations of more general principles. When a technological improvement interacts with market imperfections and reduces them, the benefits are not limited to the benefits of a better product, but also include the benefits of a more competitive market structure. Similarly, if the technological improvement aggravates market imperfections, then the net benefit will be smaller and possibly negative.

References
Better Product at Same Cost