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When More Alternatives Lead to Less Choice

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This paper shows that when the alternatives offered to consumers span the preference space (as it would be chosen by a firm), search or evaluation costs may lead consumers not to search and not to choose if too many or too few alternatives are offered. If too many alternatives are offered, then the consumer may have to engage in many searches or evaluations to find a satisfactory fit. This may be too costly and result in the consumer avoiding making a choice altogether. If too few alternatives are offered, then the consumer may not search or choose, fearing that an acceptable choice is unlikely. These two forces result in the existence of a finite optimal number of alternatives that maximizes the probability of choice.

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1. Introduction

Firms often have to decide how many alternatives to offer to their customers. On the one hand, the marketing principle of satisfying customers seems to suggest that the more the number of alternatives, the better. On the other hand, we do not see unlimited choice anywhere. No doubt supply-side considerations have a role to play in this, but it may be that unlimited choice is not good even for consumers. In fact, salespeople often do not offer too many alternatives. A shoe salesman quoted in the *New York Times* (Waxman 2004) said, "As a neophyte shoe salesman, I was told never to show customers more than three pairs of shoes. If they saw more, they would not be able to decide on any of them."

A number of academic studies seem to confirm the shoe salesman's intuition. Jacoby et al. (1974) show in an experimental setting that if consumers are provided with more choices, they may end up making worse choices. In a field experiment, Iyengar and Lepper (2000) find that when the number of flavors of jams offered to consumers increases, consumers are less likely to make a choice. Boatwright and Nunes (2001) show that reducing the assortment size in a grocery store can increase sales.[1] In the financial realm, employees have shown a greater willingness to enroll in 401(k) retirement plans when the plans offered fewer funds (Iyengar et al. 2004), and Bertrand et al. (2005) find the same phenomenon in loan offers.[2]

Why might consumers balk at choice sets with a large number of alternatives? Keller (1998, p. 464) suggests that "different varieties of line extensions may confuse and perhaps even frustrate consumers as to which version of the product is 'the right one' for them." Presumably this frustration would then lead them to preferring smaller choice sets. Jacoby et al. (1974) are more explicit in putting the blame on information processing costs. They find evidence of consumers making worse choices from larger choice sets after being told to "examine and evaluate all the information" (Jacoby et al. 1974, p. 64).[3] Awareness of their suboptimal performance from large choice sets would induce consumers to prefer smaller choice sets.[4] Other studies have manipulated variables that

[1] In the first half of the 1990s, Procter & Gamble cut its number of products by one third, often with gains in market share (Schiller and Burns 1996, p. 96).

[2] Madrian and Shea (2001) show an example where a firm automatically enrolls employees in the company 401(k) plan, and this leads to an increase in retirement savings, even though employees can easily opt out of the enrollment. See also the evidence in Thaler and Benartzi (2004) and Choi et al. (2004). This could potentially be seen as employees avoiding "active" choice.

[3] Other explanations in the literature include avoiding choice to exercise more self-control (Gul and Pesendorfer 2001, Bénabou and Tirole 2004, Fudenberg and Levine 2005) and to avoid regret (Loomes and Sugden 1987, Irons and Hepburn 2007, Sarver 2008).

[4] In the experiments in Jacoby et al. (1974), however, consumers indicated greater satisfaction with a larger number of alternatives. Diehl and Poynor (2010) argue that this effect may result from greater consumer expectations because of the greater assortment. Keller and Staelin (1987) argue that quality of information may

affect information processing costs and found the predicted results. Chernev (2003) shows that when consumers articulate their preferences then they tend to prefer larger sets of alternatives. This may be because articulation of preferences makes it easier to evaluate the alternatives. Note that having consumers articulate their preferences imposes an upfront cognitive cost of articulation on them, and thus consumers who were not induced to articulate their preferences by the experimenter seem to choose not to do so. Gourville and Soman (2005) show that the "alignability of alternatives" increases consumers' preferences for larger choice sets, presumably because alignable alternatives are easier to compare.[5]

This paper provides a model-based examination of the effect of search or evaluation costs (e.g., Stigler 1961) on preference for number of alternatives. The paper considers a sequential search process when the alternatives offered span the preference space and are not independently located (as it would be the case of products offered by a firm). In addition, the paper explicitly considers the possibility of choice without evaluation. The behavioral accounts referred to earlier do not consider the issues of fixed sample or sequential search, the effect of the alternatives offered being independently distributed or spanning the preference space, or the possibility of choice without evaluation. Given sequential search, would a consumer actually prefer a smaller choice set given that a smaller choice set may limit the possible alternatives to evaluate? If the alternatives offered are independently distributed, do we still have that consumers prefer a not-too-large choice set? With respect to choice without evaluation, would a consumer necessarily be averse to large choice sets given the possibility of choosing randomly?

The paper sheds light on a number of factors that have a bearing on consumers' preferences among choice sets. One of them is the role of supply-side effects in shaping consumers' beliefs about the distribution of alternatives in preference space. The expected costs of finding an acceptable alternative from a choice set via evaluation, and the expected utility obtained from it, depend on how consumers perceive alternatives to be distributed. The utility from random choice also depends on this distribution. The distribution of alternatives, in turn, depends on the suppliers' strategic behavior: how they perceive the distribution of consumer preferences and how they respond to them. The paper shows that firms would like to offer products that span the preference space and that under sequential search this leads to an optimal finite number of products offered to maximize the probability of choice.[6] In contrast, if the products offered are independently located (which is not the case if they are offered by a firm), and there is sequential search, then the optimal number of products is infinite. The intuition is that with alternatives spanning the preference space, fewer alternatives help the consumers in the search process; however, this is not the case when alternatives are independently located.[7] Second, given beliefs about the distribution of alternatives, the consumer's own ideal point affects her preference for large versus small choice sets. For example, we show that search behavior is in general a nonmonotonous function of the extremity of consumer preferences: it is possible that both somewhat extreme and average consumers do not search, whereas moderately extreme ones do. The model allows us to make predictions about the effects of importance of fit, evaluation costs, and consumer location in the preference space on the optimal number of alternatives.

The idea of costly evaluation costs goes back to the idea that decision makers may only be able to process a limited amount of information (e.g., Simon 1955, Miller 1956). 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.

Some work in the literature has considered the effect of evaluation costs on choice problems. Hauser and Wernerfelt (1990) argue that consumers may strategically limit their consideration sets (with search under fixed sampling) to limit evaluation costs at each consumption occasion. In relation to that paper, this paper formalizes the costly product sequential

help decision making, whereas quantity of information may affect decision making negatively. See also Jacoby (1977). In a setting with interaction among agents, more information is not necessarily better (e.g., Guo 2009).

[5] Salgado (2005) also shows that individuals may prefer fewer options because of contemplation costs.

[6] If there is a fixed cost of production per alternative offered, the optimal number of alternatives is also obviously finite. This may be an important factor in some market situations. The paper shows that even without the cost of providing an additional alternative, costly evaluation of alternatives yields a finite optimal number of products offered and may be a force towards a lower number of alternatives. The extant literature related to the product line design considered how the optimal number of products (alternatives) may be restricted by the adverse selection problem in the case of vertically extended product line (e.g., Moorthy 1984, Desai 2001), by the costs of maintaining the product line (e.g., Shugan 1989), or by the costs of communication (e.g., Villas-Boas 2004). This paper adds to the above literature by considering how the consumer product evaluation costs may lead to a shorter optimal length of the product line.

[7] Note also that if too few products are offered, consumers may choose not to buy because it is unlikely for an alternative to be close to the consumer's ideal point.

evaluation process. In a sequential evaluation process having more alternatives is always better if the alternatives are independently distributed (in contrast with fixed sampling), as consumers can always stop searching after checking each alternative. However, as shown here, in a sequential evaluation process, if the alternatives are not distributed independently (and span the preference space) then fewer alternatives can be better. In this setting, consumers do not infer their preferences from the alternatives offered, but rather the number of alternatives offered affects the costs and benefits of that evaluation process. Also in relation to Hauser and Wernerfelt (1990), this paper provides a choice-based reason for firms to offer a limited number of alternatives, while in Hauser and Wernerfelt a consumer can strategically limit their consideration sets without the help of the firms and without additional choice effects. Van Zandt (2004) considers competition where firms communicate about their products and consumers evaluate a limited and fixed number of alternatives, and 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 that affects the other firms. In relation to that paper, this paper concentrates on the optimal consumer sequential evaluation process when a firm offers multiple products and models the firm's decisions on the number and location of products.[8] Note also that under competition with the possibility of a firm offering several alternatives, offering fewer alternatives may hurt a firm's competitive position. This issue is not considered here. In independent work, Kamenica (2008) and Norwood (2006) consider the possibility of the products offered affecting the preferences of consumers. In contrast to this paper, Kamenica considers a firm that is better informed than some consumers about which products are most popular. By offering a smaller set of (the most popular) products, the uninformed consumers are more likely to purchase (at random) a more popular product. Norwood considers free-entry price competition among fixed products that are vertically differentiated; one product per firm, under the assumption that only the most popular products are offered; and includes an approximation to the consumer sequential evaluation process.

Finally, it may also be that a greater number of alternatives may lead the decision maker to delay choice (and not to choose when the choice set is first presented) to gather more information on the choice problem (e.g., Dhar and Simonson 2003). It is possible that this new information could come at a lower cost than that of evaluating different alternatives at the present. Note that this explanation could then be seen again as consistent with a search-cost explanation for not choosing when many alternatives are presented.

The rest of this paper is organized as follows: The model is presented in §2. Section 3 presents the consumer search behavior and shows that for the maximal probability of choice, it is never optimal to offer an infinite number of alternatives, i.e., that there is always a number of alternatives that is "too many." Section 3 also discusses the optimal behavior of the firm, the relation of the results to the experimental evidence, and testable empirical implications. The conclusion is presented in §4, and the proofs are presented in the appendix.

2. The Model

A population of consumers is interested in choosing one alternative from a set of alternatives that spans the preference space. Consumers are uncertain about the value of each alternative and incur an evaluation or search cost c per alternative evaluated. A consumer's preference is determined by the pair (v, x), which is the consumer's type, with v and x assumed to be independently distributed in the population, to clearly distinguish their different roles, and with $v \in [0, \bar{v}]$ being a utility level of the ideal alternative and $x \in [0, 1]$ being the location of the consumer's ideal alternative. The alternatives are characterized by locations $z \in [0, 1]$.[9] A consumer's utility of choosing alternative z is $v - t|x - z|$. The term t is a disutility parameter reflecting the consumer's disutility when the ideal point of the consumer is different from the alternative located at z. The location of a consumer's ideal alternative, x, is exogenous; it is not a function of the alternative set.[10]

Before deciding whether to spend effort on evaluating the alternatives, consumers observe the number n of alternatives being offered and know their own taste parameters, interest-in-the-category parameter v, and horizontal preference x. For example, this could be the case when a consumer sees the length of shelf

[8] For product line competition without evaluation costs, see, for example, Klemperer and Padilla (1997). For models of competition with differentiated products and search costs for the price information, see, for example, Anderson and Renault (1999) and Kuksov (2004).

[9] Several of the results presented here can be easily obtained for consumer ideal points and alternatives distributed on a circle. That case would not allow us to consider what happens at the extreme points of the distribution of consumers (there are no extreme points on a circle), and the optimal location of products would not be unique. This paper focuses on the product horizontal differentiation case to illustrate the effects of search costs to concentrate on the question of product fit. It would also be interesting to consider the effects of vertical differentiation.

[10] In §4 we discuss an extension where the alternative set may provide information to the consumers about their preferences.

space provided in a supermarket or department store for a category, or when a consumer sees the total list of products available in a Web page. In many market situations consumers may first have a sense of the number of products available. Then, after observing the number of products available, a consumer has to decide whether it is worth incurring evaluation costs to find out how much each product is worth 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 displayed or advertised. The provider of the alternatives, henceforth also referred to as the firm, decides on the number n of alternatives to offer and where to position them.

After observing the number of alternatives offered (but not their locations), the consumer decides whether to start the evaluation process, to choose an alternative at random, or to do neither—bailing out of the whole choice problem. The last possibility may be interpreted as "no choice." If he chooses at random, his final utility is $v - t|x - z_i|$, where z_i is the randomly picked alternative and z_i remains uncertain until after the purchase. If the consumer wants to evaluate alternatives, he engages in a sequential search: at each search step, the consumer determines the location of one randomly picked alternative at a cost c (independent of t, x, or z_i). After evaluating an alternative, the consumer may decide to choose one of the alternatives already evaluated, to choose at random one of the alternatives not yet evaluated, to evaluate an additional alternative, or to not choose. The utility of not choosing any alternative (gross of any costs incurred) is normalized to zero.

Thus, if a consumer decides to engage in the search and evaluation process and chooses alternative i after evaluating $m \geq 0$ alternatives, he obtains utility

$$U = v - t|x - z_i| - mc. \tag{1}$$

To simplify the analysis, we assume that x and v are distributed uniformly and that the search cost $c > 0$ does not vary across consumers or from evaluation to evaluation.[11] We assume that the alternatives are equidistantly located to best cover the set of consumer ideal points; that is, $z_i = (2i-1)/2n$, $i = 1, \ldots, n$. We discuss in §3.7 how these locations could be the ones optimally chosen by a firm, given the number of alternatives n.

Although consumers may not observe the locations of the products without incurring the incremental search evaluation costs, consumers may form beliefs about product locations. Given the unique mapping above from the number of alternatives to their locations, this implies that consumers are able to infer the distribution of the product locations from the number of products offered. However, consumers remain uncertain about which product is which.

Essential features of our model are that (a) consumers are unsure of how and which alternative fits their preferences, (b) consumers face search costs which make exhaustive (sequential) evaluation of all alternatives offered costly, and (c) consumers expect the alternatives to span a broad range corresponding to the diverse tastes in the market.[12]

3. Consumer Search and Choice Behavior

3.1. Introduction

Consider the situation where the consumer has evaluated m alternatives, comprising a set that we denote by I. Then, the expected payoff of a consumer with preference characteristics (v, x) after having evaluated the alternatives in this set I is

$$\begin{aligned} V(v,x,I,n) &= \max\Bigg\{0, \max_{i\in I} v - t|x-z_i|, \sum_{i\notin I} \frac{1}{n-m}(v - t|x-z_i|), \\ &\qquad -c + \sum_{i\notin I} \frac{1}{n-m} V(v,x,I\cup\{i\},n)\Bigg\}. \end{aligned} \tag{2}$$

The right-hand side of this equation represents the four possible options available to a customer at every stage of his sequential decision process. The first element in the max function represents the option of

[11] More generally, the cost of evaluating an additional alternative could vary with the number of alternatives evaluated, for example, with diminishing costs of search. The main messages of this paper would also go through in such setting if the search cost of an additional alternative is always strictly positive. The supplier of alternatives can also potentially choose to structure the presentation of alternatives to lower the consumers' evaluation costs. This possibility is not considered here in order to focus on the number of alternatives/evaluation costs effects, but it would be interesting to explore in further research (possibly with more attribute dimensions).

[12] It is instructive to relate our setup to the Iyengar and Lepper (2000, p. 997) jam experiment. In that experiment, the first of our essential features was present because "careful attention was given to selecting a product with which most consumers would be familiar, yet not so familiar that preferences would already be firmly established. Hence, to ensure that potential customers would not just reach for the more traditional flavors such as strawberry and raspberry, these common flavors were removed from the set of 28, leaving a choice set of 24 more exotic flavors." Second, consumers clearly faced costs in evaluating the various jams: not only their own time was involved, but in addition, there was the social pressure of doing the tasting in front of the experimenter. Perhaps, this induced a demand effect of not appearing to be too picky. Finally, given the diversity of flavor labels on the jams, the consumer could be reasonably sure that a random choice would prove to be quite suboptimal.

dropping out—not choosing any alternative. The second element represents the option of stopping the sequential decision process and choosing the best alternative among the ones already evaluated. The third element represents the option of choosing an alternative at random among the alternatives not yet evaluated. Finally, the fourth element represents the option of continuing the search by evaluating one more alternative. All the options have the sunk cost of having evaluated m alternatives, mc (not reflected in (2)). The problem represented by (2) is a finite search problem without replacement, but with recall and with the possibility of random choice without search, and with nonindependent attributes across alternatives.

Note first that the optimal consumer behavior cannot involve not choosing an alternative after starting the search process and evaluating at least one alternative. This is because evaluating an alternative either results in finding an alternative that dominates the no-choice option or not. In the former case, no choice is clearly inferior. In the latter case, searching further or choosing at random from the remaining alternatives beats no choice because the set of remaining alternatives has only gotten better, not worse. Thus, if it was optimal to search from the original set, it continues to be so now. Therefore, the expected utility for a consumer with a given v and x starting the decision process can be written as $V(v, x, \varnothing, n) = v - \tilde{d}(x, n)$, where the function $\tilde{d}(x, n)$ represents the expected disutility of a consumer located at x given that the firm offered n alternatives. This expected consumer disutility is composed of the expected costs of searching plus the expected misfit of settling on an alternative that may not match the consumer preferences exactly. Let $d(n) = \int_0^1 \tilde{d}(x, n)\, dx$, which represents the average expected disutility of consumers with high enough v who decide to proceed with an alternative evaluation or to choose at random. For later consideration, let also $\tilde{r}(x, n) = \sum_{i=1}^{n} t|x - z_i|/n$ be the expected misfit from a random choice before evaluating any alternative, when there are n alternatives and the consumer ideal point is x, and let $r(n) = \int_0^1 \tilde{r}(x, n)\, dx$ be the average consumer misfit in random choice.

The valuation v of the marginal consumer located at x indifferent between choosing and not choosing is determined by $\hat{v}(x, n) = \tilde{d}(x, n)$. For a cumulative distribution function $F(v)$ of the consumer valuations v, the number of consumers choosing an alternative is $\int_0^1 [1 - F(\hat{v}(x, n))]\, dx = \int_0^1 [1 - F(\tilde{d}(x, n))]\, dx$. Given the uniform distribution of v, this expression becomes $\int_0^1 (\bar{v} - \tilde{d}(x, n))/\bar{v}\, dx$. The question of what number of alternatives results in the largest number of consumers actually choosing an alternative is then the question of what n minimizes the expected consumer disutility $\int_0^1 \tilde{d}(x, n)\, dx = d(n)$. Thus, if the provider of the alternatives is a firm whose profit is a fixed margin times the number of consumers choosing an alternative or a social planner maximizing consumer welfare, the provider of alternatives problem reduces to[13]

$$\min_n d(n). \tag{3}$$

To offer intuition on the model above, the next subsection considers the case of up to three alternatives. In the following subsections we consider the case of an infinite number of alternatives and argue that the optimal number of alternatives that maximizes the probability of choice is finite. We then compute an "approximate" optimal number of alternatives, discuss the firm's decision of product locations, and consider some testable empirical implications.

3.2. Up to Three Alternatives

3.2.1. One Alternative. When the firm offers only one alternative, consumers do not need to search. The location of the alternative in the center of the market yields the lowest expected disutility. The disutility ranges from $t/2$ for type $x = 0$, to $t/4$ for type $x = 1/4$, to zero for type $x = 1/2$. Consumers choose the alternative if and only if $v > t|x - 1/2|$. The expected disutility of the product bought across consumers is

$$d(1) = r(1) = t \int_0^1 \left| x - \frac{1}{2} \right| dx = \frac{t}{4}. \tag{4}$$

Note that this disutility is lower than the expected disutility of random choice from any number of alternatives more than one, because $\int_0^1 |x - z_i|\, dx = z_i^2 - z_i + 1/2$ is minimized at $z_i = 1/2$.

To gain some intuition for the benefit of offering a small number of alternatives, note that in the case of an infinite number of alternatives (see §3.3), the expected disutility from random choice ranges from $t/2$ for type $x = 0$ to $5t/16$ for type $x = 1/4$, to $t/4$ for type $x = 1/2$, for an expected disutility across all consumers of $t/3$. The expected disutility for one alternative is lower than for random choice with a higher (such as an infinite number) of alternatives because with only one alternative, consumers in the center of the market get a disutility close to zero, and this is not the case with random choice from a larger number of products. This example of one alternative illustrates

[13] We concentrate on the choice effects without including price-setting effects of firm decision making to simplify the presentation. This case can be seen as relevant for some situations where prices are not present, when the supplier of alternatives does not have influence over prices, or when the price cannot be informative about the attribute under consideration because of other attributes present (although in that case the model would have to be extended with further attribute dimensions). Villas-Boas (2009) considers the case of endogenous prices with (fixed) search costs that allow a consumer to learn all product locations.

one reason the provider of alternatives may want to restrict the number of alternatives to offer: when offering a smaller number of alternatives, the more "generic" ones (i.e., the ones fitting more customers) will be offered. This reason becomes less important when more alternatives are offered, and consumers engage in active search.

3.2.2. Two Alternatives. In the case of only one product being offered, no consumer incurs the search cost c. Consider now the case of the firm offering two products, such that a positive mass of consumers will actually incur search costs. In this case, the assumed pair of locations 1/4 and 3/4 is also the location of the products that minimize the expected disutility for consumers (see the appendix) and may be optimal for the firm (see §3.7). In this case, a consumer is more indifferent to the choice between the two products if x is in the middle than if it is at either end. Therefore, consumers in the middle find it optimal not to search but to buy at random instead, whereas the more extreme consumers may find it optimal to search. We have the following result:

Lemma 1. *Suppose that two alternatives are offered. If $c/t \geq 1/4$, consumers with $v \geq t/4$ choose at random, and consumers with $v < t/4$ choose not to choose. If $c/t < 1/4$ consumers with $x \in (1/2 - c/t, 1/2 + c/t)$ and $v > t/4$ choose an alternative at random, consumers with $x \leq 1/2 - c/t$ and $v > |x - 1/4|t + c$ or $x \geq 1/2 - c/t$ and $v > |x - 3/4|t + c$ search once and choose the alternative that fits them better. All other consumers choose not to choose. Furthermore, the average expected disutility of consumers who choose an alternative for $c/t < 1/4$ is*

$$d(2) = \frac{t}{8} + c - \frac{c^2}{t}. \tag{5}$$

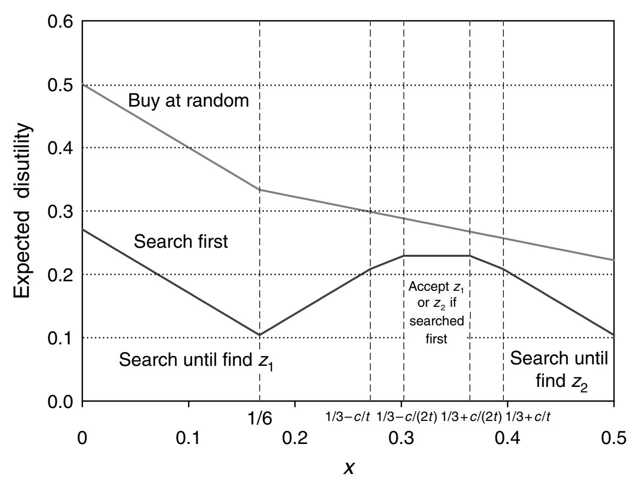
To gain intuition on the results above, let us consider the first search of a consumer located at $x = 0$ under both the case of two alternatives and the case of an infinite number of alternatives. Under an infinite number of alternatives, the expected distance of the first alternative searched is 1/2, and choosing any other alternative after the first search gets also an expected distance of 1/2. However, with just two alternatives, the expected distance of the chosen alternative with the first search is 1/4. Either the alternative searched is at 1/4, in which case it is the chosen one, or the alternative searched is at 3/4, and then the consumers knows that the other alternative is located at 1/4. This illustrates the advantage of searching without replacement (with just two alternatives), discussed above.

3.2.3. Three Alternatives. Consider now the case where the firm offers three alternatives. This case allows us to consider a situation where all consumers who buy a product may engage in the search process (in contrast with the two-alternative case above, where there are always some consumers who bought a randomly chosen product). The locations for the three products will be $z_1 = 1/6$, $z_2 = 1/2$, and $z_3 = 5/6$. As in the two-alternative case, it can be shown that these locations are also the ones that minimize the expected disutility of the consumers. The expected disutility of choosing a random product in this case is $r(3) = 35t/108$.

The appendix completely characterizes the sequential decision process in a setting where all consumers buying a product engage in the evaluation of at least one product and shows that all consumers who eventually choose an alternative do search at least one alternative if $c/t < 2/21$ (see Proposition 4 in the appendix). The proposition illustrates again that consumers who are located in a certain range in between two alternatives are willing to take either of the two alternatives. The proposition also shows that this range is different depending on whether the consumer has searched one of these two alternatives or whether the consumer has searched all alternatives except these two alternatives. In the former case, the consumer would benefit from searching by twice the distance to the midpoint. In the latter case, the consumer chooses at random between these two alternatives and would benefit from searching by an amount proportional to the distance from his ideal point to the expected product location, which is the midpoint between the two alternatives.

Figure 1 shows the expected disutility for each x when the firm offers three alternatives and the consumers search once. As expected, the consumers located close to the alternatives' locations do better. However, consumers could also decide not to search at all and just to buy at random among the three alternatives.

Figure 1 **Expected Disutility of Strategy "Search First" and Strategy "Buy at Random" for Each x, for Three Alternatives, $t = 1$, and $c = 1/16$**



Notes. $z_1 = 1/6$, $z_2 = 1/2$, and $z_3 = 5/6$. If z_3 is searched first, then buy at random if x in $[1/3 - c/t, 1/3 + c/t]$.

Note that if $c/t \in (2/21, 1/6)$, some consumers, when faced with three alternatives, would buy at random while other consumers would engage in the evaluation of a first alternative. Figure 1 shows the expected disutility when consumers buy at random and when they engage in the evaluation of the first alternative for $c = 1/16$ and $t = 1$, in which case all consumers engage in the evaluation of at least one alternative. Figure 2 shows the same curves when $c = 1/9$ and $t = 1$, in which case some consumers engage in the evaluation of at least one alternative while other consumers buy at random.

For the case in which all consumers who buy a product do evaluate the first alternative, $c/t < 2/21$, one can compute the expected disutility across all consumers as

$$d(3) = \frac{t}{12} + \frac{5}{3}c - \frac{c^2}{t}. \tag{6}$$

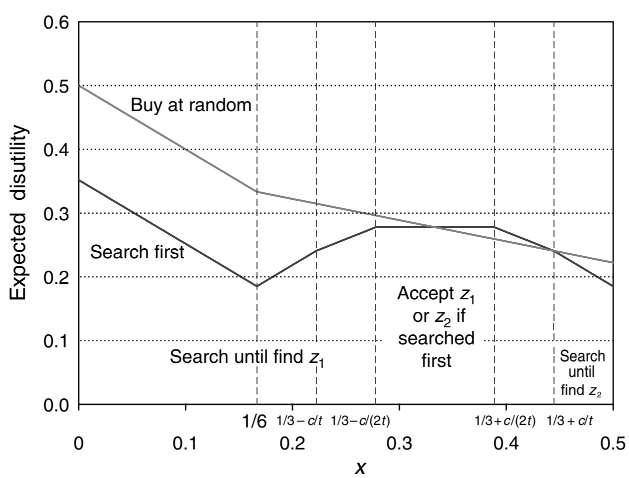
3.2.4. Comparison Across One, Two, and Three Alternatives. For purchase at random, we have $r(1) < r(2) < r(3)$. Also, comparing the case of two alternatives with the case of one alternative we have

$$d(2) < d(1) \quad \text{if and only if } \frac{c}{t} < \frac{2-\sqrt{2}}{4}; \tag{7}$$

that is, offering two products increases the probability of choice if and only if the search costs are low enough. The comparison between two and three alternatives leads to a threshold of c/t of 1/16. Comparing the probability of choice among the cases of one, two, and three alternatives, we have then the following result:

Proposition 1. *Suppose that the possible options are to offer one, two, or three alternatives. Then if* $c/t > (2-\sqrt{2})/4$, *the probability of choice is highest when only one alternative is offered. Otherwise, if* $c/t < 1/16$ *the probability of choice is highest with three alternatives, whereas if* $c/t \in [1/16, (2-\sqrt{2})/4]$, *the probability of choice is highest with two alternatives.*

Figure 2 **Expected Disutility of Strategy "Search First" and Strategy "Buy at Random" for Each x, for Three Alternatives, $t = 1$, and $c = 1/9$**



Notes. $z_1 = 1/6$, $z_2 = 1/2$, and $z_3 = 5/6$. Buy at random is better than search first for some x.

This comparison illustrates that offering a smaller number of products may increase the probability of choice if the search costs are not too low and suggests that lower search costs may lead the firm to offer more alternatives.

The above proposition also shows that if a firm offers too many alternatives, some consumers may not make any choice and may stay out of the market because they understand that it will be too costly (in terms of search costs) for them to find the alternative that best fits their preferences (that is, there would be a higher threshold $\hat{v}(x, n)$). Similarly, if the firm offers too few alternatives, some consumers may also stay out of the market because they feel that the alternatives that are available may not fit well with their preferences. In sum, given the existence of search costs, there may be a (sufficiently large) number of alternatives that results in a lower probability of choice than a smaller number of alternatives. Note that the threshold $\hat{v}(x, n)$ depends on x and n. For example, for c/t small, we have $\hat{v}(1/2, 1) = 0$, $\hat{v}(1/2, 2) = t/4$, $\hat{v}(1/2, 3) = 5/3c$ and $\hat{v}(0, 1) = t/2$, $\hat{v}(0, 2) = t/4 + c$, $\hat{v}(0, 3) = (5/3)c + t/6$.

3.2.5. Preferences of Extreme vs. Mainstream Consumers for the Size of the Set of Alternatives. It is also interesting to consider how the preference for a smaller or larger set of alternatives differs between the consumers in the center and consumers with more extreme preferences. In relation to this, note that the consumers exactly in the center are happiest with the smallest possible set of alternatives: they know that if the provider of alternatives has to choose only one alternative to provide, it will be exactly the alternative that they want, because the compromise alternative is their preferred alternative. This outcome will lead consumers in the center not to waste any resources on search and, at the same time, to obtain their best preferred alternative.

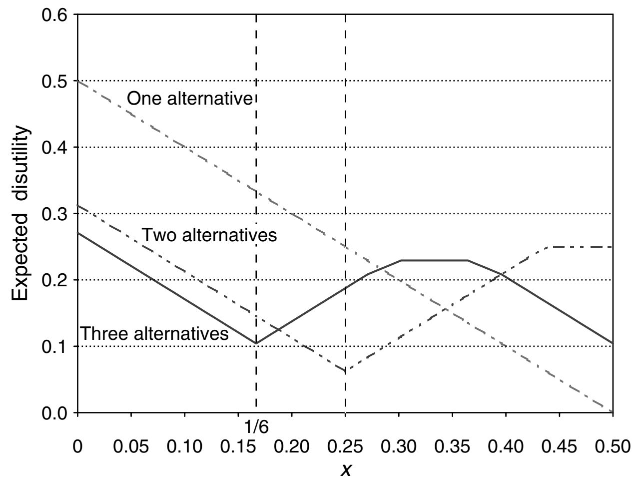
On the other hand, consumers whose preferences are not in the center face a trade-off: if the number of alternatives is higher, then their search costs go up, but the fit of their preferences to the better alternative that they may find may be larger. This means that these consumers may prefer a larger set of alternatives than the consumers in the center.[14] We have the following proposition:

[14] Note, however, that although the results suggest the message above, the expected disutility of consumers at a particular location does not move monotonically with the number of alternatives offered. Suppose that the search costs are sufficiently small, so that

Proposition 2. *Suppose the firm can offer one, two, or three alternatives, and suppose $c < 2t/21$.*[15] *Then, consumers with x at most $1/8 + c/(2t)$ from the center of the interval prefer one alternative to be offered, consumers with x at a distance of $1/8 + c/(2t)$ to $7/24 + c/(3t)$ from the center prefer two alternatives to be offered, and consumers even further away from the center prefer three alternatives to be offered.*

The above proposition implies that mainstream consumers prefer a smaller number of alternatives and that the more extreme type the consumer is, the more alternatives he prefers to have. Figure 3 presents the expected disutility as a function of x for one, two, and three alternatives. Note that, in addition to the result above, the smaller the search cost, the more alternatives a consumer at $x \in [0, 1]$ prefers. The result in this proposition could be seen as expected and clarifies the way in which choice overload affects consumers depending on the degree of extremeness of their preferences.

Figure 3 **Expected Disutility for Each x for Choice Sets with One, Two, or Three Alternatives with $t = 1$ and $c = 1/16$**



3.3. Infinite Number of Alternatives

To consider the case with any number of alternatives, let us consider first the case of an infinite number of alternatives. Given the assumption on the location of alternatives, this reduces to the case in which the alternatives are uniformly distributed on the segment $[0, 1]$. In this case, the optimal search process is the same as a search process with replacement (e.g., Diamond 1971). The problem, generally defined, is the following: let the alternatives be distributed with density $f(x)$ (and cumulative distribution $F(x)$) on the line. It is well known that in such problems, the optimal search process involves a stopping rule where the decision maker keeps on searching until he finds an alternative that provides a utility greater than or equal to some reservation utility. In this particular setup, the problem is for the decision maker to find a product that is sufficiently close to his ideal point. This means that a consumer located at x will have a reservation alternative located to his left, $R_L(x) \le x$, and a reservation alternative located to his right, $R_R(x) \ge x$. If the product searched falls in $[R_L(x), R_R(x)]$, the consumer stops searching and buys that alternative; otherwise, the consumer keeps on searching. Note that under this search strategy, the expected disutility of a consumer located at x is $t\int_{R_L(x)}^{R_R(x)} |y - x|\, dF(y)/[F(R_R(x)) - F(R_L(x))] + c/[F(R_R(x)) - F(R_L(x))]$.

Coming back to our problem of search with alternatives distributed uniformly on $[0, 1]$, one can see that for a consumer located close to the center of the segment $[0, 1]$ (where "close" is defined below), there are two reservation products, one located to the left and one located to the right of the consumer's location. The reservation product is defined by the condition that the marginal cost of searching for an extra product, c, is equal to the marginal expected benefit (in terms of better fit) of that search, given that a reservation product has just been found. This condition can be written for a consumer located at x as

$$c = \int_{x-\delta}^{x+\delta} t|x - y|\, dy, \tag{8}$$

where δ is the distance from the reservation product to the consumer's location. This yields $\delta = \sqrt{c/t}$; that is, if $\sqrt{c/t} < x < 1 - \sqrt{c/t}$, the consumer can achieve the reservation utility with a product either on the right or on the left of its location. The expected search costs plus the disutility of the product bought for a consumer located at x are equal to the disutility of the reservation product because the consumer is indifferent to the choice between getting that product and engaging in the search process. This expected search cost plus disutility, for $\sqrt{c/t} < x < 1 - \sqrt{c/t}$, is then $t\delta = \sqrt{ct}$. We should compare this with the expected disutility if the consumer does not search and instead buys at random, which is $\int_0^1 t|y - x|\, dy = t(x^2 - x + 1/2)$. Note then that if $c/t < 1/16$, all consumers $\sqrt{c/t} < x < 1 - \sqrt{c/t}$ engage in the search process. This means that if the search costs are low enough, or if the importance of alternative fit is

with three alternatives, a consumer chooses always to search at least once, $c/t < 2/21$, as shown in Proposition 4 in the appendix. Then, for $x = 1/2$, the expected disutility is zero for one alternative but goes up to $t/4$ for two alternatives and falls to $(5/3)c$ for three alternatives. On the other hand, for $x = 1/4$, the expected disutility is $t/4$ for one alternative, falls to c for two alternatives, and goes up to $(5/3)c + t/12$ for three alternatives.

[15] The same holds with larger c but with different equations on the cutoff points. When c is large enough, the ranges of x where consumers prefer two and three products become empty sets.

high enough, all consumers in the center of the market who choose one alternative engage in the search process.

Consider now the case of $x < \sqrt{c/t}$ or $x > 1-\sqrt{c/t}$. Here, the reservation utility may only be obtained on one side of the consumer's location. Consider the case of $x < \sqrt{c/t}$. Here, the reservation product on the right of x is defined by

$$c = \int_0^x t(x-y)\,dy + \int_x^{x+\tilde{\delta}(x)} t(y-x)\,dy, \tag{9}$$

where $x+\tilde{\delta}(x)$ is the reservation product for the consumer located at x. From this, one can obtain $\tilde{\delta}(x) = \sqrt{2c/t - x^2}$, which is decreasing in x and such that $\tilde{\delta}(\sqrt{c/t}) = \delta$.

If a consumer located at $x < \sqrt{c/t}$ engages in the search process, his expected search costs plus disutility of the product bought is then $t\tilde{\delta}(x) = t\sqrt{2c/t - x^2}$ (the case of $x > 1-\sqrt{c/t}$ is symmetric). Note that this expected search cost plus the disutility of the product bought is concave in x. That is, for x close to $\sqrt{c/t}$, when the location of the consumer moves away from the center of the distribution of preferences, the expected search costs plus the disutility of the product bought increases "steeply" because the consumer is willing to accept a product that is relatively far away from his location. However, if x is close to zero, then when the consumer's location moves away from the center of the market, the expected disutility of searching and of product misfit increases less steeply because the consumer is less willing to accept a product much further away.

Comparing the utility of buying after search above with the expected disutility of choosing a product at random, $t(x^2 - x + 1/2)$, one can obtain that for $c/t < 1/16$, all consumers prefer to search at least once over buying at random. Furthermore, the expected disutility of buying at random is $r(\infty) = t/3$. Therefore, we have the following result:

Lemma 2. *Suppose that an infinite number of products is offered and that $c/t < 1/16$. Then, consumers with v satisfying*

$$\begin{aligned} &v < \sqrt{2ct - x^2t^2} \quad \textit{for } x < \sqrt{\frac{c}{t}},\\ &v < \sqrt{2ct - (1-x)^2t^2} \quad \textit{for } x > 1-\sqrt{\frac{c}{t}}, \\ &v < \sqrt{ct} \quad \textit{otherwise} \end{aligned} \tag{10}$$

prefer the no-choice option, whereas the rest of consumers use the following search strategy: consumers with $x \in (\sqrt{c/t}, 1-\sqrt{c/t})$ search until they find a product at most $\sqrt{c/t}$ away from them; consumers with $x < \sqrt{c/t}$ search until they find a product at most $\sqrt{2c/t - x^2}$ away from them; and finally, consumers with $x > 1-\sqrt{c/t}$ search until they find a product at most $\sqrt{2c/t - (1-x)^2}$ away from them.

Consider now what happens with greater search costs (the complete analysis is presented in the appendix). Comparing the expected disutility of buying a product at random with searching, we can obtain that if $c/t > 1/8$, then no consumer engages in the search process and all consumers buy at random.

If $c/t \in [1/16, c^*]$, where c^* is defined in the appendix and is close to 0.078, we have a situation where consumers located in the center of the market buy at random, whereas the rest of the consumers engage in the search process. This implies an interesting consumer search strategy that depends on their preferences: consumers who have relatively specific preferences (in the model, with a location close to zero or one) search, and consumers who have more generic preferences (around the center of the market) do not evaluate a product prior to purchase and buy at random.

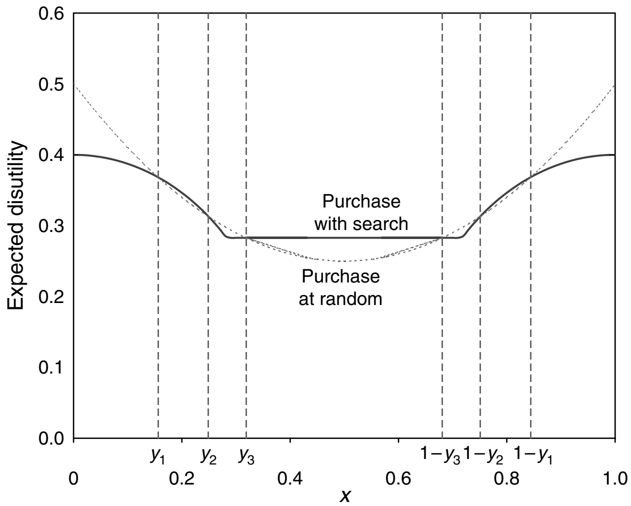
If $c/t \in (c^*, (3-2\sqrt{2})/2]$, the set of consumers who choose at random is not convex. That is, starting from the center of the market and going to either extreme, we have first consumers who choose at random, then consumers who engage in the search process, then consumers who choose at random, and finally, again, consumers who engage in the search process. To gain some intuition for this possibility, note that for small x, the expected disutility is decreasing in x both when a consumer engages in the search process and when a consumer buys at random. As argued above, when a consumer engages in the search process, the expected search costs plus the disutility of the product bought is concave in x. On the other hand, the expected disutility of the product bought when a consumer buys at random is convex in x; that is, the further away a consumer is from the center of the market, the increasingly worse is the consumer's situation. This then allows for the possibility that for some search costs, there is an intermediate low region of x where buying at random is better than engaging in the search process. Figure 4 illustrates this possibility by comparing the consumer payoffs under search and under choice at random.

Returning to the case $c/t < 1/16$ and integrating over all x, we can get the expected disutility of the product bought as[16]

$$\begin{aligned} d(\infty) &= 2t\left[\left(\frac{1}{2} - \sqrt{c/t}\right)\sqrt{c/t} + \frac{c}{4t}(2+\pi)\right] \\ &= \sqrt{ct} + c\,\frac{\pi-2}{2}. \end{aligned} \tag{11}$$

[16] To get this expression, the appendix shows that $\int_0^{\sqrt{c/t}} \sqrt{2(c/t) - x^2}\,dx = c/(4t)(2+\pi)$.

Figure 4 **Expected Search Costs Plus Disutility of Product Bought for Each Location x for the Case of an Infinite Number of Products Under Purchase at Random, and Purchase with Search for $c/t = 0.08$, $t = 1$**



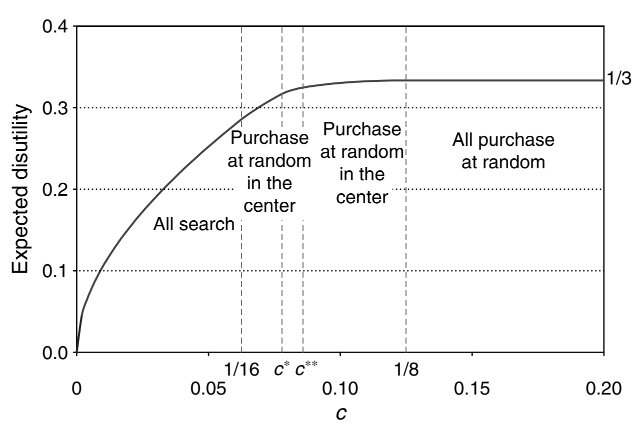
Note. $y_3 = (1 - (4c^{1/2} - 1)^{1/2})/2$.

As noted previously, for $c/t > 1/8$, all consumers choose at random, and the expected disutility across all consumers is $t\int_0^1 (x^2 - x + 1/2)\,dx = t/3$. For $c/t \in (1/16, 1/8)$, the expression for $d(\infty)$ is more complicated because some consumers engage in the search process while other consumers choose at random. However, by the principle of the optimum, it is easy to see that $d(\infty)$ is weakly increasing in c and t, as c or t represent a cost for the decision maker. Figure 5 shows $d(\infty)$ as a function of c for $t = 1$.

Comparing the expected disutility of one product with the case of an infinite number of products, one can see that

$$d(1) < d(\infty) \quad \text{if and only if } \frac{c}{t} > \frac{1}{2(\sqrt{\pi} + \sqrt{2})^2}, \tag{12}$$

Figure 5 **Expected Search Costs Plus Disutility of the Product Bought as a Function of the Search Costs When There Is an Infinite Number of Products**



Notes. c^* is defined in the text, and $c^{**} = (3 - 8^{1/2})/2$. $t = 1$.

where $1/2(\sqrt{\pi} + \sqrt{2})^2$ is close to $0.05 < 1/16$. Therefore, if consumer search costs are sufficiently large, offering only one alternative results in a higher probability that a consumer will choose an alternative than offering very many alternatives. This also illustrates the result in Proposition 3 below that a finite number of alternatives (not necessarily just one alternative) is better than an infinite number in terms of increasing the probability of choice when search costs are positive.

Note again that for $c/t > 1/8$, consumers facing an infinite number of alternatives choose at random and get an expected disutility of the product bought, $t/3$, that is greater than when the firm offers only one alternative. Because $d(\infty)$ is weakly increasing in c, we can immediately see that for $1/16 < c/t < 1/8$, we have $d(1) < d(\infty)$.

Comparing two products with the case of an infinite number of products, we can see that

$$d(2) < d(\infty) \quad \text{if and only if } \frac{c}{t} > \hat{c}, \tag{13}$$

where $\hat{c}$ satisfies $\hat{c}^2 - (2 - \pi/2)\hat{c} + \sqrt{\hat{c}} - 1/8 = 0$. It can be easily seen that $\hat{c}$ is uniquely defined and is close to $0.017 < 1/(2(\sqrt{\pi} + \sqrt{2})^2)$.

Comparing three alternatives with an infinite number of alternatives, one can see that $d(3) < d(\infty)$ if and only if $c/t > \tilde{c}$, where $\tilde{c}$, defined by $\tilde{c}^2 - (8/3 - \pi/2)\tilde{c} + \sqrt{\tilde{c}} - 1/12 = 0$, is below 1/16 and close to 0.009.

3.4. Comparative Statics

The results above suggest how the consumer search behavior and the probability of choice depend on the model parameters. First, a larger highest valuation $\bar{v}$ results in a higher probability of choice but does not change the search behavior given that the consumer ultimately buys. This is because to the extent that the value of the category is high enough to justify a choice, it does not affect the trade-offs between different products within the category.

Second, because the search behavior depends on c and t only through c/t, a consumer's search behavior and his preferred number of alternatives are affected by the importance of fit t *relative* to the consumer's evaluation costs c; however, if we keep one of these variables constant, the consumer will prefer a larger set of alternatives if the evaluation costs c are lower or if the importance of fit t is higher. Within the model, a higher value of the importance of fit t also means that the probability of choice (versus no choice) is lower. This is because the parameter v corresponds not to the average value of the category to the consumer but to the value of the ideal product in the category. This means that higher t results in the higher expected disutility from the choice that will be eventually made. However, in a more colloquial interpretation, a higher importance of fit may mean that the utility of the ideal fit is larger. Therefore, the model results should not be interpreted as saying that, in practice, a higher importance of fit necessarily means a lower probability of choice.

Third, the location of the ideal point of a consumer *relative* to the distribution of the locations of the ideal points of other consumers affects the search behavior and the preference for the number of alternatives to choose from. This is because consumers expect a certain distribution of product locations given their number, and they expect that this distribution is chosen to optimally serve all consumers.

3.5. There Is Always a "Too-Large" Set of Alternatives

We now show that a certain finite number of alternatives will increase the probability of choice relative to an infinite number of alternatives. Consider c/t small ($c/t < 1/16$),[17] and suppose that the firm offers $\hat{n}$ products located at $z_i = (2i-1)/(2\hat{n})$, for $i = 1, 2, \ldots, \hat{n}$, where $\hat{n}$ is the smallest integer that is greater than or equal to $1/(2\sqrt{c/t})$. That is, $\hat{n} - 1 < 1/(2\sqrt{c/t}) \leq \hat{n}$. To show that offering these $\hat{n}$ products generates a higher probability of choice than offering an infinite number of products, it suffices to show that this set of products would generate a lower consumer disutility as consumer search is restricted to some (not necessarily optimal) search rule. Specifically, consider the consumer's search process, which is to search until the consumer finds the alternative that is closest to him.

Let us denote the expected disutility under this search process by $\hat{d}(\hat{n}) \geq d(\hat{n})$ and compare it with the expected disutility $d(\infty)$, given an infinite number of products.

With $\hat{n}$ alternatives and with the proposed consumer search process, the expected disutility of fit is $t/(4\hat{n})$. The expected search costs for each consumer are

$$c\frac{1}{\hat{n}} + 2c\frac{\hat{n}-1}{\hat{n}}\frac{1}{\hat{n}-1} + 3c\frac{\hat{n}-1}{\hat{n}}\frac{\hat{n}-2}{\hat{n}-1}\frac{1}{\hat{n}-2} + \cdots + (\hat{n}-1)c\frac{1}{\hat{n}} + (\hat{n}-1)c\frac{1}{\hat{n}} = (\hat{n}-1)\left(\frac{1}{2}+\frac{1}{\hat{n}}\right)c. \quad (14)$$

We then have $\hat{d}(\hat{n}) = t/(4\hat{n}) + (\hat{n}-1)(1/2 + 1/\hat{n})c$. By the definition of $\hat{n}$, one can then obtain that $d(\hat{n}) \leq \hat{d}(\hat{n}) < (3/4)\sqrt{ct} + c < \sqrt{ct} < d(\infty)$, because $c/t < 1/16$. That is, the expected disutility under $\hat{n}$ alternatives is lower than the expected disutility under an infinite number of alternatives. This means that the probability of choice is strictly higher with this finite number of alternatives than with an infinite (very large) number of alternatives. As the number of alternatives increases toward infinity, and the probability of choice tends to the inferior outcome of infinitely many alternatives, we obtain that there is an N such that it is not optimal to have more than N alternatives in terms of maximizing the probability of choice. Therefore, the optimal number of products is finite, and we have the following proposition:

Proposition 3. *When search costs are positive, the probability of choice is strictly greater for a certain finite number of alternatives than for an infinite number of alternatives. That is, there is a finite number of alternatives that maximizes the probability of choice.*

The intuition is that by spreading out the location of the alternatives, and by offering a small number of alternatives, the provider of alternatives allows the consumers to save on search costs. This is because, by having fewer alternatives to search through, a consumer can rule out areas of the product space that are less appealing to him because of search without replacement. When c/t approaches zero, $\hat{n}$ alternatives allow the consumers to save, in expected value, half of the search costs in the case of an infinite number of alternatives. This result also shows that if too many alternatives are offered, the consumers realize that they will incur too many search costs and will therefore prefer not to search—that is, not to choose.

The number of alternatives offered generates a trade-off between potentially providing consumers with a better fit and complicating their search process. The positive effect of better fit only holds when the number of products is not very large, although the search process is more costly as the number of alternatives increases to infinity. This is because when the number of alternatives is very large, consumers adopt a reservation rule strategy that never involves an exhaustive search for all alternatives but rather a search until they find the first product satisfying the reservation rule. When consumers adopt such a rule and the number of products is high enough that they do not search exhaustively, increasing the number of the products further does not increase the expected fit between the first product found to satisfy the reservation rule and the consumer preferences. On the other hand, increasing the number of products keeps increasing the expected cost of the search until finding the first product that satisfies the reservation rule. The intuition for this result is that search with replacement is less efficient than search without replacement, and as the number of products tends toward infinity, the search process approaches search with replacement. Therefore, when the number of alternatives is large, there is only the negative effect and no positive effect of increasing the number of alternatives on the probability of choice. To formalize this intuition, consider

[17] The case of $c/t > 1/16$ is considered in §3.3.

consumers distributed uniformly on a circle of perimeter one (the same argument goes through in a segment with a large number of products or a sufficiently small search cost), with each consumer with an acceptance region A, such that with N products, each consumer has at least one product in his acceptance region. Suppose all products are equally spaced. Now, compare the total expected search costs of consumers with N and $N' > N$ products. Across all consumers, the average probability of finding a product in the acceptance region in the first search is A, when consumers are faced with either N or N' alternatives. Note, however, that after U searches outside the acceptance region, the probability of the next search being in the acceptance region is higher with N alternatives than with $N' > N$ alternatives; $AN/(N-U) > AN'/(N'-U)$. With a higher hazard rate, it is then straightforward to obtain that the expected number of searches is smaller with N alternatives than with N' alternatives; i.e., given the same acceptance region, the expected search costs are greater with a greater number of alternatives.[18]

Although we considered a particular distribution of consumers (uniform) and a particular functional form of the utility cost of misfit (linear travelling cost), the above intuition suggests that the optimality of a finite number of alternatives would hold both for a more general distribution of consumer preferences and when the utility cost of misfit is any decreasing function of the distance between the consumer's ideal point x and the product location.

3.6. "Approximate" Optimal Number of Alternatives

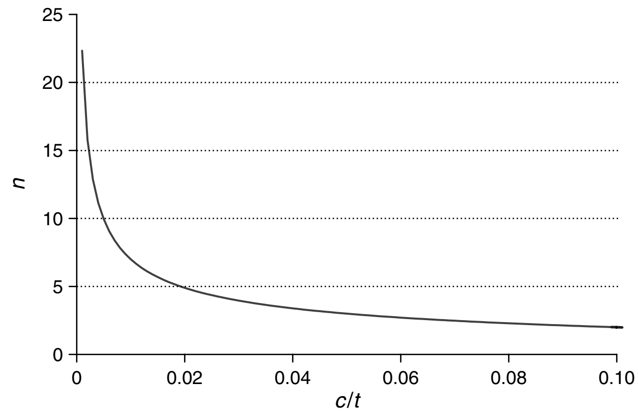
The analysis above suggests an approach to try to get at an approximate number of products that maximizes choice. Suppose that the firm chooses a number of products such that a set of consumers close to a product always keeps on searching until they find the product closest to them. In addition, consider the approximation where all consumers are in this situation. That is, no consumer settles for the product that is not their most preferred product, and no consumer buys at random. As seen above, this may not be the optimal search process for some consumers.

Given this approximation, the expected disutility across all consumers of the firm offering n products is

$$\tilde{d}(n) = \frac{t}{4n} + (n-1)\left(\frac{1}{2} + \frac{1}{n}\right)c.$$

[18] We thank the area editor for having raised this question. With a greater hazard rate for N alternatives than N' alternatives, for all U, the probability of the number of searches needed being greater than U is smaller for N alternatives than for N' alternatives.

Figure 6 "Approximate" Optimal Number of Product as a Function of c/t



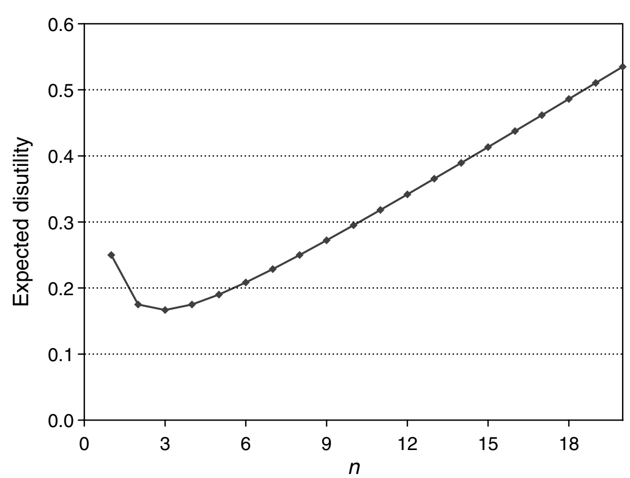
The optimal number of products can then be obtained to be (without worrying about integer issues)

$$n = \sqrt{\frac{t}{2c} - 1}.$$

Figure 6 illustrates the optimal number of products as a function of c/t, which illustrates that the optimal number of products reduces quickly when c/t increases. Figure 7 illustrates the expected disutility as a function of the number of products and shows that the expected disutility increases when the firm offers a number of products larger than the optimal number of products, which is the information overload due to search costs. It also shows that the expected disutility decreases for a lower number of products because of less fit between the products offered and the consumer preferences.

This approximation does not account for the fact that consumers in a range between two alternatives may be willing to accept either of them. In the

Figure 7 Expected Disutility for Each Number of Products Under Search Until Finding the Closest Product for $t = 1$ and $c = 05$



appendix, we derive an approximation for the optimal number of products (which is close to the one above) that accounts for this possibility.[19]

3.7. Firm's Decision on Product Locations

To show that the locations of the alternatives offered by the firm are equidistant, consider that a fraction ε of consumers, with ε close to zero, have zero search costs. These consumers will always optimally choose the product that generates the best fit. The number of zero-search-cost consumers who choose an alternative is maximized when the alternatives are equidistant on the segment $[0, 1]$, so that the subsegment of points that are closer to any given product than to any other product is of equal size across products. Therefore, the n products are located at $(2i-1)/(2n)$ with $i = 1, 2, \ldots, n$.[20]

Consider now a consumer with positive search costs who decides to engage in a search by looking for at least one product. If the consumer expects the above locations and the firm actually chooses them, the consumer will definitely buy a product. This is because each search results in either (1) a product that the consumer wants to buy or (2) a further search becoming even more preferable to the consumer than before as one of the worse-fitting products is eliminated. Therefore, the firm cannot gain any more consumers with positive search costs by deviating from the above location choice but will lose some consumers with zero search costs. This proves that the location choice above is an equilibrium choice.

To get a unique product positioning equilibrium, one could assume that consumers observe the distribution of the products offered without knowing which product is which. This could potentially be justified with a reputation or social learning argument. Alternatively, if consumers have a sufficiently high cost to enter the market, the ones who enter the market will always end up buying a product, and therefore the product location is uniquely determined by the zero-search-cost consumers. Given that these locations are the best for the firm, consumers may be able to infer the location of the products (without knowing which is which) after observing the number of products offered. The exact inference of the product locations is not essential for the results. When $n \to \infty$ this distribution of the alternatives' locations converges to the continuous uniform distribution in the interval $[0, 1]$. That is, the limit when the number of products goes to infinity is a continuum of alternatives with a uniform distribution. If the distribution of preferences is not uniform, the optimal location of alternatives would no longer be with the alternatives equidistant from each other, but it would still lead to a distribution of alternatives that would span the preference space. The intuition for the results above would follow.

3.8. Testable Empirical Implications

Several testable empirical implications result from the model above. One important implication of the model above is that if consumers are facing a nonstrategic supplier of alternatives who provides alternatives with locations independent of each other, then one should observe a significant reduction in information overload effects. That is, if one varies the number of alternatives and manipulates whether or not the consumers expect the supplier of alternatives to be strategic, one should be able to find that the information overload effects are smaller for the nonstrategic supplier of alternatives condition.

The model has also testable empirical implications about consumers' different search behaviors depending on their location in the consumer preferences space. In particular, one should be able to obtain that consumers at the extremes of the parameter space search more and have a higher preference for a greater number of alternatives than consumers who have mainstream preferences. Considering purchases at random, one should also be able to obtain that consumers with mainstream preferences are more likely to purchase at random than consumers at the extremes of the preference space. Another implication for possible experiments is that when comparing product categories that are "highly differentiated" versus "commodity-like" one should obtain that consumers are less likely to purchase at random and prefer a greater number of alternatives in "highly differentiated" product categories. It would be interesting to test this prediction in the context of the Iyengar and Lepper (2000) jam experiment.

4. Conclusion

This paper examines consumers' preferences over choice sets with different numbers of alternatives. This preference is induced by a trade-off between the costs of searching/evaluating alternatives in the choice set and the potential gain in utility from finding a fit to one's preferences. It may be seen as a formalization of the intuitions that have arisen from laboratory and field experiments that find consumers preferring smaller choice sets over large choice sets. The formalization brings with it the benefit of a

[19] In particular, we show that when the search costs go to zero, the fraction of consumers that settle on the second-best alternatives is bounded away from zero, and we derive an approximation of this fraction of consumers and the optimal number of the products under the condition that search costs are small.

[20] It can be shown that these locations also minimize $d(n)$ for a given n, if the products are such that for any given product there is a positive mass of uninformed consumers that continues to evaluate products until they find that particular product.

rigorous confirmation of these intuitions as well as the discovery of new effects that can now be subjected to more tests. In particular, this paper shows that it is essential that the alternatives offered span the preference space (as it would be chosen strategically in markets by firms), for the intuition that search costs may lead to optimal smaller choice sets to be valid.

In our model, consumers make decisions sequentially, at each instance choosing whether to search further, to choose from the items already searched, to choose randomly from the items remaining, or to abort the decision process altogether. Perhaps our most noteworthy result in this context is that this decision process leads to an optimal finite number of products offered if the alternatives are not located independently from each other, spanning the preference space, as firms may optimally choose to maximize choice and profit. Also noteworthy in this context is that the preference for smaller choice sets can survive this expanded set of options, particularly the option to bail out of search. We find that the preference for smaller choice sets depends on consumers' beliefs about the distribution of alternatives and their own preferences in terms of how mainstream versus extreme they are. The preference for smaller choice sets is strongest for consumers with mainstream tastes because they believe, correctly, that they can find a good alternative even from smaller choice sets because sellers are motivated to cater to their mainstream tastes.

It is also possible that in some markets, some consumers may face uncertainty about the importance of fit, whereas the firm may have more information. In this case, consumers may try to infer their preferences, specifically the importance of a good fit, from the number of alternatives offered by the firm. In the context of the model above, for example, the firm might have private information on t. One can then show that, in this situation, if a fraction of consumers know their preferences and have no search costs, the firm would offer a lower number of alternatives when it has private information than when it does not, so that consumers believe that the importance of a good fit is not too important. That is, private information can influence a firm to offer a lower number of alternatives. This can also be interpreted as implying that the number of alternatives, or the specific alternatives offered, can give information to consumers about their preferences. That is, consumers can construct their preferences from the choice sets offered.

It would also be interesting to investigate what happens when there is competition and price learning in a context where product attributes have to be evaluated to check for consumer fit. In this situation, it is possible that competing firms, on the contrary, might try to signal that fit is actually more important to increase consumer perception of differentiation. In this case, another possibility is that the existence of competitors may lead to more confusion and more information overload and these effects may not be internalized by the firm offering the additional products (Van Zandt 2004). Another interesting issue to consider is that firms roll out their product line through time. In a context with information overload effects, it is interesting to consider how this sequential product introduction affects the optimal product locations and the optimal number of products.[21]

What can firms learn from this research? Our model suggests that for less important decisions (smaller t) and for decisions where the consumer thinks the firm knows what the average customer wants, consumers prefer not to have a choice at all or have few choices rather than have many choices. For example, the consumer may want Dell to decide which parts of Microsoft Office to preinstall on a computer but may prefer that Dell provide a choice between Microsoft and a competitor's version of Microsoft Office. This example also suggests that the model presented above could help us understand the potential limits to versioning strategies in information goods industries (see Shapiro and Varian 1999, p. 67). Another way that firms may try to help consumers is by providing a "default" or "suggested" choice, targeted at consumers with high search costs or that are less informed than other consumers. This suggested choice may help these consumers avoid search costs, and the default choice may not be too suboptimal if, as it is likely, these consumers do not find the decision to be important (if the decision was important, they would have gotten informed). Firms may also structure the choice problem to make it easier for consumers to search for a good alternative. For instance, a firm can arrange its information display to "align" the alternatives (Gourville and Soman 2005) by brand (say) in a store (Hoch et al. 1999). Another structural decision is how to merge choice sets. Consider two choice sets, A and B, each having alternatives that are easily comparable within the respective choice sets. Then, in structuring a choice set $A \cup B$, there are two options: (i) mix the alternatives from A and B, or (ii) keep them separate. Our research suggests that the seller can accommodate a larger set of choices with the latter strategy than with the former. This might be relevant for branding strategy after a merger.

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[21] With product line rollout, consumers able to observe the final choice of previous consumers may also lead to interesting effects (e.g., Zhang 2009).

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Appendix

Proof of Lemma 1. To show that the pair of locations $\{1/4, 3/4\}$ minimizes the expected consumer disutility, consider general locations for the two alternatives. Denote z_1 as the location of the product that is located closer to zero, and denote z_2 as the location of the other product, with $z_1 < z_2$ (the case of $z_1 = z_2$ being the case of one product presented above). Suppose that $z_2 - z_1 \geq 2(c/t)$ (otherwise, all consumers prefer to search at random, and we are back in the one-alternative case). A consumer who searches one product gets his most preferred product (between the two) because if the searched product is not the most preferred, the consumer knows that the other product will be. Then, if a consumer located at x searches one product, he gets a total cost (the search cost plus the disutility of the product bought) of $c + t\min[|x - z_1|, |z_2 - x|]$. If a consumer chooses a product at random, he gets an expected disutility of $(t/2)|x - z_1| + (t/2)|z_2 - x|$.

From this, one can see that if $x \in ((z_1 + z_2)/2 - c/t, (z_1+z_2)/2+c/t)$, then a consumer prefers to choose an alternative at random; if $x < (z_1 + z_2)/2 - c/t$, then a consumer searches to find product z_1 and gets a search cost plus a disutility of the product bought equal to $c + t|x - z_1|$; and finally, if $x > (z_1 + z_2)/2 + c/t$, then a consumer searches to find product z_2 and gets a search cost plus disutility of the product bought equal to $c + t|x - z_2|$.

The expected search costs plus the disutility of the product bought across all consumers as a function of z_1 and z_2 is then equal to $z_1(c + t(z_1/2)) + (1 - z_2)(c + t(1 - z_2)/2) + ((z_1 + z_2)/2 - c/t - z_1)[c + t/2((z_1 + z_2)/2 - c/t - z_1)] + (z_2 - (z_1 + z_2)/2 - c)[c + (t/2)(z_2 - (z_1 + z_2)/2 - c/t)] + 2(c/t)((z_2 - z_1)/2)t$, which reduces to

$$t\left\{\frac{c}{t} - \left(\frac{c}{t}\right)^2 + \frac{z_1^2}{2} + \frac{(1 - z_2)^2}{2} + \left(\frac{z_2 - z_1}{2}\right)^2\right\}. \qquad (15)$$

Minimizing with respect to the location of the products (for the firm to offer the best pair of alternatives), one gets $z_1 = 1/4$ and $z_2 = 3/4$, which are also the optimal locations with two products and zero search costs. Substituting the equilibrium $(z_1, z_2) = (1/4, 3/4)$ into Equation (15), one can obtain $d(2) = t/8 + c - c^2/t$ for $c < t/4$ (for $c > t/4$, consumers choose to buy at random, and then just having one product is optimal). Q.E.D.

Statement and Proof of Proposition 4 (Three Alternatives)

Proposition 4. *Suppose that the firm offers three alternatives and that $c/t < 2/21$. Then all consumers who prefer choice to no choice search at least one alternative. The consumers' optimal search process is characterized by the following: if $x < 1/3 - c/t$, then the consumer keeps z_1 if he finds it first and keeps on searching if he does not find z_1 first, for an expected disutility of $(5/3)c + t|x - 1/6|$. If $x \in [1/3 - c/t, 1/3 - c/(2t)]$, the consumer buys z_1 if he finds it first, keeps on searching if he finds z_2 first, and buys at random if he finds z_3 first, for an expected disutility of $(4/3)c + t(2x/3 - 1/18)$. If $x \in [1/3 - c/(2t), 1/3 + c/(2t)]$, the consumers buys z_1 or z_2 if he finds one of these alternatives in the first search, and, if he finds z_3 first, he buys at random one of the other two remaining alternatives, for an expected disutility of $c + t/6$. If $x \in [1/3 + c/(2t), 1/3 + c/t]$, the consumer buys z_2 if he finds it first, keeps on searching (to find z_2) if he finds z_1 first, and buys at random one of the other two remaining alternatives if he finds z_3 first, for an expected disutility of $(4/3)c + t(7/18 - 2x/3)$. Finally, for $x \in [1/3 + c/t, 1/2]$, the consumer buys z_2 if he finds it first and keeps on searching (to find z_2) if he finds z_1 or z_3 first, for an expected disutility of $(5/3)c + t(1/2 - x)$. The consumer at x and having the valuation parameter v prefers the no-choice option if and only if the expected disutility reported above is larger than v.*

Proof. Note that the expected disutility of random choice is $r(3) = 35t/108$. To derive the optimal consumer search strategy, consider the locations of consumers $x \leq 1/2$ (the case $x > 1/2$ is the symmetric case) and $c/t < 1/6$ (for $c/t > 1/6$, two alternatives are better than three alternatives as discussed below). Let us look first at the case where consumers buy at random. If $x > 1/6$, the expected disutility as a function of x is $t[(1/3)(5/6 - x) + (1/3)(1/2 - x) + (1/3)(x - 1/6)] = t(7/18 - x/3)$. If $x < 1/6$, in the same way, we can find that the expected disutility as a function of x is $t(1/2 - x)$.

Consider now the case in which consumers search first for one of the alternatives (restricting our attention for now to $x > 1/6$). Suppose that the consumer finds alternative $z_1 = 1/6$ first. Then, (i) the consumer can choose to buy this alternative, in which case the consumer gets a disutility of $c + t(x - 1/6)$; (ii) the consumer can choose to search once more, in which case the consumer can get his most preferred alternative, $z_2 = 1/2$, for a disutility of $2c + t(1/2 - x)$; or (iii) the consumer can choose to buy at random from among the other two alternatives, in which case the consumer gets an expected disutility of $c + (t/2)(1/2 - x) + (t/2)(5/6 - x) = c + t(2/3 - x)$. It can be easily seen that buying at random between the other two alternatives is worse than searching once more, as long as $c/t < 1/6$, which was assumed. Finally, buying the alternative just searched, z_1, is better than searching once more if and only if $x < 1/3 + c/(2t)$. Note that this means that there are some consumers who, even though they prefer z_2 to z_1 (if $x > 1/3$), still keep alternative z_1 if they find it first because of the additional search costs of trying to find z_2. Note that this also implies that if $x < 1/6$, if the consumer finds z_1 first, he will then naturally buy this alternative.

Suppose now that the consumer first finds alternative $z_2 = 1/2$. If the consumer buys this alternative, he gets a disutility of $c + t(1/2 - x)$. If the consumer searches once more, he finds his most preferred other alternative for a disutility of $2c + t(x - 1/6)$. It can be seen that the consumer buying at random between the other two alternatives is dominated by either buying z_2, or searching once more. One can then see that buying the alternative just searched is better than searching once more if and only if $x > 1/3 - c/(2t)$. Again, some consumers who prefer z_1 to z_2 will be happy to keep z_2 if they find it first.

Finally, suppose that the consumer first finds alternative $z_3 = 5/6$. If the consumer buys this alternative, he gets a disutility of $c+t(5/6-x)$. If the consumer buys at random one of the other two alternatives, he gets an expected disutility of $c+t/2(1/2-x)+t/2(x-1/6)$. If the consumer searches once more, he gets his most preferred alternative, with a disutility of $2c+t(1/2-c)$ if $x>1/3$ and a disutility of $2c+t(x-1/6)$ if $x<1/3$. One can then obtain that buying alternative z_3 is always dominated by either buying at random or searching once more, and that buying a random one of the two other remaining alternatives is better than searching once more if $x\in[1/3-c/t, 1/3+c/t]$.

It remains for us to prove that all consumers prefer to search at least once if $c/t<2/21$. To show this, we need to check the conditions under which the expected disutility of buying at random, $t(1/2-x)$ for $x<1/6$ and $t(7/18-x/3)$ for $x>1/6$, is greater than the expected disutility of evaluating the first alternative, as stated in Proposition 4. For $x<1/6$, the condition is $c/t<1/5$. For $x\in[1/6, 1/3-c/t]$, the condition is $c/t<1/3$. For $x\in[1/3-c/t, 1/3-c/(2t)]$, the condition results in $c/t<2/15$. For $x\in[1/3-c/(2t), 1/3+c/t]$, the condition results in $c/t<2/21$. Finally, for $x\in[1/3+c/t, 1/2]$, the condition results in $c/t<1/9$. All these conditions are satisfied if $c/t<2/21$. Q.E.D.

Computation of Equation (6)

The expected disutility $d(3)$ across all consumers can be obtained to be $(1/3)(5c/3+t/12)+(1/3-2(c/t))(5c/3+t(1/12-c/(2t)))+c/t(4c/3+t(1/6-c/(2t)))+2(c/t)(c+t/6)+(c/t)(4c/3+t(1/6-c/(2t)))+(1/3-2(c/t)(5c/3+t(1/12-c/(2t)))$, which reduces to Equation (6).

Proof of Proposition 1. Comparing $d(3)$ with $d(2)$ for $c/t<2/21$, one obtains directly $d(3)<d(2)$ if and only if $c/t<1/16$. To complete the proof, one has to consider what happens when $c/t\in[2/21, 1/6]$. For $c/t\in[2/15, 1/6]$, one obtains $d(3)=t/12+(19/9)c-(14/3)(c^2/t)$, and one obtains $d(3)<d(2)$ if and only if $c/t<(20-\sqrt{202})/132<1/16$, a contradiction. Finally, for $c/t\in[2/21, 2/15]$, one obtains $d(3)=t/12+(16/9)c-(49/12)(c^2/t)$, and one obtains $d(3)<d(2)$ if and only if $c/t<(28-\sqrt{562})/74<1/16$, a contradiction. Q.E.D.

Proof of Proposition 2. Comparing the expected disutility as a function of x for 1, 2, and 3 alternatives, we obtain that for $x<5/24-c/(3t)$, the consumer prefers 3 to 2 and 2 to 1 alternatives; for $x\in(5/24-c/(3t), 1/3-4c/(5t))$, the consumer prefers 2 to 3 and 3 to 1 alternatives; for $x\in(1/3-4c/(5t), 3/8-c/(2t))$, the consumer prefers 2 to 1 and 1 to 3 alternatives; for $x\in(3/8-c/(2t), 1/2)$, the consumer prefers 1 to 2 or 3 alternatives. For $x>1/2$, the preferences are symmetric around 1/2. Choosing the ranges where 1, 2, or 3 alternatives are best and subtracting the cutoff points from 1/2, one obtains the claimed. Q.E.D.

The Case of an Infinite Number of Products, and $c/t>1/16$

First, consider consumers with $x\in(\sqrt{c/t}, 1-\sqrt{c/t})$; i.e., those who are not too close to the ends of the segment. If $c/t\in(1/16, (3-2\sqrt{2})/2)$, consumers with

$$x\in\left(\frac{1-\sqrt{4\sqrt{c/t}-1}}{2}, \frac{1+\sqrt{4\sqrt{c/t}-1}}{2}\right)$$

buy at random, and the other consumers with $x\in(\sqrt{c/t}, 1-\sqrt{c/t})$ engage in the search process as described in the text. If $c/t>(3-2\sqrt{2})/2$, all consumers with $x\in(\sqrt{c/t}, 1-\sqrt{c/t})$ choose to buy at random. As noted in the text, this implies an interesting search strategy for the consumers, depending on their preferences: consumers who have relatively specific preferences (in the model, with a location close to zero or one) search, and consumers who have more generic preferences (around the center of the market) do not evaluate a product prior to purchase and buy at random.

Now, consider consumers with $x<\sqrt{c/t}$ (consumers with $x>\sqrt{c/t}$ behave similarly to these). For $1/16<c/t<1/8$, the expected disutility decreases in x both when a consumer engages in the search process and when a consumer buys at random. Note first that, as argued above, when a consumer engages in the search process, the expected search costs plus the disutility of the product bought is concave in x. On the other hand, the expected disutility of the product bought when a consumer buys at random is convex in x. In other words, the further away a consumer is from the center of the market, the increasingly worse is the consumer's situation.

Comparing the strategy of engaging in the search process with buying at random, we find the condition on x that makes the first strategy preferable is $x^2-x+1/2\geq\sqrt{2(c/t)-x^2}$ which reduces to $f(x;c/t)\equiv x^4-2x^3+3x^2-x+1/4-2(c/t)\geq 0$. This polynomial function is convex and decreasing in c/t. Therefore, there is a c^* such that if $c/t<c^*$, then $f(x;c/t)=0$ has no solutions; if $c/t>c^*$, then $f(x;c/t)=0$ has two distinct solutions; and if $c/t=c^*$, then $f(x;c/t)=0$ has exactly one solution (c^* is close to 0.078). We also know that $f(x;(3-2\sqrt{2})/2)=0$ at $x=(2-\sqrt{2})/2$ and that $(3-2\sqrt{2})/2$ is the only $c/t\in(1/16, 1/8)$ in which $x=\sqrt{c/t}$ satisfies $f(x;c/t)=0$ and $f(\sqrt{c}, c/t)<0$ for $c/t\in((3-2\sqrt{2})/2, 1/8)$. Furthermore, $f'((2-\sqrt{2})/2; (3-2\sqrt{2})/2)>0$ and $f(0;(3-2\sqrt{2})/2)>0$. Therefore, $f(x;(3-2\sqrt{2})/2)=0$ has another solution strictly greater than zero and strictly smaller than $(2-\sqrt{2})/2$. This implies that $c^*<(3-2\sqrt{2})/2$. Checking that $f(x;1/16)-x^4$ is always positive for $x\in(0,1/2)$, we have that $c^*>1/16$. We then can conclude the following. For $c/t\in(1/16, c^*)$, all consumers with $x\in(0,\sqrt{c/t})$ engage in the search process. For $c/t\in(c^*, (3-2\sqrt{2})/2)$, we have that $f(x;c/t)=0$ has two solutions, $y_1(c/t)$ and $y_2(c/t)$, with $0<y_1(c/t)<y_2(c/t)<\sqrt{c/t}$, that consumers with $x\in[0, y_1(c/t))\cup(y_2(c/t), \sqrt{c/t})$ engage in the search process, and consumers with $x\in(y_1(c/t), y_2(c/t))$ choose at random. Finally, for $c/t\in((3-\sqrt{2})/2, 1/8)$, there is only solution to $f(x,c/t)=0$ that is below $\sqrt{c/t}$, $y_1(c/t)$, and consumers with $x\in[0, y_1(c/t))$ engage in the search process, and consumers with $x\in(y_1(c/t), c/t)$ choose at random.

Putting all these results together, we have that there are $c/t\in(c^*, (3-2\sqrt{2})/2)$ such that the set of consumers that choose at random is not convex. That is, starting from the center of the market and going to either extreme, we have first consumers that choose at random,

$$x\in\left(\frac{1-\sqrt{4\sqrt{c/t}-1}}{2}, \frac{1+\sqrt{4\sqrt{c/t}-1}}{2}\right),$$

then consumers that engage in the search process,

$$x \in \left(y_2(c/t), \frac{1-\sqrt{4\sqrt{c/t}-1}}{2}\right) \cup \left(\frac{1+\sqrt{4\sqrt{c/t}-1}}{2}, 1-y_2(c/t)\right),$$

then consumers that choose at random, $x \in (y_1(c/t), y_2(c/t)) \cup (1-y_2(c/t), 1-y_1(c/t))$, and, finally, again consumers that engage in the search process, $x \in [0, y_1(c/t)) \cup (1-y_1(c/t), 1]$.

Solution of the Integral $\int_0^{\sqrt{c/t}} \sqrt{2(c/t)-x^2}\,dx$

Define the variable τ as $\sqrt{2(c/t)-x^2} = x\tau + \sqrt{2(c/t)}$, which yields $x = -2\tau\sqrt{2(c/t)}/(1+\tau^2)$. Note also that $dx/d\tau = -2\sqrt{2(c/t)}(1-\tau^2)/(1+\tau^2)^2$. Substituting variables, one can then write

$$\int_0^{\sqrt{c/t}} \sqrt{2\frac{c}{t}-x^2}\,dx = \int_{1-\sqrt{2}}^{0} 4\frac{c}{t}\frac{(1-\tau^2)^2}{(1+\tau^2)^3}\,d\tau. \tag{16}$$

Noting now that $(1-\tau^2)^2/(1+\tau^2)^3 = 4/(1+\tau^2)^3 - 4/(1+\tau^2)^2 + 1/(1+\tau^2)$, that $\int (1/(1+\tau^2))\,d\tau = \arctan \tau$, that $\int (1/(1+\tau^2))^2\,d\tau = \tau/(2(1+\tau^2)) + 1/2 \arctan \tau$, and that $\int (1/(1+\tau^2))^3\,d\tau = (5\tau+3\tau^3)/(8(1+\tau^2)^2) + 3/8 \arctan \tau$, we have

$$\int_0^{\sqrt{c/t}} \sqrt{2\frac{c}{t}-x^2}\,dx = 4\frac{c}{t}\left[\frac{\tau(1-\tau^2)}{2(1+\tau^2)^2} + \frac{1}{2}\arctan \tau\right]_{1-\sqrt{2}}^{0} = \frac{c}{4t}(2+\pi). \tag{17}$$

"Approximate" Optimal Number of Products with the Possibility of Consumers Settling for the Second-Best Alternative

As we already know, the optimal distribution of n products is such that the distance between neighboring products is $1/n$. Here, we estimate the approximate expected disutility of a consumer engaging in the optimal search when some consumers always search until finding their first-best alternative, and others can settle for their second-best alternative. We then minimize this approximate expected disutility over n. This approximation is exact as c goes to zero (and n goes to infinity).[22]

Because all but $1/n$ consumers are located between two products, we only consider the expected disutility of consumers located between some two products. We have assumed that n is such that consumers very close to a product search until they find that particular product. However, consumers who are located almost at the midpoint between two adjacent products will search only until they find one of these two products. In other words, all consumers search until they find the best or second-best product. If a consumer finds the best before the second-best, he chooses the best. However, if he finds the second-best before finding the best, he chooses the second-best if he is sufficiently close to the midpoint between the best and the second-best so that the expected cost of searching further until he finds the best is too high compared to the reduction in disutility.

The expected total cost of searching until the consumer finds the best alternative is approximately $(n/2)c$ (the exact value is in Equation (14)). The expected cost of continuing search for the best alternative after the second-best is found depends on how many products the consumer has already tried. Let k be the number of searches it takes to find the second-best and let us assume that the best alternative was not yet found by the kth search. The expected additional cost of searching until the first-best is found is then $((n-k)/2)c$.

The optimal consumer strategy is the following. If the consumer is further than $nc/(4t)$ from the midpoint between the best and second-best product, she will search until she finds the best one, because even if she finds the second-best one first, the cost of searching for the best product (at most $(n/2)c$) is lower than the additional utility from the best product, which is twice her distance from the midpoint times t.

Consider now a consumer located within $nc/(4t)$ of the midpoint between the best and second-best product. We have that this consumer searches at least until the best *or* second-best product is found. The probability that she will find the best or second-best product when at least q but less than $q+dq$ fraction of the products (where $q = k/n$ for some integer k and $dq = 1/n$) are searched is asymptotically $2(1-q)dq$. This is because the probability of finding one of the two best on the kth search is $(1-2/n)(1-2/(n-1)) \cdot \cdots \cdot (1-2/(n-k+2))2/(n-k+1) = 2/(n-1)(1-k/n) \approx 2(1-q)dq$. Once she found the first or second-best, she has spent qnc on search and with probability 1/2 found the best product. The expected disutility of the best product across all consumers we are considering is $t/(2n) - (n/8)c$.

With probability 1/2, however, the consumer has found the second-best product. In this case, when she considers further search until she finds the best product, she faces the benefit of twice her distance to the midpoint times t and the expected additional cost of $(1-q)(n/2)c$. Hence, she will not search further for the best product if and only if she is at most $(1-q)(nc/(4t))$ from the midpoint. Hence, in the case we are considering, the consumers who would decide to search further are located at a distance between $nc/(4t)$ and $(1-q)(nc/(4t))$ from the midpoint between the best and the second-best product. These $q(n^2c/(2t))$ consumers will incur further search costs of $(1-q)(n/2)c$ and will have a product disutility from the best product of, on average, $t/(2n) - (1-q/2)(nc/4)$. The other $(1-q)(n^2c/(2t))$ consumers, located closer than $(1-q)(nc/(4t))$ to the midpoint, will not search further and will have product disutility from the second-best product of, on average, $t/(2n) + (1-q)(n/8)c$.

Integrating the total expected disutilities of consumers located within $nc/(4t)$ from the midpoint between their best

[22] We can compute the exact expected disutility and exact optimal number of products under the assumption that consumers close enough to a product always keep searching until finding this product. This computation for large n is, however, more complicated than the approximation presented here and does not yield major new insights.

and second-best choice over all values of q, we obtain that the sum of their expected disutilities is

$$\frac{n^2c}{2t}\int_0^1\left(ncq+\frac{1}{2}\left(\frac{t}{2n}-\frac{nc}{8}\right)\right.$$
$$+\frac{1}{2}\left(q\left(\frac{(1-q)nc}{2}+\frac{t}{2n}-\left(1-\frac{q}{2}\right)\frac{nc}{4}\right)\right.$$
$$\left.\left.+(1-q)\left(\frac{t}{2n}+\frac{(1-q)nc}{8}\right)\right)\right)2(1-q)\,dq,$$

where $n^2c/(2t)$ is the total number of such consumers. Let $a \equiv n^2c/(2t)$. Then, the above expression reduces to $at((5a+4)/(8n))$, and it is (asymptotically) the sum of disutilities from the fraction a of all consumers who can possibly stop the search process at the second-best. The remaining $1-a$ fraction of the consumers always search until the best alternative is found. They each incur an expected search cost of $(n/2)c = at/n$, and an average product disutility of $t/(4n)-(n/8)c = (1-a)(t/(4n))$.

Hence, the total consumer disutility is $t(2+8a-a^2)/(8n)$. This expression is minimized at $n = (\sqrt{24-6\sqrt{10}})/3\sqrt{t/c} \approx 0.7473\sqrt{t/c}$. When n is chosen as above, asymptotically, a fraction $n^2c/(2t)\int_0^1 1/2(1-q)\,2(1-q)\,dq = n^2c/(6t) = (4-\sqrt{10})/9 \approx 0.093$ of consumers end up choosing the second-best product; the rest of the consumers end up choosing the best product.

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