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Product Variety and Endogenous Pricing with Evaluation Costs

J. Miguel Villas-Boas
Haas School of Business, University of California, Berkeley, Berkeley, California 94720,
villas@haas.berkeley.edu

One important decision firms must make is to select the product line (characteristics and number of products) to offer consumers. This paper explores the effect of the interaction between consumer evaluation costs and pricing on the optimal product line length to offer consumers. Before deciding to buy a product among all products offered, a consumer learns the product line length. Given the product line length, a consumer decides whether to evaluate the products available and their prices. This decision to evaluate depends on the expected consumer surplus after the evaluation being greater than the evaluation costs. When the firm offers few products, the firm may not attract many consumers because of lack of product fit and may be forced to offer low prices. When the firm offers many products, all consumers will find a great product fit; that is, the variance of consumer valuations per product chosen is lower. This allows the firm to charge high prices to extract ex post consumer surplus, resulting in lower ex ante expected consumer surplus, which may lead consumers not to evaluate the products in the first place. That is, by offering fewer products a firm can commit not to extract all possible consumer surplus. These two forces may then lead to the existence of an interior optimal number of products to offer. The optimal number of products offered is decreasing in the evaluation costs.

Key words: marketing; product policy; pricing; search costs; information overload; consumer choice
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1. Introduction

When consumers have to incur evaluation costs prior to making a purchase, they may refrain from product evaluation, and purchase if they are concerned about the ex post consumer surplus that the seller may allow. This paper explores the possibility of a firm committing to a reduced number of supplied products as a way to guarantee to consumers that they will have ex post surplus to compensate for their evaluation costs. There is also some evidence that when a firm offers too many products, consumers may feel that there are too many choices and end up not purchasing any product.[1] One important issue in such a setting is that firms may also act strategically in setting prices and other product characteristics, which consumers only find out about after they incur some evaluation costs.

This paper explores this issue of the interaction of the firm decisions on prices and product characteristics to be evaluated by consumers and the consumer evaluation costs. That is, in a choice overload setting where consumers have evaluation costs, what is the effect of firms being strategic about the prices they charge? Does strategic pricing accentuate or attenuate the choice overload effects, leading the firms to either choose a shorter or longer product line? What is the effect of the information about prices and qualities being observed and processed prior to consumers engaging in the evaluation costs of the different alternatives?

The main result of this paper is that consumers' evaluation costs in understanding pricing and product characteristics information is a force toward a firm offering fewer products. The idea is that by offering fewer products, a firm can commit not to extract all possible consumer surplus. The effect is not through the information a product line may provide to consumers, but rather through the variance in consumer valuations that it induces. If the firm offers too many products, the existence of a product with good fit for each consumer implies lower variation in the consumer valuations of consumers who end up buying each product, which therefore allows the firms to extract more consumer surplus. In other words, if there are fewer products, after being evaluated, the products have to offer some surplus to the consumers for them to be willing to buy, which means that the consumers who have a good fit will have a significant surplus. Therefore, in expectation, more consumers will be willing to evaluate the products, which will generate greater demand. If a seller offers too many

[1] Some evidence on this effect with exogenous prices can be seen, for example, in Iyengar and Lepper (2000).

products, consumers realize that all consumers will find a product that provides a good fit (low variance of consumers valuations around best product fit), which means that consumers have to find that product, and the firm will extract the most it can from the surplus generated by that good fit.

This idea is present in markets where many alternatives are offered and consumers realize that finding the best alternative is important, as only the better alternatives can generate some significant surplus. Sellers with greater variety may be able to charge more specific (higher) prices, keeping other factors fixed, which may yield lower consumer surplus.[2] For example, restaurants that offer greater variety in service may be able to charge higher prices for their specific dishes. Supermarkets that offer a large variety in a certain category may be able to charge higher prices because they provide better product-consumer fit. In some markets for services, greater service is the ability to better respond to the specific demands of each customer (greater variety of services provided), which can allow the firm to extract more consumer surplus, given the specific needs satisfied. Examples of some types of services where these effects may be present are high-end restaurants, hotels, or hairdressers. Greater service in these cases may mean the ability to respond to the specific consumer demands. In some markets where the information on prices is more costly to obtain or is less advertised, we may expect that these effects are more important. The main results here may also suggest that firms that advertise more (and advertise their prices) may have more dense product lines, as the effects discussed here will not be present.

Consider a situation when consumers are able to observe first the length of the product line (number of products) offered by a firm. For example, this could be the case when a consumer sees the length of shelf space provided in a supermarket or department store for a category, or when a consumer sees the total list of products available on a webpage. In many market situations, consumers may have first a sense of the number of product available. Then, after observing the number of products available, a consumer has to decide whether it is worth incurring evaluation costs to find out the value of each product for the consumer. Processing the information of the attributes of each product and the prices being charged may be costly or take time, even if the product attributes or prices are displayed or advertised.[3] But once the evaluation costs are incurred, they are sunk costs, and the consumer only purchases a product if the product offers a positive surplus (excluding the evaluation costs, as they are sunk at the purchase stage). The firm can then benefit from reducing the surplus of the consumers (excluding the evaluation costs) by increasing prices or reducing product quality, if these can be checked only after the products are evaluated. This then gives less incentive for consumers to evaluate the product (as they know that they will have a reduced surplus after evaluation), and the firm ends up with less demand. By offering a smaller number of products, the firm can commit that it will offer some significant consumer surplus, as it may still find it profitable to attract consumers who do not have such a great fit with any product (which is more likely with a smaller number of products). With a smaller number of products, the firm lowers its prices to attract the consumers who do not have a good product fit, generating higher ex post surplus for the consumers who search. That is, the interaction between firm pricing and quality decisions and evaluation costs is a force toward a smaller number of products.

This paper considers the pricing case and shows that there is an interior and finite optimal number of products. The optimal number of products is decreasing in the evaluation costs and converges to infinity when the evaluation costs go to zero. If the evaluation costs are high enough, the market can disappear. In equilibrium, the consumers who evaluate the products are the ones who have a higher general valuation for the category, and some consumers who evaluate the products end up not buying any product. The same results (available upon request) can be obtained when firms also make decisions on the quality of each product, which is only found out after the consumer evaluation, and prices are observed prior to the consumers incurring the evaluation costs. One can obtain similar results when the general consumer valuation for a category is positively correlated with how much a consumer cares about product fit.

Note that the effects of the evaluation costs presented here can be seen as choice overload effects (e.g., Iyengar and Kamenica 2007), as the existence of evaluation costs makes the consumers choose not to buy (and not incur the evaluation costs) when faced with too many alternatives. In the formulation below, evaluation costs are not allowed to vary with the number of products offered, in order to isolate the essence of the effect of endogenous pricing. In this setting, endogenous pricing leads to a small number of

[2] Note, however, that this effect holds when keeping other factors fixed. For example, if there are economies of scope in variety, sellers that offer more variety could have lower costs, which could be a force toward lower prices.

[3] See Dickson and Sawyer (1990) on the extent to which consumers are uninformed about prices after purchase decisions and on a conceptual model of price encoding and knowledge, and information processing with respect to prices (see also Jacoby and Olson 1977). If consumers at the time of purchase are unsure of their preferences at the time of consumption (Guo 2006), they may benefit less from searching and processing information.

optimal products, and exogenous pricing leads to an infinite number of products. We know from previous work (e.g., Kuksov and Villas-Boas 2006) that under exogenous pricing, if the evaluation costs are increasing in the number of product offered (or searched), the optimal number of products offered may be small. Putting the two results together, we would have that in a setting where the evaluation costs are increasing in the number of products offered, endogenous pricing would lead to an even smaller optimal number of products offered. This issue is further discussed in the model set-up.

1.1. Literature Review

Related to this paper, there is a literature that looks at the opportunism of sellers when consumers have to incur sunk evaluation costs before they make a purchase. Diamond (1971) considers search costs in consumers finding out about prices with competing sellers, each selling only one product, and each consumer having a downward-sloping demand. In contrast, here there is only one firm selling multiple products, and the firm can choose product attributes and the number of products it sells. Lal and Matutes (1994) and Wernerfelt (1994) discuss the possibility of advertised prices as a form of the seller commiting not to exploit the consumer sunk costs,[4] and Wernerfelt also discusses the possibility of return policies and seller colocation. In relation to that literature, this paper considers the possibility of firms choosing a product line, where the length of product line may be more easily observed than prices or product quality. The length of the product line commits the seller to the extent of consumer surplus that is provided. Note also that there may be consumer processing costs for advertised prices, and if prices can be observed without processing or evaluation costs, unobserved quality decisions generate the same problems (see discussion above). In addition to that literature, this paper also notes that the product line specification allows ex ante evaluation costs to generate information/choice overload effects.

As noted above, some experimental work has found that consumers are more likely to make a choice and purchase when confronted with a smaller choice set. This work has argued that consumers may feel overwhelmed or overloaded with too many alternatives. This idea goes back to the information overload literature (see, for example, Jacoby 1977 and the references listed there) and the idea that decision makers may only be able to process a limited amount of information (e.g., Simon 1955, Miller 1956) and mental evaluation costs (e.g., Bettman 1979).[5] In this regard, Shugan (1980) considers the costs of thinking and provides a quantitative measure of that cost related to the number of comparisons necessary to make a decision, given some level of confidence. Hauser and Wernerfelt (1990) have argued that consumers may strategically limit their consideration sets (with search under fixed sampling) to reduce evaluation costs. Another important aspect that is not considered here involves the possibility of using attribute information to eliminate alternatives (Payne et al. 1988). Beach and Mitchell (1978) address the issue of decision makers eliminating options on the basis of deviation from their ideal point. Huffman and Kahn (1998) discuss the issue of variety choice creating confusion in preferences (see also, Mick et al. 2004, Lurie 2004, Gourville and Soman 2005). There is also some evidence (e.g., Iyengar and Lepper 2000) that even though lager choice sets may reduce choice, consumers are attracted to sellers with greater choice sets. This paper will not address this later effect, which could depend on what is kept constant when choice sets are enlarged. For example, in the particular contexts that are considered, consumers might not have full information about search costs and might consider larger choice sets better given the information that they have.

Kuksov and Villas-Boas (2006) consider search costs in evaluating the fit of each alternative and show that a strategic supplier of alternatives (spanning the alternatives through the product space) does better by offering a finite number of alternatives than an infinite number, reducing overall consumer search costs and leading more consumers to choose an alternative. Some of the issues discussed in that paper can also be seen from the side of the firms through their communication strategies (Villas-Boas 2004). Van Zandt (2004) considers competition where firms communicate about their products and consumers evaluate a limited and fixed number of alternatives; he finds that there is too much communication in equilibrium, as a firm communicating about its product does not consider the negative externality on consumer information processing affecting the other firms. Kamenica (2008) considers the possibility that the information implicit in the product line may affect customers' beliefs about how much they would enjoy particular products.[6] Norwood (2006) considers free-entry price competition among fixed products that are

[4] See also Simester (1995) and Rao and Syam (2001). See also Kuksov (2004) for the effect of search costs on product design under competition.

[5] Keller and Staelin (1987) argue that with regard to information, quality of information may help decision making, whereas quantity of information may affect decision making negatively. In a market setting, Boatwright and Nunes (2001) show that reducing the assortment size in a grocery store can increase sales.

[6] In a working paper version, Kamenica (2007) also considers endogenous prices with large retail cost uncertainty (unknown to the consumers), such that prices cannot signal product characteristics.

vertically differentiated, one product per firm, under the assumption that only the most popular products are offered; Norwood includes an approximation to the consumer sequential evaluation process and finds that there is excessive entry in equilibrium.

Finally, it may also be that a greater number of alternatives leads the decision maker to delay choice (and not choose when the choice set is first presented) in order to gather more information on the choice problem (e.g., Dhar and Simonson 2003). This new information could come at a lower cost than the cost of evaluating different alternatives at the present. For example, consumers could gain some information about what other consumers have chosen (Zhang 2009). Note that this explanation could then be seen as a search cost explanation for no choice when many alternatives are presented.[7] Note that the objective of this paper is not to argue that this explanation is the most compelling one for the existence of limited product lines.[8]

In relation to the papers above, we consider the effect of the interaction between the consumer evaluation costs and firm decision making about variables that affect the consumer surplus (price and quality) on the optimal number of products for a firm to offer. In relation to other explanations for choice overload, this paper focusses on the explanation based on simple evaluation costs, which is enough to generate information overload effects with endogenous pricing.

The remainder of this paper is organized as follows. The model is presented in §2. Section 3 presents the main results, and §4 concludes.

2. Base Model

Consider a firm deciding how many and which products at what prices to offer to a set of consumers. The products are located on a circle of unit length and have zero production costs (without loss of generality). Before deciding whether to search, consumers know their general valuation v for the category and observe the number of alternatives n being offered by the firm. After searching and incurring the search costs k, the consumers learn the location of all the products offered and their prices and the location of their ideal product x.[9] The firm decides the number of alternatives to offer n, the location of each of these alternatives on the circle, and the price of each alternative.[10]

Consumers are heterogeneous on their general valuation v for a product in the category and on the location of their ideal product x in the circle. If the product consumed is at a distance d of the consumer's ideal product, the consumer incurs a disutility td, where t is a parameter measuring the importance of the product fit. The distribution of v and x is assumed independent among consumers. The marginal distribution of x is assumed uniform along the unit circle, and the marginal distribution of v has positive density on the support $[0, \bar{v}]$, with the cumulative distribution function $F(v)$ (density $f(v)$).

The ex post utility of a consumer with valuation v purchasing a product at price p at distance d of his ideal product is

$$U = v - td - p - k.$$

Prior to incurring the search costs k, the consumer does not know d or p but may be able to infer both the distribution of d from the best product available and the price p from the number of products offered n. After incurring the search costs, a consumer chooses to buy the best product available, which is at distance d, if and only if $v - td - p \geq 0$, as the search costs are sunk at the purchase decision time.

A consumer with valuation v decides to incur the search costs k if the expected surplus after search is greater than k. That is, a consumer searches if and only if $E_d[\max\{v - td - p, 0\} \mid n] \geq k$, where E_d is the expected value operator over the distance d to the best product for that consumer. As the expected value is increasing in v, there is going to be a threshold $\hat{v}$ such that a consumer searches if and only if $v \geq \hat{v}$. The firm chooses the prices of the different products (and their location) to maximize profits given that consumers who have searched have $v \geq \hat{v}$. Note that the consumers foresee this behavior by the firm; therefore, the determination of $\hat{v}$, the valuation of the consumers indifferent between searching and not searching, takes into account the firm's pricing strategy.

Wathieu and Bertini (2007) consider the effect of the price being close to the expected willingness to pay, generating further incentives for consumers to invest in evaluating the purchase decision.

[7] Note also that consumers could prefer smaller choice sets because of self-control problems (see, for example, the discussion in Gul and Pesendorfer 2001, Bénabou and Tirole 2004, Fudenberg and Levine 2006) and regret preferences (see, for example, Loomes and Sugden 1987, Irons and Hepburn 2007, Sarver 2008).

[8] For example, the existence of fixed costs per product carried can generate a limited product line. Here, the paper presents an additional force toward a smaller number of products offered.

[9] Consumers could also have search costs per additional product being evaluated, but the main messages of the results presented here should also extend to that setting. That set-up would complicate the analysis, although it would not be central to the market forces presented here. Search costs could also be different across consumers without affecting the main results presented here.

[10] Note that if the search costs k are increasing in the number of products offered n, we would then immediately obtain choice overload effects with exogenous prices, with an optimal finite number of products. The results show that endogenous pricing is a further force toward an optimal smaller number of products if k is not also increasing in n.

Before consumers decide whether to search, the firm chooses the number of products to sell, n, such that it maximizes its profit and foresees that the consumers are going to choose whether to search depending on n and the firm's optimal pricing strategy. To emphasize again the timing of actions, the firm chooses simultaneously the number of products and their locations and prices; prior to searching, the consumers only observe the number of products; after searching, the consumers are also able to observe the product locations and prices.

3. Consumer and Firm Behavior

In this section, we consider the consumer behavior of whether to search and the optimal decision of the firm with respect to prices and the number of products.

3.1. Consumer Behavior

Consider the expected surplus of consumers after they incur the search costs. Given the number of products offered, n, consumers are able to anticipate the equilibrium price charged for each product and to see that in equilibrium the products are equally spaced around the circle.[11]

If the consumer's valuation v is sufficiently greater than the price p, the consumer will always purchase a product. As there are n products, the furthest that a product can be from the ideal product of the consumer is $1/(2n)$, with an expected distance from the best product of $1/(4n)$. The expected surplus obtained by the consumer is then $v-p-t/(4n)$.

However, if the consumer's valuation v is not much greater than the price p, the consumer only buys if his or her ideal product is sufficiently close to one of the products. This will occur if $(v-p)/t < 1/(2n)$. In this case, the probability of a consumer purchasing the product after evaluating the product line is $2n((v-p)/t)$ and the expected surplus, given that the consumer purchases a product, is $v-p-t((v-p)/(2t)) = (v-p)/2$. The expected surplus after searching unconditionally on the location of the consumer's ideal product is then $((v-p)^2/t)n$.

From this, if $\hat{v} \geq p + t/(2n)$, the marginal consumer $\hat{v}$ is determined by $\hat{v}-p-t/(4n)=k$, and all consumers that search buy a product. Yet if $\hat{v} < p + t/(2n)$, the marginal consumer $\hat{v}$ is determined by $((\hat{v}-p)^2/t)n=k$, and some of the consumers that search after inspecting the products decide not to buy any product. Depending on the firm behavior, the market can be in either case.

3.2. Firm Pricing Decision and Market Outcome Given the Product Line Length

Consider now the firm's pricing decision. Note that given that consumers have searched, the best thing that the firm can do to extract the most surplus from the consumers who have searched is to offer equally spaced products at the same price.

If the optimal price will be such that $\hat{v} \geq p + t/(2n)$, such that all consumers after searching choose to buy a product, then the optimal price is the one that makes the marginal consumers at the midpoint between two products to be indifferent between buying and not buying a product, $p = \hat{v} - t/(2n)$. Then, independent of which case we are in (either all consumers that search buy or only some consumers that search buy), we have that the optimal price satisfies $p \geq \hat{v} - t/(2n)$.

Given this condition, the total demand given the price p, the number of products n, and the threshold $\hat{v}$, $D(p, n, \hat{v})$, is

$$D(p,n,\hat{v}) = \int_{p+t/(2n)}^{\bar{v}} dF(v) + \int_{\hat{v}}^{p+t/(2n)} 2n\frac{v-p}{t}\,dF(v), \quad (1)$$

where the first integral represents the demand of the consumers with a sufficiently high valuation such that they always buy after searching, and the second integral represents the demand of the consumers who only buy after searching if their preferences end up sufficiently close to one of the available products, and if there is any positive mass of such consumers. Note that the second integral is equal to zero if all consumers that search decide to buy, as $p = \hat{v} - t/(2n)$ in that case.

The optimal price—given the number of products n and the marginal consumer's valuation $\hat{v}$—results from the maximization of the firm's profit $pD(p, n, \hat{v})$, which results in the first-order condition

$$1 - F\left(p+\frac{t}{2n}\right) - p\frac{4n}{t}\left[F\left(p+\frac{t}{2n}\right) - F(\hat{v})\right] + \int_{\hat{v}}^{p+t/(2n)} \frac{2n}{t} v\,dF(v) = 0. \quad (2)$$

Note that the left-hand side of (2) is strictly positive when $p = \hat{v} - t/(2n)$, which means that the optimal price is $p > \hat{v} - t/(2n)$; that is, the case in which all consumers that search end up buying a product is never an equilibrium. The equilibrium price p and marginal consumer's valuation $\hat{v}$ is then determined by jointly solving (2) and $((\hat{v}-p)^2/t)n = k$. Totally differentiating these two equations with respect to the price p, the marginal consumer valuation $\hat{v}$, and the number of products offered n one obtains the following result (the proof is presented in the appendix).

[11] As noted below, the equilibrium price is the same across products, and the optimal locations are equally spaced around the circle. Even though the equilibrium price is the same across products, consumers only find out about the actual prices after visiting the store and paying the search costs k. Note that if consumers could buy at random without checking prices, then their always buying at random cannot be an equilibrium, because otherwise they could be charged a very high price for one product. Note also that in such a setting, checking the price of only one product would not guarantee that the prices of the other products would be the same.

Proposition 1. *When the number of products offered, n, increases, the equilibrium price p increases by more than the marginal consumer valuation $\hat{v}$.*

As the number of products increases, every consumer knows two things. First, once he incurs the fixed evaluation cost k, he is more likely to find a product that fits his taste. The firm knows this. This would then lead to a better matching of consumers to their favorite products, so consumers with very similar taste and willingness to pay will be matched to any given product. Second, because the firm anticipates this, it can charge a higher price to extract the consumer's surplus. Foreseeing this, consumers become less willing to purchase, i.e., the valuation of the marginal consumer that searches, $\hat{v}$, is likely to be greater. Note that the price increases because of the increase in both the number of products and the marginal valuation of the consumers who search. In contrast, the marginal valuation increases with the price increase but decreases with the increase in the number of products. Therefore, the effect on price of an increase in the number of products is greater than the effect on the marginal valuation.

Note also that for this equilibrium to exist we have $p + t/(2n) > \hat{v} = p + \sqrt{kt/n}$, which reduces to $k < t/(4n)$. If $k \geq t/(4n)$, the equilibrium is for no consumer to search, as consumers know that once they search, the price they face will be so high that their ex ante surplus would be negative. In other words, if the firm chooses a number of products n that is too high, then no consumer will search or buy. Consider the extreme case with an infinite number of products. Then all the consumer surplus would be extracted, but because consumers know this, they will not search. Then, as argued below, a firm will choose optimally not to offer as many products.

To illustrate the results above for the case $k < t/(4n)$, consider the example where v is distributed uniformly in $[0, \bar{v}]$. In that case (2) becomes $\bar{v} - p - t/(2n) - (n/t)(t/(2n) - \sqrt{kt/n})(2p - t/(2n) - \sqrt{kt/n}) = 0$, generating an equilibrium price

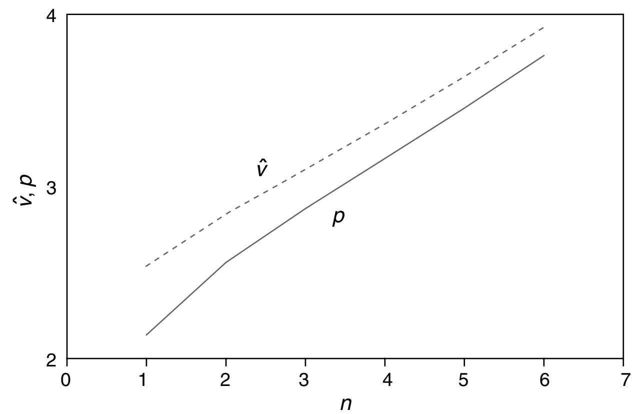
$$p = \frac{1}{2}\frac{\bar{v} - t/(4n) - k}{1 - \sqrt{nk/t}}.$$

It is straightforward to check that the equilibrium price is increasing in n and that it increases faster than the equilibrium $\hat{v}$. Figure 1 shows how $\hat{v}$ and the price p vary with the number of products for $\bar{v} = 4$, $t = 2$, and $k = 0.08$. Note that for this example if $n \geq 7$, then $k > t/(4n)$ and no consumer chooses to search.

Using the proof of Proposition 1,[12] one can also see that when the search costs k increase, fixing the number of products n, the equilibrium price p, and valuation of the marginal consumer $\hat{v}$ increase. As the search costs increase, fewer consumers search and $\hat{v}$ is higher, which leads to higher equilibrium prices.

[12] The slope $d\hat{v}/dp$ of the condition $\hat{v} = p + \sqrt{kt/n}$ is not as steep as the same slope for (2) at the equilibrium.

Figure 1 **Evolution of Equilibrium Valuation $\hat{v}$ of Marginal Consumers and Price p as a Function of the Number of Products n, for v Uniformly Distributed on $[0, 4]$, $t = 2$, and $k = 0.08$**



3.3. Optimal Number of Products

Let us now consider the optimal decision by the firm on the number of products to offer. We already noted that if the number of products offered is too high, such that $k > t/(4n)$, then no consumer searches and the firm ends up with no demand. One can then obtain that if the search costs $k > 0$, then the optimal number of products is finite. We state this result in the following proposition (the proof is presented in the appendix).

Proposition 2. *Suppose that the search costs are strictly greater than zero, $k > 0$. Then the optimal number of products is finite.*

Consider now the question of what the optimal number of products offered, n, is. Denoting $p(n)$ as the equilibrium price per product, given that n products are offered, and $\hat{v}(n)$ the equilibrium valuation of the marginal consumers searching, we can write the problem of the firm as

$$\max_n p(n)D(p(n), n, \hat{v}(n)), \tag{3}$$

where $D(p(n), n, \hat{v}(n))$ is directly obtained from (1). By the envelope theorem, the derivative with respect to n of (3) only needs to take into account the direct effect of n on profits and the effect of n through the equilibrium $\hat{v}$. The first-order condition determining n is then

$$p(n)\frac{\partial D}{\partial n} + p(n)\frac{\partial D}{\partial \hat{v}}\frac{d\hat{v}}{dn} = 0. \tag{4}$$

It is immediately seen that $\partial D/\partial n > 0$. That is, keeping prices and the valuation of the marginal consumers fixed, an increase in the number of products increases demand. Furthermore, $\partial D/\partial \hat{v} < 0$, keeping prices and the number of products fixed, an increase in the valuation of the marginal consumers reduces demand. Then, from (4), we can obtain that close to the optimum $d\hat{v}/dn > 0$, as the number of products offered increases, the number of consumers that search falls. By Proposition 1, we also know that, close to the optimum, as the number of products offered increases, the equilibrium price also increases. We state these results in the following lemma.

Lemma 1. *Given the optimal number of products n^*, there exists a $\delta > 0$ such that for $n \in [n^* - \delta, n^* + \delta]$, as the number n of products offered increases, then both the valuation of the marginal consumers searching and the equilibrium price increases.*

This result illustrates the effect of strategic pricing on the optimal decision of the firms and on the decision of consumers not to search—the choice overload effect. That is, close to the optimum, as the number of products increases, fewer consumers choose to search (and ultimately do not purchase the product), as the high prices that they fear may not allow them to recoup the search costs incurred. This also implies that close to the optimum increasing the number of products decreases demand.[13]

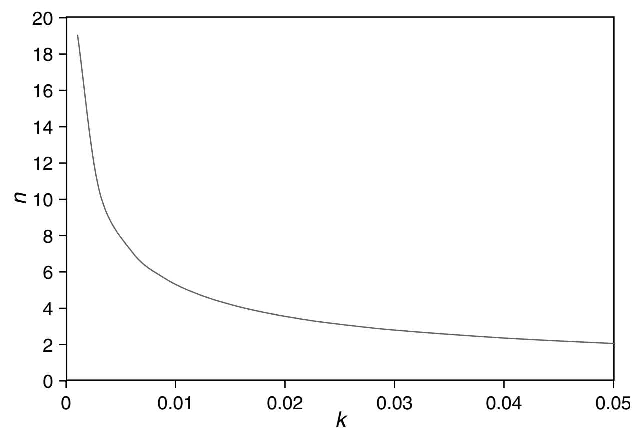
It is illustrative to investigate what happens when the search costs k go to zero. In that case, for a fixed n, we have $\hat{v}$ converging to the price p and $\partial D/\partial \hat{v}$ converging to zero, which from (4) implies that the optimal number of products offered converges to infinity. The condition on the equilibrium price (2) converges then to $1 - F(p) - pf(p) = 0$, which is the typical condition for monopoly pricing under no search costs.

One can then obtain the following result on the effect of the search costs k on the optimal number of products:

Proposition 3. *For any search cost k there is a lower search cost k' such that the optimal number of products under search cost k is lower than under search cost k'. If the probability distribution of the valuation v is uniform, then the optimal number of products is decreasing in the search costs k for all k.*

Figure 2 illustrates the optimal number of products n as a function of the search costs k when v is distributed uniformly on $[0, 4]$ and $t = 2$. As noted in the proposition, in general, one can obtain the result that, for some region of the search costs, when search costs increase, the optimal number of products decreases. The intuition is that when the search costs increase, the firm has to offer a greater surplus for consumers to be willing to search, and it can achieve that by reducing the number of products offered, as a lower number of products generates lower prices.

Figure 2 **Optimal Number of Products n as a Function of Search Costs k, for v Uniformly Distributed on $[0, 4]$ and $t = 2$**



It is also interesting to note that if firms were able to observe prices before incurring search costs, then the optimal number of products to offer would be infinity, given that price demand increases in the number of products offered.[14] However, as noted above, if consumers can observe price but are unable to observe product quality prior to incurring the search costs, then the optimal number of products would continue to be finite, as a larger number of products would allow a firm to extract too much consumer surplus by offering lower product quality.

4. Concluding Remarks

This paper investigates the role of product evaluation costs on consumer behavior and firm strategies when prices are endogenous and the firm chooses the product line length. This paper shows that if consumers have to invest resources to learn about the prices charged, then there is a choice overload effect in the sense that a greater number of products offered leads to fewer consumers being willing to choose. This effect results from the consumers being aware that more products will lead the firm to charge higher prices, as the products fit consumer preferences better. This effect then also generates the effect that the optimal number of products is finite even though there is no cost per product offered. In sum, this paper shows that with product evaluation costs, endogenous pricing leads to fewer products being offered.

[13] However, note that increasing the number of products may increase demand if the number of products is not close to the optimum. To see this, consider, for example, the case of v uniformly distributed, k close to zero, and $n = 1$.

[14] If search costs are incurred per product evaluated, then the optimal number of products to offer would still be finite if prices are observed prior to consumers incurring the search costs. The endogenous pricing effects discussed here would still be present if search costs are incurred per product evaluated.

As noted above, the results extend to the case in which product quality is also a choice variable by the firms that consumers have to check, and consumers observe price without incurring any search cost. The results also replicate when the consumers who value the product category most are also the ones who care more about product fit. This paper considers the monopoly case. It would be interesting to investigate what happens when there is competition. In such a case, if firms have sufficient market power, the same effects may hold; it would be interesting to investigate the effect of the degree of competition. Another interesting issue to investigate would be the implications on price discrimination and vertical differentiation of product evaluation costs. The analysis above considers only horizontal differentiation, but similar model features may lead themselves to study vertical product differentiation.

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Appendix

Proof of Proposition 1. Note first that (2) implies that $\int_{\hat{v}}^{p+t/(2n)}(2p-v)\,dF(v)>0$, which implies $2p>\hat{v}$. Differentiating (2) with respect to $\hat{v}$, one obtains $x\equiv(2n/t)f(\hat{v})(2p-\hat{v})$, which is positive as $2p>\hat{v}$. Adding x to the derivative of (2) with respect to p one obtains

$$y\equiv -f\left(p+\frac{t}{2n}\right)-\frac{4n}{t}\left[F\left(p+\frac{t}{2n}\right)-F(\hat{v})\right] +\frac{2n}{t}f(\hat{v})(2p-\hat{v})-\frac{2n}{t}f\left(p+\frac{t}{2n}\right)\left(p-\frac{t}{2n}\right).$$

Note that for $p=\bar{v}-t/(2n)$ the condition (2) yields $\hat{v}=\bar{v}$, which is greater than the $\hat{v}$ from the condition $\hat{v}=p+\sqrt{kt/n}$, as $t/(2n)>\sqrt{kt/n}$, given that in equilibrium we need to have $p+t/(2n)>\hat{v}$. That implies that the slope $d\hat{v}/dp$ of the condition $\hat{v}=p+\sqrt{kt/n}$ is less steep than the same slope for (2) at the equilibrium, which implies $y<0$.

Totally differentiating the condition $\hat{v}=p+\sqrt{kt/n}$ and (2) with respect to $\hat{v}$, p, and n, one obtains $d\hat{v}/dn=(z-a(y-x))/y$ and $dp/dn=(z-ax)/y$, where $a=\frac{1}{2}(kt/n^2)(kt/n)^{1/2}$ and z is minus the derivative of (2) with respect to n. One can then obtain $dp/dn-d\hat{v}/dn=a(y-2x)/y>0$. □

Proof of Proposition 2. Suppose the firm offers an infinite number of products, and the equilibrium has consumers with $v\geq\hat{v}$ with $\hat{v}\leq\bar{v}$ incurring search costs k. Note that $\hat{v}\geq\arg\max p[1-F(p)]$, as the firm would never charge a price below $\arg\max p[1-F(p)]$. But then as each consumer has his ideal product available, the firm will never charge a price below $\hat{v}$. But then a consumer with a valuation equal to $\hat{v}$ would not incur the search costs k, as after incurring the search costs the consumer would get zero surplus, for a total negative surplus. Then, with an infinite number of products, no consumer will purchase any product, and the firm would end up with zero profits. However, as noted in the text, if $n<t/(4k)$, finite, the firm gets strictly positive demand and profit. Therefore, the optimal number of products is finite if positive profits can be obtained. □

Proof of Proposition 3. Suppose search costs are k. Then we know that the optimal number of products is strictly below $t/(4k)$. For search costs k' (below k) converging to zero we know that the optimal number of products converges to infinity. Then the first statement in the proposition follows. Consider now the case where v is uniformly distributed. For this case one can obtain $\bar{v}(\partial D/\partial n)=t/(4n^2)-k/n$, $\bar{v}(\partial D/\partial\hat{v})=-2\sqrt{nk/t}$, and $d\hat{v}/dn=\sqrt{t}((t(2\sqrt{t}-3\sqrt{nk})+4n\sqrt{nk}(\bar{v}-k)-8\sqrt{nk}(\sqrt{t}-\sqrt{nk})^2)/(16n^2(\sqrt{t}-\sqrt{nk})^2))$. Using (4) one can then obtain the condition for the optimal n as

$$2t^2-6wt\sqrt{t}+5tw^2-4\bar{v}nw^2+4w^4=0, \qquad (5)$$

where w is defined as $w\equiv\sqrt{nk}$. Using (5) to write n as a function of w, and taking the derivative of n with respect to w one obtains $dn/dw<0$ as the condition $n<t/(4k)$ translates into $w<\sqrt{t}/2$. As $dw^2/dn=k+n(dk/dn)$ we have that $dn/dk<0$, a higher search cost leads to a lower optimal number of products. □

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