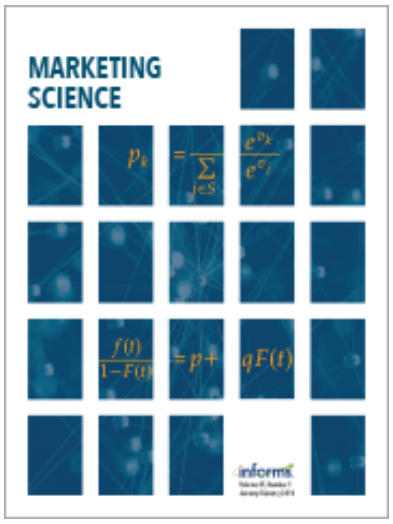

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Technological Advances, Transaction Costs, and Consumer Welfare

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Consumers incur many transaction costs in purchasing and using most products. This paper examines the effects of a reduction in such consumer transaction costs caused by market-level technological advances. Using a model in which consumers are simultaneously heterogeneous in their transaction costs and in their marginal valuations of product quality, this paper highlights two mechanisms that can cause such reductions in consumer transaction costs to lower consumer surplus and reduce consumer share of the total social surplus. Specifically, market-level technological advances reduce different consumers' transaction costs by different amounts and increase their reservation prices by different amounts, which can lead to: (i) product design changes that many current consumers do not like and (ii) homogenization in consumer reservation prices that allows a seller to extract more surplus through its pricing policy. This paper also shows that consumers may be better off with seller-induced higher consumer transaction costs. Finally, the paper shows how, depending on the nature of the quality production process, such reductions in consumer transaction costs can either lower or raise product qualities and consumer prices.

Key words: technological advances; transaction costs; consumer homogenization; product features; product pricing
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"Everything you buy costs you twice, once for the good itself, and once for the transaction."

(Forbes 1996)

1. Introduction

Transaction costs are an inevitable part of consumer purchase and consumption experiences. For almost all of the products we consume, we have to incur the monetary, time, and hassle costs of going to a store, waiting in line, making a payment, sometimes customizing the product to our own requirements before using it, sometimes learning how to use the product properly, and finally using the product itself.[1] These consumer transaction costs have two key features. First, their magnitudes can be large enough to "matter" and affect consumer choice behavior—for example, consumers with "nontechnical" backgrounds may not use a software product if its interface is not easy to use; consumers with high valuations of time may not visit an Internet business that has slow access speed, and so forth.[2] Second, these consumer transaction costs can reduce due to market-level technological developments—for example, developments in graphical interface systems have reduced consumer learning and memorization costs involved in using computer operating systems and programming languages. This paper focuses on reductions in consumer transaction costs caused by such *market-level advances* and asks the following two main questions: (i) Can a consumer become worse off from such a reduction in its transaction cost and (ii) can such reductions in consumer transaction costs lower the consumer share of the total social surplus? As secondary questions, we enquire about the effect of this reduction in consumers' transaction costs on seller's profitability, about a seller's incentive to invest in such market-level technological advances, and about the direction of change in product qualities and prices.

To examine these questions, we construct a simple model in which a seller sells a product to consumers who must incur certain transaction costs if

[1] Although we can include search costs also as part of transaction costs, we do not examine the search aspect of consumer choice behavior. What we have in mind are costs that *even* perfectly informed consumers pay while purchasing and consuming products. There are other papers, such as Lynch and Ariely (2000), that examine how consumer search costs affect prices, consumer welfare, etc.

[2] Formal surveys and empirical research also show that consumer transaction costs affect consumer choice behavior, such as store choice (Crafton 1979, Kim and Park 1997, Bell et al. 1998), offline versus online shopping choice (*Greenfield Online* 2000), and website choice (Forrester Research 1998).

they want to purchase and use the seller's product. Consumers are heterogeneous not only in their transaction costs, but also in their marginal valuations of product quality. In this framework, we show that reductions in consumer transaction costs caused by market-level technological advances can lower the surplus of some consumers and also lower the consumer share of the total social surplus. Further, such reductions in consumer transaction costs make the seller better off and, depending on the nature of the seller's quality production process, either lower or raise consumer price and product quality. Finally, we show that a reduction in consumer transaction costs caused by the seller's investment may reduce the total consumer surplus.

Although this paper derives these results in a simple setting, the intuition is more general and relies on the following three features of markets: (1) *market-level* technological advances generally reduce *individual* consumer's transaction costs by different amounts;[3] (2) consumers are usually heterogeneous in their preferences for product features; and (3) fixed costs or increasing returns to scale generally prevent sellers from offering *each* consumer in the market its "ideal" product.

Given that the sellers cannot offer products that perfectly suit each and every consumer's preference, the sellers choose product features that suit some consumers' preferences better than others', and, naturally, the sellers' decisions on which consumers' preferences to satisfy better are influenced by which consumers are more profitable to them. Because market-level technological advances generally reduce transaction costs of different consumers by different amounts, reservation prices of different consumers increase by different amounts, changing the relative profitability of different consumers to the sellers. This makes the sellers alter their product features such that the products now suit better the preferences of a different set of consumers. This change then hurts the set of consumers whose preferences are now less satisfied by the offered product features. Thus, although this latter set of consumers benefits directly from technological advances reducing their transaction costs, their surplus may be lowered overall.

Such market-level technological advances can also affect consumers adversely through another mechanism: They can reduce the heterogeneity in the total transaction costs incurred by different consumers in a market, making consumers more *homogeneous* in their effective reservation prices (valuation of product minus total transaction cost). And, as is well known, the more homogeneous the consumers are in their reservation prices, the higher the proportion of consumer surplus that a seller can extract using its marketing instruments (e.g., Adams and Yellen 1976). Therefore, market-level technological advances can homogenize consumers' effective reservation prices, leading to consumers being able to retain only a smaller share of the total social surplus.[4]

To see these ideas in some context, consider the personal computer operating system market. In the days of the command-line operating systems such as DOS where one had to remember the operating system commands and type them on the command line, tech-savvy consumers had lower transaction costs (learning cost, memorization cost, hassle cost) of using the system and less tech-savvy consumers had higher such transaction costs. Advances in the graphical-user-interface systems have clearly reduced the total transaction costs of less tech-savvy consumers by a larger amount than those of tech-savvy consumers. This has increased the effective reservation price of the less tech-savvy consumers by more than that of the tech-savvy consumers, making the less tech-savvy consumers more profitable to operating system sellers (as compared to before). This has, therefore, made the sellers design their product features keeping more in mind the preferences of these less tech-savvy consumers: For example, the design emphasis has become more on addition of multitudes of dialog boxes, requests for confirmations, pop-up help menus, hiding details of where files are stored, etc., and less on tech-savvy favorite features of efficiency (e.g., availability of wildcard characters, availability of batch-processing options to handle repetitive tasks), and stability (e.g., lack of lower-level bugs). Thus, although the tech-savvy consumers have benefited by ease of use of graphical interface systems, some may have lost overall because the software features are now farther away from their preferences and closer to those of the less tech-savvy consumers.[5] Similarly, in the word-processing software, even though the tech-savvy consumers have also benefited from the introduction of graphical interfaces (e.g., Word for Windows versus DOS-based Word

[3] For example, Internet retailing lowers consumers' "travel" costs by different amounts depending on whether or not they own a computer; improvement in road conditions lowers total transaction costs (e.g., time cost of travel) of consumers living closer to a retail outlet by a lesser amount than those of consumers living farther from the retail outlet, etc.

[4] Of course, a seller capable of perfect price discrimination can always extract all of consumer surplus. Thus, our story holds for the more realistic case where the seller cannot indulge in first-degree price discrimination.

[5] Lerner and Tirole (2000, p. 8) provide this colorful cite, "Microsoft always listens to its most ignorant customers.... The good that Microsoft does in bringing computers to nonusers is outdone by the curse that they bring on experienced users."

Perfect), some may have become worse-off overall because of the increased price and the changed feature set of the product (again skewed towards the tastes of less tech-savvy consumers).

In both the above examples of computer operating system software and word-processing software, advances in graphical interface systems have played another important role by diminishing the difference in the total transaction costs (of use) borne by tech-savvy and non-tech-savvy users—non-tech-savvy consumers can now use these softwares about as easily as can tech-savvy consumers. This *homogenization* on the dimension of total transaction costs, in turn, implies a homogenization in the effective reservation prices of consumers, allowing sellers to better extract consumer surplus.

One can also find other such instances of changes in product features in many other markets where consumer taste is very important to consumers, e.g., in movies, cuisine, arts, music, education, etc. For example, in the movie industry where consumers differ in their access to movies and in their tastes, it is often claimed that an increase in consumer access to Hollywood movies due to advances in distribution technologies and globalization has led to a change in the characteristics of these movies: There is more emphasis on special effects and action and less emphasis on nuances because the former characteristics are more understandable across consumers (François and van Ypersele 2002). One can also see the same forces working in the arena of children's schooling. Because children differ in their intellectual ability and in their parents' ability to pay to attend a school, any government help affecting the parents' ability to pay for school (e.g., vouchers) changes the ability distribution of children going to a particular school, leading to changes in quality of school curricula (Epple and Romano 2002).

Finally, the intuition for why advances reducing consumer transaction costs can cause consumer price to either rise or fall relies on the following two effects such advances generate: first, an increase in consumer reservation prices, and second, a change in product features/quality. The first effect leads to an increase in consumer price, and the second effect leads to an increase (decrease) in consumer price if the product change involves an increase (decrease) in product quality. Thus, if the product change involves an increase in product quality, then both effects work together to cause increased consumer price. On the other hand, if the product change involves a decrease in product quality, then the two effects work against each other and one can observe either a price increase or a price decrease. One implication of this result is that, to the extent one can associate Internet-based markets with lowered consumer transaction costs, one should not expect consumer prices to always decrease in these markets. This implication is consistent with the mixed empirical findings on the direction of change in consumer prices on Internet-based markets; for example, while some studies find higher consumer prices in some Internet markets (e.g., Lee 1998, Bailey 1998), other studies report lower consumer prices in such markets (e.g., Brynjolfsson and Smith 2000).

Relationship to Literature

The results in this paper are related to ideas in a number of streams of literature. The literature on congestion points out that consumers exert negative externality on other consumers by making common (fixed-capacity) facilities such as roads more congested (e.g., Vickrey 1963, 1969; Venables 1999); in our model, some consumers exert *negative preference-externality* on other consumers through their influence on the sellers' design and pricing policies for their (limited) product line.

Spence (1976) points out that markets may not offer some consumers their preferred products because the sellers face fixed costs of introducing product variants. Our model has the related idea that, in the presence of seller's fixed costs, heterogeneity in consumer preferences for product features may cause some consumers to exert negative externality on other consumers through product markets. Our model further applies this idea to examine how market-level technological advances reducing individual consumer transaction costs may adversely affect consumer welfare.

The literature on bundling shows that a firm may bundle its products to homogenize consumer reservation prices, making it easier for it to extract higher consumer surplus (e.g., Adams and Yellen 1976, Bakos and Brynjolfsson 2000). In our model, exogeneous technological advances, by reducing heterogeneity in individual consumer transaction costs, serve the role of homogenizing consumers' effective reservation prices. Thus, even without bundling, a firm in our framework faces more homogeneous consumer reservation prices, allowing it to extract higher consumer surplus and increase its share of the pie.

Finally, our paper is also related to the retailing literature that shows that consumer travel costs can influence a retailer's decision about the breadth and depth of the product assortment it carries (e.g., Betancourt and Gautschi 1990, Ratchford and Stoops 1992, and Messinger and Narasimhan 1997). In our model, consumer transaction costs influence the seller's product design and pricing decisions.

2. The Model

We consider a simple setting in which a seller chooses the price and quality of its product.

Consumer Description

Consumers differ on two dimensions. First, each consumer incurs a certain transaction cost, tx, with $x \in [0, 1]$, to purchase and consume the product. Second, each consumer has a certain marginal valuation of product quality, $\theta \in [0, 1]$.

Differences in marginal valuations of product quality, θ, could arise from differences in consumers' tastes or incomes. The transaction costs incurred by consumers, tx, with $x \in [0, 1]$, are affected by (i) parameter $t > 0$, a market-level technological parameter and (ii) parameter x, a consumer-specific parameter. One can think of the following examples to fix ideas about this formulation of consumer transaction costs: (i) in the case of use of a computer operating-system software, even though everyone in the market may face the same "ease-of-use" features in the operating system (market-level parameter t), differences in consumers' technical expertise and familiarity with the software (x) may lead to consumers incurring different total transaction costs; (ii) in the case of purchase from a retail store, even though all shoppers may face the same number of payment counters and the same service level (market-level parameter t), differences in consumers' time costs (x) may lead to consumers incurring different total transaction costs.

Consumers, as represented by the parameters (θ, x), are distributed uniformly over the unit square, with a total mass equal to one. A consumer with parameter (θ_i, x_i) gets a normalized utility of 0 if it buys the outside good (i.e., does not buy in this product category); on the other hand, if it buys a product with quality q at price p, it gets the following utility[6,7]

$$\underbrace{q\theta_i}_{\text{benefit}} - \underbrace{p}_{\text{seller's price}} - \underbrace{tx_i}_{\text{total transaction costs}}.$$

Demand Structure

The consumer with transaction-cost parameter x that is indifferent between buying and not buying has $\theta = \underline{\theta}(x)$ where $\underline{\theta}q - p - tx = 0$, or

$$\underline{\theta}(x) = \frac{p}{q} + \frac{t}{q}x. \tag{1}$$

Thus, the seller's demand from consumers with transaction-cost parameter x is $D(x) = 1 - \underline{\theta}(x)$ and its total demand is

$$D(p, q, t) = \int_0^1 D(x)\,dx = 1 - \frac{p}{q} - \frac{t}{2q}. \tag{2}$$

[6] We ignore any income effect.

[7] We also modeled utility functions with heterogeneity in only one consumer dimension (e.g., in only consumer transaction cost, or in only consumer marginal valuation of quality). However, those formulations did not allow us to get, in our setup, the key results regarding reduction in surplus of some consumers and reduction in consumer share of total surplus.

Figure 1 Consumer Mix Facing the Seller

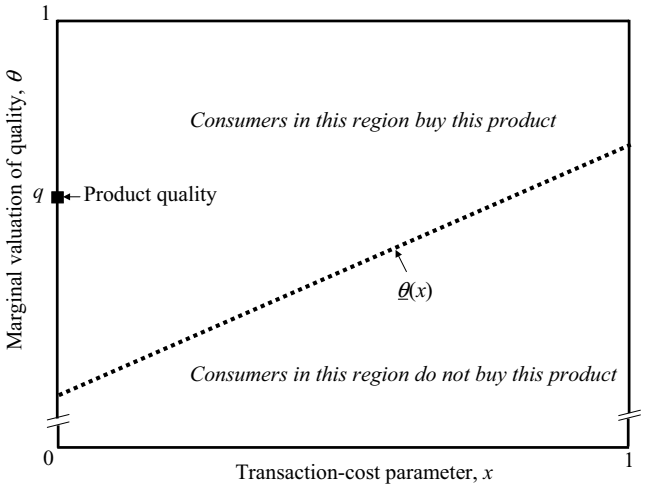


Figure 1 uses Equation (1) to show the demand structure.[8] The line representing the marginal consumers, $\underline{\theta}(x)$, slopes upward in this figure because if a consumer with high transaction cost (high x) finds it optimal to buy the product, then it must be that he values the product quality highly (high θ).

Cost Structure

We assume that the burden of quality production falls on the seller's variable costs. Further, following prior literature (e.g., Moorthy 1988), we assume that this cost is quadratic.[9]

2.1. Effects of Technological Advances Reducing Consumer Transaction Costs on Product Quality and Product Price

The seller's profit is $\pi = (p - q^2)\,D(p, q, t)$. Using (2),

$$\pi = (p - q^2)\left(1 - \frac{p}{q} - \frac{t}{2q}\right). \tag{3}$$

Product Price. Using (3) and solving the seller's profit-maximizing first-order condition, $\partial\pi/\partial p = 0$, we get[10]

$$\hat{p}(q, t) = \underbrace{-\frac{t}{4}}_{\text{reservation-price effect}} + \underbrace{\frac{q(t) + q(t)^2}{2}}_{\text{quality-effect}}. \tag{4}$$

[8] Throughout this paper, we consider small values of technological parameter t to rule out the cases where the total transaction costs ($=tx$) become so high that even consumers with the highest marginal valuation of quality ($\theta = 1$) are unable to afford to buy a product (e.g., here it implies $t \le 0.16$). Another interpretation of this restriction is that there are always *some* consumers in the society who value consumption of the product highly enough to be willing to buy it even if the transaction costs are high.

[9] We show in the appendix that a convex cost function is required in our setup for the second-order conditions to be satisfied.

[10] $\partial^2\pi/\partial p^2 = -2/q < 0$, and hence the second-order condition is satisfied.

Thus, a market-level advance that reduces consumer transaction costs affects product price through the following two routes: (i) *Direct reservation-price route*. Consumers' effective reservation prices increase, which increases the seller's ability to charge a higher price; (ii) *Indirect product-quality route.* The seller may find it optimal to change product quality, which affects its ability to charge a higher or a lower price (because buyers pay higher price for higher quality).

Product Quality. Inserting the value of $\hat{p}(q, t)$ from (4) in the seller's profit function in (3) gives

$$\hat{\pi} = \left[\frac{4q(q - q^3 - t) + t^2}{16q}\right] - \left[\frac{q(2q - 2q^2 - t)}{4}\right],$$

where the expression in the first square bracket is the seller's revenue and that in the second square bracket is the seller's cost. The choice of optimal quality q is determined by the first-order condition $\partial\hat{\pi}/\partial q = 0$, or

$$\underbrace{\frac{1}{16}\left[4 - 12q^2 - \frac{t^2}{q^2}\right]}_{\text{marginal revenue w.r.t. } q} = \underbrace{\frac{1}{4}\left[4q - 6q^2 - t\right]}_{\text{marginal cost w.r.t. } q}. \qquad (5)$$

One can then see that a decrease in market-level parameter t increases both the seller's marginal revenue w.r.t. q and the seller's marginal cost w.r.t. q. Intuitively, a reduction in t increases the seller's marginal revenue w.r.t. q because it makes all consumers richer and willing to pay more for quality. Similarly, a reduction in t increases the seller's marginal cost w.r.t. q because it makes more consumers able to buy the seller's product, and this increased sale increases the seller's marginal cost w.r.t. q as the seller has to incur quality-production cost for *each* unit it sells. Overall, the net effect of a reduction in t on the seller's optimal quality depends on which of these two effects—the increase in marginal revenue w.r.t. q or the increase in marginal cost w.r.t. q—is larger. Solving Equation (5), we get four roots and find that the following root maximizes the seller's profit[11]

$$q^*(t) = \tfrac{1}{6}\left[1 + \sqrt{1 + 6t}\right], \qquad (6)$$

which decreases as t reduces. Thus the seller reacts to market-level advances reducing consumer transaction costs by decreasing its product quality.

Inserting the expression of $q^*(t)$ from (6) in that of $\hat{p}(q, t)$ in (4) gives the following expression for optimal price

$$p^*(t) = \tfrac{1}{18}\left[2 - 3t + 2\sqrt{1 + 6t}\right]. \qquad (7)$$

[11] The other three roots are $(1 - \sqrt{1 - 2t})/2$, $(1 + \sqrt{1 - 2t})/2$, and $(1 - \sqrt{1 + 6t})/6$. The first two roots yield zero profit, and the third root yields negative profit.

Because

$$\frac{\partial p^*(t)}{\partial t} = \frac{2 - \sqrt{1 + 6t}}{6\sqrt{1 + 6t}} > 0,$$

in the relevant range of t (mentioned in Footnote 8), the optimal price decreases as t decreases. Thus, although a reduction in consumer transaction costs implies an increase in consumer effective reservation prices—which alone would imply that the seller can charge a higher price—the effect of decreased product quality overwhelms this reservation-price effect in our setup, and hence the seller charges a lower product price.

Proposition 1 (Product Quality and Price). *A market-level advance that reduces consumer transaction costs*: (i) *lowers product quality and* (ii) *lowers product price*.

2.2. Effects of Technological Advances Reducing Consumer Transaction Costs on Consumer Surplus and Seller Profit

Marginal Consumers and Consumer Surplus. Using the expressions for optimal price and quality from (6) and (7) in the expression for marginal consumers, $\underline{\theta}(t, x)$, given in (1), we get

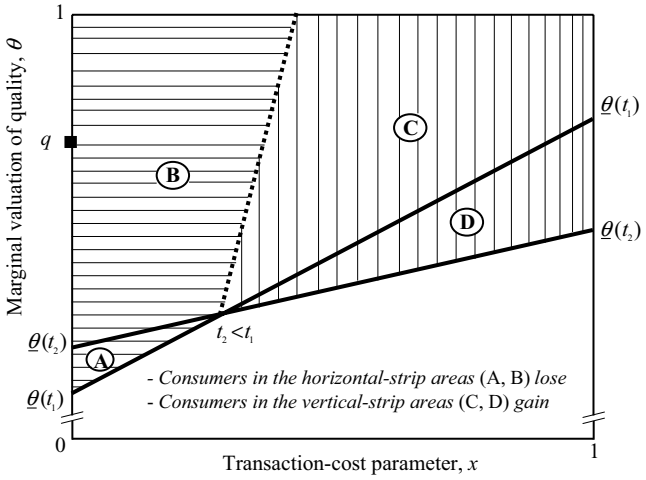
$$\underline{\theta}^*(t, x) = \tfrac{5}{6} + \sqrt{1 + 6t}\left(-\tfrac{1}{6} + x\right) - x.$$

Because

$$\frac{\partial \underline{\theta}^*(t, x)}{\partial t} = \frac{-1 + 6x}{2\sqrt{1 + 6t}} \lesseqgtr 0 \quad \text{for } x \lesseqgtr \frac{1}{6},$$

we can see that a decrease in t brings in some new consumers to this market (with $x > \frac{1}{6}$, shown in Area D in Figure 2), but excludes some existing consumers

Figure 2 Effects of Reduced Consumer Transaction Costs on Consumer Surplus



from this market (with $x < \frac{1}{6}$, shown in Area A in Figure 2).

We next examine the effect of a reduction in t on total consumer surplus, $\mathrm{CS} = \int_0^1 \int_{\underline{\theta}}^1 (\theta q - p - tx)\, d\theta\, dx$. Using (1), (6), and (7), this yields

$$\mathrm{CS}^*(t) = \frac{\left[2 - 45t + (2+21t)\sqrt{1+6t}\right]}{216} \quad \text{and}$$
$$\frac{\partial \mathrm{CS}^*(t)}{\partial t} = \frac{1}{24}\left[-5 + \frac{3(1+7t)}{\sqrt{1+6t}}\right] < 0, \tag{8}$$

in the relevant range of t (mentioned in Footnote 8). Thus, technological advances reducing consumer transaction costs increase the overall consumer surplus. To see the effect on the surplus of an *individual* consumer with parameter (x, θ), we use the expression for its surplus

$$\mathrm{CS}^*(\theta, x) = \theta q^* - p^* - tx$$
$$= \tfrac{1}{18}\left[\left(1 + \sqrt{1+6t}\right)(3\theta - 2) + t(3 - 18x)\right].$$

Because

$$\frac{\partial \mathrm{CS}^*(\theta, x)}{\partial t} = \frac{1}{6}\left[1 - 6x + \frac{3\theta - 2}{\sqrt{1+6t}}\right]$$

is not uniformly negative in the whole parametric space describing the existing consumers (i.e., in the $\theta \in [\underline{\theta}, 1]$ and $x \in [0, 1]$ space), we know that some existing consumers become worse-off with a reduction in their transaction cost tx. We further analyze this expression for $\partial \mathrm{CS}^*(\theta, x)/\partial t$ and show in Figure 2 that the following two types of existing consumers become worse-off: (i) those who could afford the product earlier (mainly because of their low transaction costs), but can no longer do so (Area A in Figure 2); and (ii) those who continue to buy the product, but lose because of the changed quality-price offering (Area B in Figure 2).

Overall, as shown in Figure 2, consumers who lose are the ones with low transaction-cost parameter (x) and high marginal valuations of quality (θ). This is intuitive because these consumers have low transaction costs to start with (i.e., low tx), and hence have the least to gain from technological changes reducing these costs; and since they value the quality highly (high θ), they have the most to lose from the reduction in product quality—although accompanied by price decrease—caused by a reduction in consumer transaction cost.

Seller Profit. Using the equilibrium expressions of p^* and q^* from (6) and (7) in the expression for seller's profit in (3), we get

$$\pi^*(t) = \tfrac{1}{54}[1 - 18t + (1+6t)^{3/2}] \quad \text{and}$$
$$\frac{\partial \pi^*(t)}{\partial t} = \tfrac{1}{6}\left[-2 + \sqrt{1+6t}\right] < 0, \tag{9}$$

in the relevant range of t. Thus, the seller benefits from a reduction in consumers' transaction costs. This is intuitive because a reduction in consumers' transaction costs (i) increases effective reservation prices of all the existing consumers, (ii) brings in some new consumers to the seller's market, and (iii) homogenizes effective reservation prices of consumers. All these effects benefit the seller.

Consumer Share of the Total Social Surplus. Using (8) and (9),

$$\frac{\partial[\mathrm{CS}^*/(\mathrm{CS}^* + \pi^*)]}{\partial t}$$
$$= \frac{24t\left[1 - 6t + \sqrt{1+6t}\right]}{\sqrt{1+6t}\left[2 - 39t + (2+15t)\sqrt{1+6t}\right]^2} > 0 \tag{10}$$

in the relevant range of t. Thus, a reduction in market-level parameter t decreases the consumer share of the total social surplus. The intuition for this result relies on the well-known fact that the less heterogeneous the consumers are in their reservation prices for a product, the higher the proportion of surplus that sellers can extract using their marketing instruments (Adams and Yellen 1979). Because the total consumer transaction costs in our framework are distributed uniformly in the interval $[0, t]$, a reduction in t reduces the heterogeneity in total consumer transaction costs and hence makes consumers more homogeneous in their effective reservation prices for the product (as also evidenced in Figure 2 by a flattening of the line $\underline{\theta}(x)$ representing marginal consumers). This enables the seller to extract more surplus from consumers.

We summarize these findings in the following proposition.

Proposition 2 (Consumer Surplus and Seller Profit). *A market-level advance that reduces consumer transaction costs*: (i) *reduces the surplus of some consumers*, (ii) *reduces the consumer share of the total social surplus*, *and* (iii) *increases the seller's profit*.

3. Seller's Incentive to Invest in Reducing Consumer Transaction Costs

The analyses in the last section considered the case where parameter t reduces due to exogeneous market-level advances. However, there are many cases where the seller can incur either some variable or fixed costs to reduce parameter t. Some examples where primarily variable costs reduce consumer transaction costs are where a seller can make its products more customizable, offer increased minutes of toll-free helpline, etc.; examples where primarily fixed costs reduce consumer transaction costs are where a seller can add online help features in software,

increase its customer parking spaces, etc. In this section, we allow for such investments by the seller and examine whether the seller may have an incentive to reduce consumer transaction costs by more than what consumers, in aggregate, prefer.

We know from the last section that the seller will have an incentive to invest in reducing parameter t because that will lead to the following pro-seller effects: (i) increase in consumers' effective reservation prices, (ii) entry of new consumers to its market, and (iii) homogenization of consumers' effective reservation prices. We also know from the last section that if parameter t reduces with no direct cost to consumers, then some consumers become worse-off, consumer share of total surplus reduces, but total consumer surplus increases. Thus, if the seller investment in reducing t were to add any additional burden on the consumers, then the total consumer surplus may also reduce. This can happen when the seller invests in reducing t because the seller will then pass on some of its cost of reducing t to the consumer price.

We confirm this intuition formally in the appendix, where we allow the seller to spend amount $C(t)$ to affect the market-level technological parameter t. We find that while a reduction in t by seller investment in fixed cost $C(t)$ does not reduce total consumer surplus, a reduction in t by seller investment in variable cost $C(t)$ can reduce total consumer surplus.

Proposition 3. *A seller's* (*variable-cost*) *investment in reducing consumer transaction costs can make consumers, in aggregate, worse-off.*

4. Extensions

4.1. When the Burden of Quality Production Is on Fixed Cost

In the main model, we considered the cases where the burden of quality production is on seller's variable cost. Here we discuss our key results in cases where this burden is on seller's fixed cost.

First, a decrease in market-level parameter t increases the seller's marginal return to quality here for the same reason as in the variable-cost case: increase in consumers' effective reservation prices and, hence, increased ability to pay for increased quality. However, unlike the variable-cost case, there is no effect of reduction in t on seller's marginal cost of quality here because the increased sales due to reduction in t does not affect the seller's (fixed) cost of quality. Thus, the seller in the fixed-cost case responds to market-level advances reducing consumer transaction costs by increasing its quality. This is in contrast to the variable-cost case where, in our setup, the seller responds by decreasing its quality. Therefore, while the consumer transaction costs and product quality are complements in the variable-cost case, they are substitutes in the fixed-cost case. Overall, since these advances reducing consumer transaction costs increase consumer reservation price and, as discussed above, also increase product quality, the seller here can command a higher price. Thus, the seller in the fixed-cost case responds to market-level advances reducing transaction costs by increasing its quality and price.

Aside from these results on product quality and product price, all other results here are the same as in the variable-cost case because their intuition is independent of the seller's cost structure. Specifically, some consumers lose with a reduction in their transaction costs because the product design is now skewed towards the taste of the "newly important" set of consumers. Consumer share of total surplus reduces because of consumer homogenization effect caused by reduction in t. Finally, the seller benefits from reduction in t because it brings in new consumers, increases existing consumers' reservation prices, and homogenizes consumers' effective reservation prices.

We summarize these results in the following proposition.

Proposition 4. *When the burden of quality production is on the fixed cost, a market-level advance that reduces consumer transaction costs*: (i) *raises product quality and product price*, (ii) *reduces the surplus of some consumers*, (iii) *reduces the consumer share of the total social surplus, and* (iv) *increases the seller's profit.*

4.2. When the Seller Offers Two Products

In the main model, the seller could offer only one product. In the technical appendix,[12] we extend the model to allow the seller to offer two products, and show the following results.

Proposition 5. *A market-level advance that reduces consumer transaction costs*: (i) *lowers the quality and price of both products*, (ii) *increases the range of product qualities*, (iii) *reduces the surplus of some consumers and the consumer share of the total social surplus, and* (iv) *increases the seller's profit.*

Thus, all the results from the main model carry over to this two-product case. The additional result we get is the increase in the range of product qualities offered by the seller.[13]

[12] The technical appendix is available from the journal's website.

[13] We also find that if the burden of quality production is on seller's fixed costs, then the seller in our setup offers only one product and all our earlier results from the one-product model hold. Intuitively, in the fixed-cost case, because the marginal cost does not increase with product quality, the prices of the two products are so close that the lower-quality product significantly cannibalizes the sales

4.3. Firm Strategy on Horizontal and Vertical Attributes

If we reinterpret parameter x in our model as representing consumers' ideal points on a horizontal product attribute and parameter t as a parameter that influences how much importance consumers place on the horizontal product attribute, then one can utilize our model to examine a different, but interesting, question: How does a reduction in consumer importance of horizontal product attribute affect seller's choice of vertical and horizontal product attributes?[14]

In prior literature, Neven and Thisse (1990) have analyzed a related setup to show an interesting "switching" result. Specifically, in a setup where two competing firms choose the values of horizontal and vertical attributes for their products, Neven and Thisse show that, depending on the importance of the horizontal attribute, the competing sellers choose either (i) maximal differentiation on the vertical product attribute and minimal differentiation on the horizontal product attribute, or (ii) vice versa. That is, a change in the importance of the horizontal attribute causes the sellers to switch between the use of vertical product attribute and horizontal product attribute to differentiate their products.

In the technical appendix, we extend our model to allow the seller to choose the values of both vertical and horizontal product attributes for its two products,[15] and show the following result.

Proposition 6. *A reduction in consumer importance of horizontal product attribute, t, causes the seller to switch from the use of horizontal product attribute to vertical product attribute to differentiate its products.*

Specifically, we show that when the consumer importance of horizontal product attribute, t, (i) is high, then the seller differentiates its products on the horizontal product attribute (chooses $x = \frac{1}{4}$ and $x = \frac{3}{4}$ in the $[0, 1]$ interval) but not on the vertical product attribute; (ii) is low, then the seller differentiates its products on the vertical product attribute but not on the horizontal product attribute (chooses $x = \frac{1}{2}$ for both products in the $[0, 1]$ interval); and (iii) decreases further, then the seller increases the degree of differentiation on the vertical product attribute, while keeping the products undifferentiated on the horizontal product attribute.

Intuitively, a reduction in consumer importance of horizontal attribute, t, decreases the seller's payoff to differentiation on the horizontal attribute, and hence it switches to the use of vertical attribute to differentiate its products. Thus, we also get a "switching" result similar to that of Neven and Thisse (1990). However, we do not get maximal differentiation on the horizontal product attribute because, unlike Neven and Thisse, the two products in our model are sold by the same seller, and hence the need for differentiating products to soften price competition is relatively lower in our model. Similarly, we do not get maximal differentiation on the vertical product attribute because, unlike Neven and Thisse, we consider that producing quality is costly to the seller and allow consumers to have outside options.

5. Concluding Remarks

Summary. This paper shows two mechanisms through which technological advances reducing consumer transaction costs can affect consumers adversely. First, such advances reduce different consumers' transaction costs by different amounts and hence can have a homogenizing effect on consumers' effective reservation prices; this consumer homogenization then allows a seller to extract a larger part of consumer surplus through its pricing policy. Second, the differential decrease in different consumers' transaction costs changes the set of consumers the seller finds more profitable, giving the seller an incentive to change the features of its products to appeal more to the tastes of this newly important set of consumers; this change in product features can then make the previously important set of consumers worse-off. Although a specific model is used to show these two mechanisms in this paper, we expect these mechanisms to also emerge in other models that incorporate the following market features: differences in consumers' transaction costs, differences in consumers' tastes for some important product feature(s), and a limited product line offered by sellers owing to their fixed costs or increasing returns to scale.

This paper also shows some results on product quality and product price that depend on the nature of the seller's quality-production process. Specifically, market-level technological advances that reduce consumer transaction costs cause, in our setup, a decrease (increase) in product quality and product price if the burden of quality production falls on the seller's variable (fixed) cost. Intuitively, such market-level advances have two effects: increase in consumer reservation prices, and change in product features/quality. The first effect leads to an increase in consumer price, and the second effect leads to an increase (decrease) in consumer price if the product change involves

of the more profitable higher-quality product. Thus, the seller there finds it optimal to offer only one product (this potentially adverse effect of increasing product line is well known from Moorthy 1984, Salant 1989, and Acharyya 1998).

[14] We thank the area editor for pointing out this alternative interpretation and the additional questions that one can ask in this interpretation.

[15] For the reason mentioned in Footnote 13, the seller offers only one product in our setup if the burden of quality production is on its fixed cost.

an increase (decrease) in product quality. Thus, in the fixed-cost case where we find product change to involve an increase in product quality, both the effects work together to increase consumer price. On the other hand, in the variable-cost case where we find product change to involve a decrease in product quality, the two effects work in opposite directions, and hence can lead to a net increase or decrease in consumer price.

Limitations and Future Research. The results in this paper are derived using specific functional forms for consumer utility function and seller's production function; specifically, they use a linear utility function and a quadratic quality production function. It will be useful to consider more general demand and production settings in future research to derive precise boundary conditions for our results. This paper also assumes independence between a consumer's transaction cost and marginal valuation of quality. One can allow positive or negative correlation between these two consumer attributes; intuitively, that will affect the characteristics of the set of consumers that become worse-off with reduction in their transaction costs. Another assumption in our setup is that technological advances reduce each consumer's transaction costs. One can also examine cases where these advances reduce some consumers' transaction costs while increasing these costs for some other consumers. For example, suppose the transaction costs of consumers with initially low (high) level of transaction costs increase (decrease) with technological advances. In that case, consumers' net reservation prices will become even closer, and the consumer homogenization effect shown in this paper will still occur. This will allow the seller to extract a higher proportion of total surplus, making the consumer share of total surplus go down with reduction in consumer transaction costs in that setting also. Further, the consumers whose transaction costs increase there will become even more worse-off than in our model, because not only will the product features be skewed away from their preferences (as in our model), but their transaction costs will also increase with these advances (unlike our model). Finally, all the results in this paper are derived in a monopoly setting; it will also be useful to examine these issues in an oligopolistic setting in future research.

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Appendix. Convex Cost Function Requirement
The seller's profit function is $\pi = (p - c(q))D(\cdot)$ where $D(\cdot)$ is as in (2). Solving $\partial\pi/\partial p = 0$ for the optimal price, we get $\hat{p} = -t/4 + [q + c(q)]/2$. Further, $\partial^2\pi/\partial p^2 = -2/q$ and hence the soc is satisfied. Using the expression of $\hat{p}$ in $D(\cdot)$ and π, we get

$$\widehat{D} = \frac{2q - t - 2c(q)}{4q}, \qquad \hat{\pi} = \frac{[2q - t - 2c(q)]^2}{16q}.$$

The soc w.r.t. q is

$$\frac{\partial^2\hat{\pi}}{\partial q^2} = \frac{[t + 2c(q) - 2qc'(q)]^2 - 2q^2c''(q)[(2q - t - 2c(q))]}{8q^3}.$$

Using the requirement that $\widehat{D} > 0$, we note that $\partial^2\hat{\pi}/\partial q^2 > 0$ for $c''(q) \le 0$. Therefore, we cannot use a linear or concave cost function.

Seller Investment in Reducing Consumer Transaction Cost
(i) *Cost of Reducing t is a Fixed Cost*. The seller's profit function is $\pi = (p - q^2)D(\cdot) - C(t)$, where $D(\cdot)$ is as in (2). Solving for profit-maximizing p and q, we get the same expressions as derived earlier in (6) and (7). Similarly, inserting these in the expression of consumer surplus, we get the same expression for consumer surplus as derived earlier in (8). Then, because we showed earlier that a reduction in t increases this total consumer surplus, the same result holds here also.

(ii) *Cost of Reducing t is a Variable Cost*. The seller's profit function is $\pi = (p - q^2 - c(t))D(\cdot)$, where $D(\cdot)$ is as in (2). Solving $\partial\pi/\partial p = 0$ for the optimal price, we get $\hat{p} = [2q + 2q^2 - t + 2c(t)]/4$. Further, $\partial^2\pi/\partial p^2 = -2/q$, and hence the soc is satisfied. Using the expression of $\hat{p}$ in π, we get $\hat{\pi} = [2(-1 + q)q + t + 2c(t)]^2/(16q)$. Solving $\partial\hat{\pi}/\partial q = 0$ for the optimal quality, we get four roots, but the following root maximizes the seller's profit:[16] $q^* = [1 + Z]/6$, where $Z = \sqrt{1 + 6t + 12c(t)}$. Inserting this in $\hat{p}$, we get $p^* = [2 - 3t + 12c(t) + 2Z]/18$. Using the expressions of p^* and q^* in the expressions for seller's profit function and consumer surplus, we get

$$\pi^* = [1 - 18t - 36c(t) + Z^3]/54,$$

$$\mathrm{CS}^* = \frac{1}{108(1+Z)}\big[2 - 6t + 63t^2 - 12c(t) + 144tc(t) + 144c(t)^2 - 2(-1 + 6t + 12c(t))Z\big].$$

Differentiating w.r.t. t, we get

$$\frac{\partial\pi^*}{\partial t} = [(1 + 2c'(t))(-2 + Z)]/6,$$

$$\frac{\partial\mathrm{CS}^*}{\partial t} = \frac{1}{12Z(1+Z)^2}\big[-2 + 63t^2 + 2Z(-1 + 3t - 2c'(t)) - 4c'(t) - 12tc'(t) + 54t^2c'(t) + 144c(t)^2(1 + 2c'(t)) + 12c(t)(-1 + 18t + (-2 + 24t)c'(t))\big].$$

Thus, for the condition for $\partial\pi^*/\partial t < 0$ and $\partial\mathrm{CS}^*/\partial t > 0$ to be simultaneously true involves $c(t)$ and $c'(t)$, and does not

[16] The other three roots are $\frac{1}{2}(1 - \sqrt{1 - 2t - 4c(t)})$, $\frac{1}{2}(\sqrt{1 - 2t - 4c(t)} + 1)$, and $\frac{1}{6}(1 - \sqrt{1 + 6t + 12c(t)})$. The first two roots yield zero profit, and the third root yields lesser profit than the root we use.

involve $c''(t)$ (e.g., concavity or convexity, etc.). Because it is not instructive to interpret a condition involving $c(t)$ and $c'(t)$, we show the result by using a simple cost function $c(t) = 1/(100t)$, and showing that this condition holds at the boundary point $t = 4/25$ (among other values of t, recalling that $t \leq 4/25$). Specifically, here $\partial\pi^*/\partial t$ (at $t = 4/25$) $= -0.012 < 0$, and $\partial CS^*/\partial t$ (at $t = 4/25$) $= 0.023 > 0$. Therefore, a seller investment in reducing t can make consumers, in aggregate, worse-off.

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