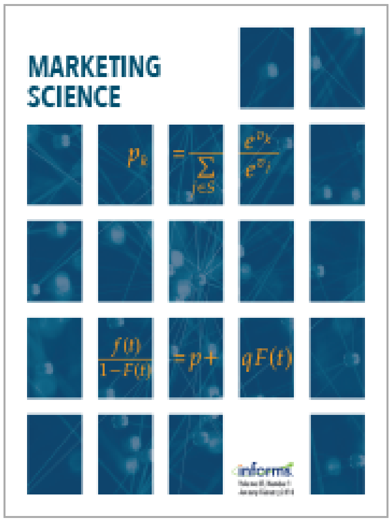

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Buyer Search Costs and Endogenous Product Design

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Buyer search costs for price are changing in many markets. Through a model of buyer and seller behavior, I consider the effects of changing search costs on prices both when product differentiation is fixed and when it is endogenously determined in equilibrium. If firms cannot change product design, lower buyer search costs for price lead to increased price competition. However, if product design is a decision variable, lower search costs for price may also lead to higher product differentiation, which decreases price competition. In this case, the overall effect of lower buyer search costs for price may even be higher prices, lower social welfare, and higher industry profits. The result is especially interesting because recent technological changes, such as Internet shopping, can affect the market structure through lowering buyer search costs.

Key words: product design; product positioning; search costs; market structure; endogenous firm decisions; e-commerce
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1. Introduction

In many cases, buyers must incur search costs to find the price of a product. These search costs affect prices through consumer behavior, thereby directly affecting the demand an individual firm faces. However, search costs also have an indirect effect: They may affect other market structure parameters, for example, the product design. Such parameters may be constant in the short term, but in the long run may be determined by the market agents as well. Changes in those parameters may, in turn, affect prices. To predict the effect of changing search costs, it is important to consider both direct and indirect effects. In this paper, I analyze the effect of consumer search costs for price on firms' product design decisions and show that this effect may have important implications for the overall effect of consumer search costs on prices, profits, and social welfare.

To point up the importance of considering the impact of search costs on product design as well as pricing decisions, consider the effect of the Internet. When e-commerce was in the early stages, most people predicted that the Internet would bring prices down to marginal costs, commoditizing markets and eroding profits. *Business Week* wrote in May 1998: "The result [of the Internet] is fierce price competition, dwindling product differentiation, and vanishing brand loyalty."

The predictions of lower prices, profits, and price dispersion were also supported in some academic literature.[1] The arguments were as follows. When people think about the Internet marketplace, one thing that immediately comes to mind is that the Internet reduces buyer search costs. Online search engines and shopbots are especially useful as price-searching tools. Therefore, buyers are better informed about prices. This may lead to higher competition and lower prices. Even if the online firms have lower fixed costs, profits are likely to erode because margins are competed away. Further, price dispersion is predicted to become lower because in the absence of frictions, the market prices should become closer to the perfectly competitive price.

The available empirical evidence, however, is at odds with the above predictions. Price dispersion online is considerable (Iyer and Pazgal 2003). In fact, Smith and Brynjolfsson (1999) and Clemons et al. (2000) show that price dispersion online may be larger than that offline.[2] Further, in some categories, prices are not close to marginal costs.

Missing in the above arguments is the consideration of the firm response in nonprice variables. For example, if firms can respond by changing product design, then we must analyze these changes or it will not be clear what happens to profits and consumer

[1] For example, see Wernerfelt (1994), Alba et al. (1997), Bakos (1997), Brynjolfsson and Smith (1999).

[2] See also Brown and Goolsbee (2002), Bayer and Morgan (2001), and references therein.

welfare. In fact, this paper shows, in particular, how the consideration of both price and product decisions may reconcile the observation that both price dispersion and prices may in some instances increase as consumer search costs for price decrease. Therefore, it is important to consider product design as an endogenous parameter.

Considering search costs is intrinsically linked to considering incomplete information. In a world with complete information, buyers could perfectly predict seller prices and would not have to search for them. This could lead to a market with prices at the monopoly level, even when search costs are infinitesimally small (Diamond 1971). However, in the real world, buyers cannot perfectly predict prices and have to search for them because buyers know that different sellers may set different prices due to, for example, different information they (sellers) have about the buyer valuation.

Through explicit modeling, I consider how the incomplete seller information about demand interacts with buyer search costs for price to produce an equilibrium intermediate between Bertrand and monopoly pricing and where the equilibrium price smoothly increases with search cost if the product design does not change. I further use this framework to analyze the effect of changing search costs on equilibrium pricing, profits, and the welfare-related variables with and without endogenous changes in the products offered. The main results of this paper are the following.

First, I find that product differentiation increases as search costs decrease. This result is intuitive and seems to be very robust. As an example, consider how the two major department stores in the St. Louis area, Famous Barr and Dillard's, differentiate from each other in the product categories they sell offline and online. Offline, their stores sell very similar product categories (full line of apparel, makeup and fragrance, home furnishings, etc.). Online, they sell different categories (Famous Barr sells jewelry, fragrances, home appliances, flowers, but no apparel except for jeans and Dockers; whereas Dillard's sells a wide range of apparel, which is, however, Dillard's exclusive, as well as shoes and accessories). Clearly, these two retailers are more differentiated online than offline in the product selection.

Second, as search costs decrease, prices, price dispersion, and profits need not always decrease. The endogenous investment in product differentiation can more than counteract the increase in competition due to a lower search cost for price. Furthermore, with individual firm's investment in product design, it is possible that as search costs decrease, the average profit in the industry would increase. This is because an individual firm's investment in product differentiation is a positive externality for the other firms. This means that in a market where seller actions and/or policies considerably affect buyer valuations, one can see that price competition is not as strongly affected—or is even decreased—by reduced search costs.

Third, lower consumer search costs need not necessarily mean an increase in social welfare. It is even possible that when search costs decrease, all agents become worse off.[3] This is because the incentives for a firm to differentiate might be higher than the incentives for a social planner to differentiate. Even though consumers might be enjoying a better fit with highly differentiated products, they might be worse off due to higher prices; firms, at the same time, may be worse off because they have spent more on the product design than they receive from higher prices. The negative effect of lower search costs on social welfare is more likely in markets where the product variety is already optimal or higher than optimal for social welfare.

A number of Internet-related papers have looked at the bundled search for prices and product information, where buyers search to find a product with the best fit (Bakos 1997, Lal and Sarvary 1999, Lynch and Ariely 2000), but these papers do not consider the firm's decision on product design. Anderson and Renault (1999) consider how the search for product attributes affects the product variety that is optimal for the firms. In contrast to the results of this paper, they find that if search costs for product attributes decrease, firms might benefit from lower product variety. Bergen et al. (1996) discuss how retailers use branded variants to increase search costs. Theoretical models of product differentiation with and without the firms' pricing decisions were considered as well (e.g., Hotelling 1929, D'Aspermont et al. 1979, De Palma et al. 1985, Moorthy 1988, Villas-Boas and Schmidt-Mohr 1999), but not as much in the context of consumer search costs. On the other hand, many papers related to competition and search costs (e.g., Narasimhan 1988, Diamond 1971, Stiglitz 1979, Stiglitz 1987, Lal and Villas-Boas 1998) do not address firms' incentives to differentiate.

The results of the paper have a number of implications for practitioners. Consider an industry where search costs for price have decreased or are decreasing. First, managers in that industry must increase efforts to differentiate their products from the products of a competitor. Furthermore, they can expect the competitors to do the same. Second, this individual firm response in product design can be quite a

[3] Bayer and Morgan (2001) consider how the Internet may reduce social welfare due to the introduction of a costly information system operated by a profit maximizing "gatekeeper."

successful countermeasure to reducing search costs, because the outcome could be an increase in profits as compared to the environment with higher search costs. Third, an analysis of such an industry that does not consider the product design decision by competing firms would result in an underestimation of such industry's profitability. This implication is of particular interest to investors as well as managers. An implication for a social planner is that reduced search costs might not be necessarily beneficial to the society: The effects of changing search costs on both price and product design need to be taken into account when deciding which technological changes to support or hinder. A more general message to both practitioners and academicians is that ignoring endogenous changes in the market structure parameters may lead to not only quantitatively but also qualitatively (directionally) erroneous predictions.

The rest of the paper is structured as follows. In the next section, I present the formal model; then I solve the model with and without product differentiation (§§3.1 and 3.2). In §3.3, I make product differentiation endogenous by introducing the cost of product development, which allows us to consider the changes in model predictions due to endogenous product design (§4). This is followed by a discussion of the model and possible extensions in §5. Section 6 concludes.

2. The Model

There are two sellers, each selling one product. There are a number of buyers, each of whom has a single unit demand, knows her valuation of each product, can obtain one price quote for free, and has a search cost s for obtaining the second price quote.

The assumption that a consumer can obtain one price quote at no cost is a technical assumption that ensures that the market exists. In fact, any assumption about first search that ensures consumer participation would suffice. For example, one could assume that a consumer wants to buy another product available in both stores, the price of which is already known. Another assumption in the literature was that of downward sloping individual demand with linear pricing constraint (Diamond 1971, Reinganum 1987). Other approaches used were to bundle search for price with product attributes (Bakos 1997, Anderson and Renault 1999, etc.) or to assume that consumers of the lower valuation do not have search cost (Stiglitz 1979, 1987). Continuous distribution of consumers does not solve the problem of the (non-) existence of markets.[4]

The assumption that the buyers know their product valuation, i.e., they do not search for product attributes, is an important assumption; it allows us to study the effects of search costs for price and not to confuse them with the effects of search costs for product attributes. The assumption may be interpreted as product attributes (except for price) either being known to the buyer, or being impossible to find through search, in which case the product valuation represents the buyer's expectation of the true valuation. Such a model can be applied to frequently purchased products whose attributes are well-known prior to the purchase decision. This knowledge might, for example, have been obtained on previous purchase occasions that are out of the scope of the current model. The model can also be understood as a part of a more general framework, where the search for product attributes occurs either (1) before search for price, (2) at the same time as the first search for price, or (3) as a benchmark for models with a more extensive list of possible information searches (as a limiting case when the search cost for other information tends either to zero or to infinity).

For example, consider a consumer looking for a digital camera on the Internet. She may visit one online store (such as amazon.com or buy.com) or a review site (such as cnet.com, or consumerreports.com) to read the product descriptions. Using the product descriptions and reviews, the consumer may decide which camera would suit her best. Let's say it is the Konica KD-400Z. After this decision, the consumer needs to decide where to purchase the product. She may be aware of the differences between different retailers (customer support, return policy, shipping speed, not charging for product before shipping, etc.) through prior experience. These retail characteristics make KD-400Z a different product when purchased at different retailers. In this example, the consumer may have found one price quote at the retailer or review site, where she searched for product attributes. The next consideration of the consumer is the search for price. This is the step to which the current model applies.

Consumer i net-of-search-cost utility of purchasing the product from firm j is

$$u_{ij} = V + \lambda_{ij} - p_j,$$

[4] One could be tempted to get away from the problem of individual consumer rationality by assuming an aggregate demand function $D_j(t, s, p_j)$ that firm j faces depending on differentiation t, search costs s, and price p_j. However, an aggregate demand form that is not derived from individual consumer behavior could lead to erroneous predictions. For example, assume $D_j(t, s) = 1 + t + s - p_j$. Then profit $\pi(p_j) = p_j(1 + t + s - p_j)$ attains maximum of $\pi^* = (1 + t + s)^2/4$ at $p_j^* = (1 + t + s)/2$. We have $\partial^2\pi^*(t, s)/\partial t\partial s = 1/2 > 0$, which means that if search costs decrease, firm j benefits *less* from differentiation. More careful consideration of how search costs and differentiation should affect the demand will lead us to the opposite conclusion.

Figure 1 Consumer Preference Space

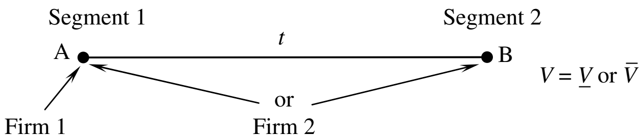
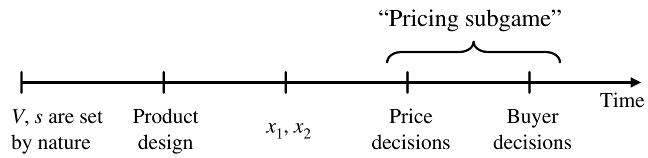


Figure 2 Timing



where V is the general level of consumer valuation for products of that kind, λ_{ij} is the fit of firm j's product to consumer i, and p_j is the price of the product at firm j. For simplicity, I assume two-segment consumer heterogeneity, so the ideal point of some consumers is located at one point (A) and the ideal point of equally as many consumers is located at the other point (B).[5] Each firm's product can be located at either of the two ideal points, and the distance between the points is t (see Figure 1). In this setup, for each j, $\lambda_{ij} = 0$ for half of consumers, and $\lambda_{ij} = t$ for the other half. The relative preferences of consumers (the distribution of λ) are known to both firms. However, the general valuation level V is uncertain for the firms. The common prior on V is that it is $\underline{V}$ or $\overline{V}$ with equal probability. Further, each firm receives a private signal x_j of consumer demand that either tells the firm the valuation parameter V exactly, or is completely non-informative (the latter case I denote by $\varnothing$):[6]

$$(x_j \mid V) = \begin{cases} V, & \text{Prob. } 1/2, \\ \varnothing, & \text{Prob. } 1/2. \end{cases}$$

I assume that signals x_j are independent across firms j given the true value of V.

Note that because V can possibly attain two values and there are two segments of consumers differing in fit, there are four potential consumer segments; however, only two of them actually exist.

Each firm's product design problem is whether to position the product at A or B given a fixed cost of design.[7] The cost of positioning at A is normalized to 0, and the cost of positioning at B is C. Without loss of generality, $C > 0$. Both sellers have zero marginal cost.[8]

Finally, the timing of the game is as follows (see Figure 2). At the beginning of the game, nature draws V to be $\underline{V}$ or $\overline{V}$, which remains unknown for the firms. Next, sellers simultaneously decide on the product design, then both sellers and buyers learn the decisions of sellers on product design. Next, each seller $j = 1, 2$ receives her private signal x_j of the demand, and both sellers simultaneously set prices for their products. Finally, buyers decide whether to search and pay s if they want to search for the second price, and which product to buy (if any). The buyer's decision on the purchase defines the final buyer surplus and seller payoffs of the game.

To simplify calculations, assume that the uncertainty and consumer heterogeneity is such that a monopoly would serve buyers of all possible valuations. More explicitly, I assume that the following conditions hold:

$$t < \underline{V},\ \overline{V} - \underline{V} < \underline{V}, \quad \text{and} \quad \min\{t, \overline{V} - \underline{V}\} < \frac{\underline{V}}{3}. \qquad (1)$$

The equilibrium concept used in this paper is perfect Bayesian equilibrium.

3. Model Solution

Recall that the product design decision precedes the pricing decision, and when firms set prices, they know the product design decision of the other firm. The actions and payoffs of the market agents after the product design decisions will be henceforth referred to as the pricing subgame. The full game is solved in a standard backward procedure, in which we first consider the outcomes of all the possible pricing subgames and then derive which product design decisions are optimal, given the derived outcomes of the pricing subgame.

Because each firm may position its product at either of the two points (A or B), there are two conceptually different pricing subgames: In one, products are not differentiated (both located at A or B); in the other, products are differentiated (one located at A, and the other located at B). The subgame in which both

[5] Alternatively, the total demand can be represented by a single consumer whose preference is unknown to the seller and is V or $V + t$ with equal probability. I also considered a setup with uniformly distributed preferences (as in the Hotelling model), which leads to conceptually the same conclusions (see technical appendix).

[6] I also considered the structure of the signals such that a signal equals $\underline{V}$ or $\overline{V}$ and is true with probability $q > 1/2$. The conceptual implications of such structure of signals is the same as with the above one.

[7] One can also consider the case when a firm's differentiation efforts result in increasing consumer heterogeneity, i.e., when firms are located at A or B, but the value of the parameter of heterogeneity t increases. An example of such effort could be a pharmaceutical firm research showing the differences in effects of similar drugs. The implications of such a model are similar.

[8] The key results would not change if the marginal cost is allowed to be variable or not equal across firms.

products are located at A differs from the subgame where both products are located at B only through a fixed cost of product design C, which is a sunk cost for the purpose of the pricing subgame and therefore does not affect actions. The next two subsections consider these two pricing subgames in turn. Without loss of generality, I assume that firm 1's product is located at A, and firm 2's product is located at A or B. The full game is solved in subsection 3.3

3.1. Nondifferentiated Products

Proposition 1. *In the model above, there is a unique symmetric equilibrium in the pricing subgame when goods are not differentiated. In the equilibrium, consumers do not search, and the price is determined by the following rule*:

$$p_0^e(x) = \begin{cases} \underline{V} & \text{if } x = \underline{V} \text{ or } x = \varnothing, \\ \min\{\underline{V} + 2s, \overline{V}\} & \text{otherwise}. \end{cases}$$

In the case $V = \underline{V}$, buyers expect prices to be $\underline{V}$, and buyers do not search. In the case $V = \overline{V}$, buyers expect each price to be $\underline{V}$ or $\min\{\underline{V} + 2s, \overline{V}\}$ with equal probability and search if and only if $\overline{V} > \underline{V} + 2s$ and they see a price $p > \underline{V} + 2s$.

Proof. See appendix. □

The intuition for this result is that when a firm believes that the demand is low, it is not afraid that the other firm thinks demand is lower (because it is common knowledge that demand cannot be below $\underline{V}$); on the other hand, when a firm thinks demand is high, it is afraid that the other firm may not know that demand is high, and therefore price lower. The price does not depend on t because, due to assumption (1), firms do not want to miss demand from consumers with lower fit, and therefore the consumers with lower fit (those that have valuation V) are the ones that matter for the pricing decision.

The following corollary summarizes the properties of the equilibrium price.

Corollary 1. *In the case of not differentiated products, if $2s \le \overline{V} - \underline{V}$,*

(a) *the expected equilibrium prices and profits are smoothly increasing in s;*

(b) *the expected buyer surplus is smoothly decreasing in s;*

(c) *equilibrium price dispersion increases in s.*

Proof. The expected (before the signal x is known) equilibrium price is

$$\mathrm{E}p = \frac{3}{4}\underline{V} + \frac{1}{4}(\underline{V} + 2s) = \underline{V} + \frac{s}{2},$$

and the average buyer (consumer) surplus is

$$\mathrm{E}\,CS = \frac{1}{2}\cdot t/2 + \frac{1}{2}\left(\frac{1}{2}\cdot t/2 + \frac{1}{2}(\overline{V} - \underline{V} - 2s + t/2)\right) = \frac{\overline{V} - \underline{V} - 2s + t}{4},$$

where $t/2$ comes from the half of buyers with better fit, and the average is taken over all possibly a priori consumer valuations. The first two claims of the proposition immediately follow from the above formulas.

The equilibrium price dispersion is zero in the case of low valuation (since signals are $x = \underline{V}$ or $x = \varnothing$) and possibly $2s$ in the case of high valuation. Hence, the expected variance of price dispersion is $(2s)^2/4 = s^2$, which increases in s. □

This corollary confirms that if product design decision is not considered as endogenous, the predictions of the model are consistent with general beliefs about the effects of search costs on the equilibrium prices, profits, and buyer surplus (e.g., Alba et al. 1997). We will see that considering exogenously differentiated goods does not change these conclusions. However, the results may change if product differentiation is considered as endogenous (see §3.3).

3.2. Differentiated Products

Now consider the case when products are differentiated: one located at A, and the other located at B. In this case, one consumer segment values one product at $\underline{V}$ or $\overline{V}$ and the other product at $\underline{V} + t$ or $\overline{V} + t$, respectively; and the other consumer segment values the first product at $\underline{V} + t$ or $\overline{V} + t$ and the other at $\underline{V}$ or $\overline{V}$, respectively. Therefore, a price differential of t is required for a given segment to consider the products as perfect alternatives. This means that a firm that believes demand is high is not so afraid that the other firm does not know that the demand is high, which results in a higher price differential as reflected in the following proposition.

Proposition 2. *There is a unique symmetric equilibrium in the above model with differentiated products. In the equilibrium, consumers do not search, and the price is determined by the following rule*:

$$p_d^e(x) = \begin{cases} \underline{V} + t & \text{if } x = \underline{V} \text{ or } x = \varnothing, \\ \min\{\underline{V} + 2t + 2s, \overline{V} + t\} & \text{otherwise}. \end{cases}$$

Proof. See appendix. □

The minimal level of prices is raised to $\underline{V} + t$, because consumers search at the best-fitting location first. Sellers, realizing that they see only consumers with better fit, are able to raise prices and extract this consumer surplus. The better fit increases social welfare (if the sunk costs of product design are not considered), and the benefit is fully extracted by the firms.

Note the following two effects of differentiation. First, a larger variety of products increases the fit for some consumers by t. Because firms expect that consumers will self-select and go only to the firm that fits them better, surplus from this better fit is fully extracted by the firms. Second, differentiation reduces competition and allows a firm that knows demand is high to raise the price by an additional t (up to the valuation constraint $\overline{V}+t$), because the alternative product fits the buyer at the current firm not as well.

The following corollary summarizes the properties of the equilibrium price in the case of differentiated products.

Corollary 2. *In the case of differentiated products, if* $2s \le \overline{V} - \underline{V} - t$,
(a) *the expected equilibrium prices and profits are smoothly increasing in* s;
(b) *the buyer surplus is smoothly decreasing in* s;
(c) *the equilibrium price dispersion increases in* s *and* t.

Proof. The proof follows from the formula for the equilibrium price rule, just as in Proposition 1. □

Note that this corollary shows that, as expected, search costs and differentiation by themselves reduce competition and increase prices and profits (if costs of differentiation are not considered). The positive correlation of search costs and price dispersion when product differentiation is kept constant (Corollaries 1 and 2) is empirically supported (Zhao 2003).

3.3. Endogenous Product Differentiation

Recall that there is a cost C associated with positioning a product at point B, whereas the cost of positioning at A is normalized to 0 (without loss of generality, $C > 0$). Each firm is to produce a single product and must decide whether to position its product at A or B.[9]

It cannot be an equilibrium strategy for both firms to position their products at B because in such a case, either firm benefits from deviating and choosing A, because choosing A has the benefits of both lower cost and higher differentiation. Consequently, the product of one firm will be located at A (without loss of generality, assume it is firm 1), and the product of the other firm may be located at A or B, depending on the parameters of the model.[10]

To see if firm 2 would invest in designing a product at B (given that firm 1 does not invest and produces the product at A), one must compare the individual firm's expected benefit of differentiation $\mathrm{E}B(t,s)$ to the cost of differentiation C.

[9] The model can be extended to allow firms to produce one or both products. Conceptual implications of such a model remain the same.

[10] There is also a possible equilibrium with mixed strategy in product positioning, where each firm locates at A with probability $q = q(s,t,C)$, which is a decision variable, and at B with probability $1-q$. The implications of considering this symmetric equilibrium are similar to the implications of considering pure strategy in product positioning equilibrium, because it turns out that the probability of differentiated outcome $2q(1-q)$ increases when search costs s decrease.

Comparing the expected equilibrium price with and without product differentiation, we see that the expected benefit of differentiation is $t/2$ in case $x = \underline{V}$ or $x = \varnothing$, and in the case $x = \overline{V}$ we have

$$B(t,s,\overline{V}) = \frac{1}{2} \cdot \begin{cases} t & \text{if } 2s > \delta, \\ t + \delta - 2s & \text{if } 2s \in (\delta - t, \delta), \\ 2t & \text{if } 2s < \delta - t, \end{cases}$$

where $\delta = \overline{V} - \underline{V}$. This means that the expected (before receiving signal x) benefit of differentiation is

$$\mathrm{E}B(t,s) = \begin{cases} t/2 & \text{if } 2s > \delta, \\ t/2 + (\delta - 2s)/8 & \text{if } 2s \in (\delta - t, \delta), \\ 5t/8 & \text{if } 2s < \delta - t. \end{cases} \quad (2)$$

Thus we have the following result.

Proposition 3. *The expected benefit of differentiation* $\mathrm{E}B(t,s)$ *in the above model is positive and a nonincreasing function of the search cost* s. *Furthermore,* $\mathrm{E}B(t,s)$ *decreases in* s *when* $2s \in (\delta - t, \delta)$.

Because a seller will be willing to design the product if and only if $C < \mathrm{E}B(t,s)$, a seller is willing to pay a larger fixed cost to design the differentiated product if the search costs are smaller. In other words, across a distribution of possible costs of differentiating product design, a seller is more likely to invest in differentiating product design if the search cost s is smaller.

The Proposition 3 implies that the buyer price search cost and product differentiation are substitutes. The result that the benefit of differentiation may increase and does not decrease when s decreases may be interpreted as saying that in an economy with a broad range of costs of differentiation (parameter C) across different product categories, lower s implies an increase in the average equilibrium product differentiation as more and more products become differentiated. This fact leads to important implications that are discussed in the following subsection.

The following proposition summarizes the equilibrium with endogenous product design.

Proposition 4. *If* $C > 5t/6$ *or* $s > 2t + \delta/2 - 4C$, *both firms position their products at A (and hence, there is no differentiation in the equilibrium). If* $C < t/2$ *or* $s < 2t + \delta/2 - 4C$, *one firm positions its product at B and the other positions its product at A (and hence, there is differentiation in the equilibrium). Further, firms price according to Proposition 1 if both firms are positioned at A, and according to Proposition 2 otherwise.*

Proof. This is an immediate consequence of the fact that a seller will be willing to spend an additional C on positioning the product at B if and only if $C < \mathrm{E}B(t,s)$ and the formula (2) for $\mathrm{E}B$. □

Figure 3 A Firm's Decision on Product Design

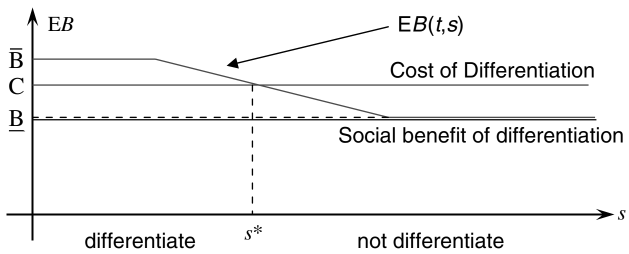


Figure 3 illustrates a firm's decision on product differentiation through a graph of the expected benefit of differentiation as a function of consumer search cost for price s. One can see that when $C \in (5t/8, t/2)$, if $s > s^\star \equiv 2t + \delta/2 - 4C$, then there is no differentiation in the equilibrium, whereas if $s < s^\star$ then one firm differentiates (redesigns the product).

4. Implications of the Endogenous Product Design

First, consider the effect of the search cost s on equilibrium prices. Propositions 1, 2, and 3 show that a decrease in the search cost s has the direct effect of decreasing prices and an indirect effect of increasing prices through an increase in product differentiation. The resulting change in the equilibrium price can be either positive or negative. In the context of the model in this paper, we have the following proposition.

Proposition 5. *Let $s_1 < s_2$. Then $\mathrm{E}p^e(s_1) > \mathrm{E}p^e(s_2)$ if and only if the equilibrium product differentiation under $s = s_1$ is higher than under $s = s_2$, and $5t/2 > s_2 - s_1$.*

Proof. See appendix. □

In other words, the price increases when product differentiation increases, and a reduction in prices due to the search costs decrease is smaller than the increase due to higher product differentiation. This suggests that the effect of search costs on prices might be different, depending on the possibilities of product differentiation in a particular industry. One can expect that prices might increase as search costs decrease in an industry where a small change in the incentive to differentiate prompts firms to substantially increase differentiation.

Besides the effect on the level of prices, decreasing search costs may have a counterintuitive effect on the price dispersion. This is shown in the following proposition.

Proposition 6. *As search cost s decreases, price dispersion may increase.*

Proof. Indeed, without product differentiation, one can expect prices to differ by at most $2s$. With product differentiation, prices can be different by $t + 2s$. If t is greater than the change in $2s$, and the change in s causes differentiation, price dispersion increases. □

Note that the increase in price dispersion is not due to one product being better than the other, but rather is due to product differentiation allowing the differences in firm beliefs about buyer valuations to result in more different pricing.

In the empirical literature, the finding that prices or price dispersion increases in certain instances online (e.g., Brynjolfsson and Smith 2000, Brown and Goolsbee 2002) seems to conflict with the theoretical predictions of the effect of lower consumer search costs for price. Note, however, that those findings are consistent with the above proposition.

If the equilibrium prices increase, sellers benefit from the increased prices. However, this increase in prices comes at the cost of increasing investment in the differentiating product design. At first glance, one could argue that because firms did have the ability to invest in product design when search costs were higher, a decrease in search costs should result in lower industry profits. However, because an investment in product differentiation by one firm is a positive externality for the other firms, pressure on the industry as a whole may benefit individual companies. The following proposition shows that this is, in fact, the case.

Proposition 7. *As s decreases, equilibrium industry profits might increase, whereas buyer surplus and social welfare might decrease.*

Proof. See appendix. □

The intuition for the possibility of decreasing social welfare as consumer search costs decrease is that the benefit of increasing differentiation for consumers comes from better fit, and for firms comes from both better fit and lower competition. It turns out that the benefit of differentiation for a firm is higher than the benefit to society, and therefore a firm might overspend on product differentiation, i.e., the amount spent in the society on differentiation will be higher then the benefit of differentiation to the society (within this model, the change in prices affects only the distribution of welfare between buyers and sellers, but not the social welfare).

The possibility of decreasing social welfare when product differentiation is endogenous contrasts with the implication of the model with exogenous product differentiation where social welfare does not increase in s. In that model, social welfare was not changing when s changed. In a more general model with a possibility of some deadweight monopoly loss, social welfare would increase when prices decrease.[11]

[11] This situation occurs when the model is extended to heterogeneous buyers, with some buyers not buying a product.

5. Discussion

Search costs for prices and products may have very different effects (Anderson and Renault 1999, Lal and Sarvary 1999), and it is important to understand these differences. Even in situations where prices can be easily found, perceived search costs may be significant (Mehta et al. 2003, Zwick et al. 2003). Assuming that consumers know their valuation of the products allows us to better understand the effects of changing search costs for price alone. However, not having search costs for product attributes in the model at all is a limitation.

In the model, we allowed firms to decide on the product design, which may be interpreted as saying that products change over time. Unless firms advertise those changes, consumers either might not be aware of them, or might need to search for them. Because product attributes might not be changed as frequently as price, it could be that consumers are able to find the attributes of the products/retailers in some purchase occasions and therefore know them on the subsequent occasions. This would restrict the applicability of the model predictions to the later periods in which consumers have learned the product attributes. One can think of this extended game setup as a multiperiod game in which at the beginning, firms decide on the product design, and then set prices in a sequence of periods.[12] Not modeling these dynamics is a limitation of the current model and could be an area of future research.

The equilibrium price charged is partially due to seller fear that her price can be undercut. One might think that in some retail environments, one store may check the other store's prices and therefore get a better idea of whether its prices are being undercut. However, even then, in any situation when consumers are possibly searching for a bundle of goods, it could be difficult to see if one store is undercutting another on the bundle a consumer wants. Also, some discount programs or coupon availability may not be fully observed. Furthermore, if there are other costs that consumers absorb (e.g., traffic, parking, checkout lines, etc.), it might not be clear which retailer is cheaper from a consumer point of view.

Alternatively, the model with endogenous product differentiation allows an increase in prices as search costs decrease, and therefore deadweight monopoly loss would be another reason (except for overspending on product design) for the social surplus to decrease as search costs decrease, which would strengthen the contrast. Also, if the first search is costly, then lower search costs could imply lower waste on search, and therefore, another factor in making social welfare higher.

[12] If demand does not vary across the periods, firms may learn it from past demand. However, it could be that there are shocks to demand that are independent across periods. In terms of the model, it could mean that $V = \underline{V}$ or $\overline{V}$ independently across time, and firms receive signals x_{jt} that are i.i.d. across time.

The model considers a single possibility of differentiation for the firms. In reality, there could be a number of possibilities for differentiating product design. The model can easily be extended to the multiple possibilities of differentiation over independent directions (e.g., four consumer segments with ideal points at the corners of a rectangle). This would make the decision to differentiate symmetric across firms; i.e., in the equilibrium both firms could decide to invest in differentiating product design (over orthogonal attributes). The major implications of such a model are similar. If the possibilities to differentiate are so numerous as to provide a virtually continuous product space, the product position could be a continuous variable, and the effect of increasing differentiation when search costs decrease would be continuous as well. A managerial implication of the increasing differentiation is that the estimate of future profitability in the environment with falling search costs has to be adjusted upward due to increasing differentiation.

Another question of interest to managers and consumers is when they could expect that profits and/or prices increase in an environment with falling search costs. The answer could be that it would be in an industry where the additional benefits of an individual firm's differentiating product design is large compared to the additional costs of product design (perhaps in service industries as opposed to commodities).

The case of product differentiation that is unknown to buyers might also be of interest. In such a situation, it would be interesting to consider how consumers could update their beliefs on product differentiation/variety depending on what they see at a particular seller. The incentives of the firm to introduce features that buyers are not sure about before they search are ambiguous. On one hand, uncertainty about the valuation may attract more buyers (because they might expect higher possible surplus, and the downside is limited for them because they are not required to buy). On the other hand, if buyers expect wider distribution of their possible valuation at the other stores as well, buyers may have more incentive to continue to search at other stores.

One may also consider what happens under a wider range of a priori possible signals, as in Kuksov (2003). It turns out that with the lack of common knowledge (when firms have to infer information about other firms' possible signals based on the signals they get themselves) the effects of search costs and differentiation on price are magnified.

6. Conclusion

In this paper, I consider the interconnection of buyer search costs and firm decisions on product design. I have shown that when product (store) design is considered endogenous, lower buyer search costs can lead to higher differentiation. This prediction seems to be consistent with observed market behavior. Furthermore, the model in this paper shows that the indirect effect of lower search costs on the equilibrium price through increasing level of differentiation could outweigh the direct effect of lower search costs, and so when the buyer's search cost for price decreases, equilibrium prices need not decrease. Therefore, considering the effect of a change in buyer search cost on price competition alone could lead to erroneous conclusions.

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Appendix

Proof of Proposition 1.

Proof.

Existence. To prove that the specified price strategy and consumer behavior is an equilibrium one, consider the following.

(1) Given the price strategy $p_0^e(x)$ followed by the firms, it is optimal for consumers not to search: Expected benefit of search $\mathrm{E}BS$ of consumer with valuation V who sees price p_0 possible under pricing p_0^e is at most

$$\begin{aligned}\mathrm{E}BS &\le (\max p - p_0)\mathrm{Prob}\{p \ne p_0\}\\ &\le (\max p - \min p)\cdot \tfrac{1}{2} \le 2s\cdot\tfrac{1}{2} = s,\end{aligned}$$

where minimum, maximum, and probability are taken over prices p that are possible if firms follow pricing strategy $p_0^e(x)$ with any signal x possible given the valuation parameter V. Therefore, the maximum benefit of search does not exceed the cost of search s, and it is optimal for all consumers not to search. Furthermore, because the price is at or below the consumer valuation, it is optimal for consumers to buy. Hence, consumer behavior given the equilibrium pricing is optimal.

(2) Given consumer behavior, it is suboptimal for firms to set price lower than $p_0^e(x)$: Indeed, if a firm lowers the price, it obtains no additional demand, because consumers do not search.

(3) Setting the price above $p_0^e(x)$ is suboptimal for the firm because of the following. If $x = \varnothing$ or $x = \underline{V}$, the firm would loose a fraction of the demand, and due to assumptions (1) it is suboptimal. If $x = \overline{V}$, and the firm sets price higher than $\underline{V} + 2s$, it loses all the demand due to consumer search (consumers search and find a better price as far as the other firm follows the equilibrium strategy). If the firm sets price higher than $\overline{V}$, it loses half of the demand, which is suboptimal due to assumptions (1).

Hence, firm and consumer strategies are individually optimal given the other players' strategies.

Uniqueness. To prove that an equilibrium price $p^e(x)$ and consumer behavior must be as stated, consider the following.

(1) A price below $\underline{V}$ cannot be optimal in a subgame perfect equilibrium. Indeed, consider the minimal price $\underline{p}$ that is a part of an equilibrium strategy. Because consumers know it is the lowest price, if they see that price, they do not search, and they would not search even if the price were raised by $\varepsilon < s$. Hence, if $\underline{p} < \underline{V}$, the firm might raise the price by $\varepsilon < s$ without losing any demand. Hence $\underline{p} < \underline{V}$ is suboptimal. We also have $p^e(\underline{V}) \le \underline{V}$ due to consumer valuation. Therefore, $p^e(\underline{V}) = \underline{V}$.

(2) In the equilibrium, consumers do not search. Indeed, because search costs and information of all consumers are the same, if one consumer finds it optimal to search given a price, all consumers must find it optimal to search.

(3) $p^e(\varnothing) = \underline{V}$ because consumers do not search and conditions (1) are exact conditions under which the monopoly price given signal $x = \varnothing$ is $\underline{V}$.

(4) $p^e(\overline{V}) \le \overline{V}$ due to consumer valuation and conditions (1). $p^e(\overline{V}) \le \underline{V} + 2s$, because otherwise consumers would search for the possible lower price $p^e(\varnothing)$ hoping that the other retailer's signal is $\varnothing$, which should not be according to (2). If $p(\overline{V}) < \min\{\underline{V} + 2s, \overline{V}\}$, the firm can raise the price without sacrificing demand. Hence, $p^e(\overline{V}) \ge \min\{\underline{V} + 2s, \overline{V}\}$. Hence, $p^e(\overline{V}) = \min\{\underline{V} + 2s, \overline{V}\}$. This concludes the proof of uniqueness. □

Proof of Proposition 2.

This proof follows closely the Proof of Proposition 1.

Proof.

Existence.

(1) Given the pricing strategy $p_d^e(x)$, consumers search first at the firm that fits them better, do not search, and buy. The price differential that induces consumers to search in case of differentiated products is $2s + t$ because consumers do not only spend s on search, but they would also have to forgo the benefit of the better fit if they buy at the other firm.

(2) Given consumer behavior, it is suboptimal for firms to set price lower than $p_d^e(x)$ as they would gain no additional demand.

(3) Again, consumer search and valuation constraints together with conditions (1) make it suboptimal for a firm to set price above $p_d^e(x)$.

Uniqueness. (1) $p_d^e \ge \underline{V}$. The proof is exactly same as in the Proposition 1. Furthermore, in a symmetric price equilibrium, consumers search first at the store that fits them better. Hence, minimal consumer valuation a firm faces is $\underline{V} + t$ and so, $p_d^e \ge \underline{V} + t$.

(2) As in the Proof of Proposition 1, one derives that there is no search in the equilibrium.

(3) $p_d^e(\varnothing) = \underline{V} + t$ due to no search and the assumptions (1).

(4) $p_d^e(\underline{V}) = \min\{\underline{V} + 2s + 2t, \underline{V} + t\}$ because of the consumer valuation constraint and no-search constraint, that is now that consumers do not search if the price differential with $p_d^e(\varnothing)$ is at most $2s + t$. □

Proof of Proposition 5.

Proof. The expected price in the case of nondifferentiated products is

$$\mathrm{E}p_0^e(s,t) = \tfrac{3}{4}\underline{V} + \min\{\underline{V} + 2s, \overline{V}\},$$

and in the case of differentiated products, it is

$$\mathrm{E}p_d^e(s,t) = \tfrac{3}{4}\underline{V} + \min\{\underline{V} + 2s + t, \overline{V}\} + t.$$

Therefore, if under $s = s_1$ products are differentiated and under $s = s_2$, they are not, the difference in expected prices is

$$\mathrm{E}\,(p^e(s_2) - p^e(s_1)) = t + \min\{\underline{V} + 2s_2, \overline{V}\}/4 - \min\{\underline{V} + 2s_1 + t, \overline{V}\}/4,$$

which is greater than zero if $5t/2 > s_2 - s_1$ or if $\min\{\underline{V} + 2s_1 + t, \overline{V}\} = \overline{V}$. □

Proof of Proposition 7.

Proof. Instead of working out exact conditions on when industry profits increase, to see that industry profits could increase, consider a special case of $C \in (t/2, 5t/8)$ and s changing from $s_2 \equiv s^* + \varepsilon$ to $s_1 \equiv s^* - \varepsilon < s_2$, where $s^* = 2t + (\overline{V} - \underline{V})/2 + 4C$. It is easy to see that at s^*, expected benefit of differentiation for firm 2 is exactly equal to the cost C. Hence, at $s = s_1$ firm 2 differentiates, and at $s = s_2$ it does not. Therefore, at $s = s_1$ relative to $s = s_2$, firm 2 is worse off by a multiple of ε and firm 1 is better off by a multiple of t. Hence, when ε is small enough, industry profits increase as s decreases from s_2 to s_1.

The condition for a decrease in social welfare is exactly that equilibrium changes from a no differentiated to a differentiated-products one, because in that case, $C > t/2$ is spent on differentiation and the social benefit of differentiation is $t/2$. In particular, when industry profits increase, social welfare decreases, because for industry profits to increase, differentiation must increase.

When social welfare decreases and industry profits increase, consumer surplus must decrease. This concludes the proof. □

Continuous Distribution of Buyers

For the purpose of simplicity, the distribution of buyers was assumed to come from two consumer segments (whose valuations differ by the parameter t). Instead, one could consider a uniform buyer distribution between these two points a la Hotelling. The technical appendix, available online or by a request from the author, shows that the qualitative results do not change with the uniform buyer distribution: Benefit of product differentiation increases as search costs decrease. As a result, prices, price dispersion, and industry profits could increase and consumer surplus decrease as search costs decrease. Again, this is due only to the endogenous *change* in the product differentiation.

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