Research Note
Consumer Addressability and Customized Pricing

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Abstract
The increasing availability of customer information is giving many firms the ability to reach and customize price and other marketing efforts to the tastes of the individual consumer. This ability is labeled as *consumer addressability.* Consumer addressability through sophisticated databases is particularly important for direct-marketing firms, catalog retailers such as L.L Bean and Land's End, credit card-issuing banks, and firms in the long-distance telephone market. We examine the strategic implications of consumer addressability on competition between database/direct marketing firms. We address questions such as: In a competitive environment, how should firms invest in addressability? Will future improvements in the degree of addressability increase or mitigate the intensity of competition between the firms? Will greater addressability always be beneficial for firms?

We model competition between two firms in a market where consumers differ on a horizontal attribute of product differentiation. The market comprises consumers located on a linear attribute space and firms located at the ends of the line. We represent the degree of addressability (or the reach of a firm's database) as the proportion of consumers at each point in the market who are in the firm's database. Consequently, the firm can offer these consumers customized prices.

Consumer addressability creates two effects that govern the competition between firms: a ''surplus extraction'' effect because a firm might address a consumer who is not reached by its competitor and a ''competitive'' effect that is created by the set of consumers who can be addressed by both firms. The key results of the paper pertain to when the addressability decision is endogenous. When the extent of market differentiation (or consumer heterogeneity in preferences for a product/brand attribute), as well as the incremental cost of addressability, are sufficiently large, firms make symmetric investments in equilibrium. Given high costs, firms choose sufficiently low levels of addressability. Low addressability and high levels of market differentiation both help reduce price competition, which facilitates symmetric choice of addressability by the firms in equilibrium. However, when market differentiation and the cost of incremental addressability become small, firms face the prospect of destructive competition. As a result, they strategically differentiate in their choice of addressability to mitigate this competition. Interestingly, even in the extreme case when incremental addressability is costless, not every firm chooses full addressability in equilibrium. This has useful implications for direct marketing. Given that the advances in information technology should improve the ability of firms to address their consumers, it might indeed not be desirable for all direct marketing firms to indefinitely pursue greater addressability as costs of doing so decline. The analysis also shows an interesting effect of market differentiation in addressable markets: Equilibrium profits can decrease with an increase in market differentiation when the marginal cost of addressability is sufficiently high. Finally, we discuss the competitive outcome that would result when firms compete with addressable as well as uniform posted prices.

(*Customized Pricing; Direct Marketing; Database Marketing; Consumer Addressability; Marketing Information; Individual Marketing; Competitive Price Discrimination*)

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1. Introduction

In the past decade, advances in information technology have led to rapid reduction in the cost of processing and holding customer level information. Many firms have developed sophisticated databases, and this is particularly true of direct marketing firms and catalog retailers such as L.L. Bean and Land's End, credit card-issuing banks, and firms in the long-distance telephone market. A consequence of this phenomenon is that it gives firms the ability to reach individual customers and to customize price and promotional efforts. This capability of information-enabled direct marketing firms has been labeled as consumer ''addressability'' by Blattberg and Deighton (1991). This paper analyzes how this ability to address individual consumers affects market competition. Specifically, we are interested in the ability of direct marketing firms using customer databases to reach consumers and customize price and promotional activities.

Consider, for example, the bank issued credit card industry. There is intense competition among the major players, and direct marketing through customer databases is the important method of marketing in this industry.[1] First USA has been the leader in building and leveraging one of the largest customer databases (which includes 60 million customers as reported in *Cards International,* September 11, 2000) and is currently Number 2 in bank card receivables, behind Citigroup Inc. The company continues to aggressively expand its direct marketing operations.[2] Given this, a question that arises is: How might this impact on other major players such as Citibank, MBNA, and Bank of America and on their strategic incentives to invest in consumer addressability? Understanding these incentives is a key objective of this paper.

Another interesting question pertains to the manner in which future improvements in the degree of addressability and reductions in the cost of developing and maintaining customer databases affect market competition. In the North American long-distance telephone market, the major competitors, AT&T, MCI, and Sprint have been able to improve the sophistication of customer databases that help them address a majority of the consumer population by providing specialized discounts. Anecdotally, such activities seem to have turned the long-distance service into a low margin/low profit business.[3] Our analysis provides an understanding of how improvements in addressability affect the nature of competition between firms.

We examine competition in a model of horizontal differentiation between two direct-marketing firms. Consumers are heterogenous in their preferences, and this is captured by their location in a product attribute space. The location of a consumer determines her ''ideal'' preference for the product attribute, and the consumer incurs a disutility for buying from a firm that is not at her ideal preference. This disutility is a measure of the extent of consumer heterogeneity in preferences for the product attribute and also represents market differentiation between competing firms. Next, we represent the degree of addressability (or the reach of a firm's database) as the proportion of consumers at each point on the line who are in the firm's database. Consequently, the firm can offer these consumers customized prices. An equivalent way of interpreting the degree of addressability is that for the mass of consumers at each point on the line there is a given probability of a consumer being in the firm's database. As the analysis shows, the degree of addressability has a significant effect on the competitive strategies of firms.

Given this framework, consumer addressability creates two effects that govern market competition. The first effect is labeled as the ''surplus extraction'' effect, and it occurs because a firm might reach con-

[1]U.S. banks spent nearly $1.72 billion on corporate CRM and direct marketing activities in the year 2000. (See the *American Banker,* May 2, 2001.)

[2]A company release reports that First USA has signed exclusive agreements with the five largest search engines (including Yahoo, Excite, and MSN) and that no other companies can market credit cards through these channels for a significant period of time. See http://careers.yahoo.com/employment/co/firstusa/company_info.html.

[3]For instance, AT&T has unveiled a seven-cents-a-minute calling plan amid an escalating price war. AT&T's chairman, C. Michael Armstrong, has conceded that intense price competition in the long-distance market was eroding profits (*The Wall Street Journal,* 8/31/1999).

sumers who are not reached by its competitor. The firm has monopoly power over this segment of consumers and is assured of having them even if it charges them their reservation prices. We show that the profit gain from the surplus extraction effect for each firm is increasing in its own addressability but decreasing in its competitor's addressability. The second effect, which we label the "competitive" effect, is created by the segment of consumers that is addressed by the databases of both firms. Consequently, the two firms compete for these consumers. Our analysis shows that the gain in profit for a firm from the competitive segment first increases and then decreases in its own addressability and is increasing in its competitor's addressability.

1.1. The Results

The main results of the paper pertain to the endogenous investments made by firms in acquiring addressability and the resulting competition. The nature of the equilibrium depends upon the extent of market differentiation between the firms (i.e., the extent of consumer heterogeneity w.r.t preference for the product attribute) and the marginal costs of investing in addressability. An equilibrium in which firms make symmetric investments in addressability obtains in situations where the extent of market differentiation/consumer heterogeneity, as well as the marginal cost of addressability, is sufficiently high. Given high marginal costs, firms will choose sufficiently low levels of addressability, which leads to less intense competition for the segment of competitive consumers who are reached by both firms. Furthermore, a higher level of market differentiation also helps firms mitigate price competition, which facilitates symmetric choice of addressability by the firms. However, when market differentiation and the marginal cost of addressability become small, firms face the prospect of destructive competition if they adopt symmetric strategies. Consequently, firms strategically differentiate in their choices of addressability to mitigate competition.

Interestingly, even in the extreme case when incremental addressability is costless, full addressability might not be chosen in equilibrium by both firms. Rather, the firms differentiate in their choices of addressability: While one firm chooses full addressability, the other chooses imperfect addressability in equilibrium. Thus it is possible for firms that are ex-ante symmetric to be asymmetric in their choices of addressability. This result has useful implications for direct marketing in general. Given that the advances in information technology should improve the ability of firms to address their consumers, the result indicates that it might indeed not be desirable for all direct-marketing firms to pursue greater addressability indefinitely as costs of doing so decline. Finally, the analysis also reveals an interesting effect of market differentiation/consumer heterogeneity on the horizontal attribute in addressable markets. We show that equilibrium profits can go down with increasing consumer heterogeneity when the marginal cost of addressability is sufficiently high.

1.2. Related Research

This paper is related to the stream of research on competitive price discrimination. Thisse and Vives (1988) examine competition between firms that are differentiated in geographical space. They assume that the firms have the ability to perfectly address all the consumers in the market and that each customer faces prices that are adjusted from base mill prices for the transportation of the product to the customer's physical location. Thus firms effectively bear the cost of transportation. In this paper, we allow for competition when firms choose their addressability and show that a situation with full addressability (as assumed by Thisse and Vives) does not occur in equilibrium, even if the marginal cost of addressability is zero. Rather, the equilibrium involves at least one firm having imperfect addressability. There are also several other papers that analyze price discrimination under different types of competitive environments but under the same basic assumption of perfect addressability (see, e.g., Borenstein 1985, Holmes 1989).

Shaffer and Zhang (1995) examine rivalry in price discrimination through targeted couponing in a spatial setting. In their model, firms first choose a regular price and then choose the length of the market where coupons can be targeted, but the value of coupons does not vary across consumer locations. Here we allow for prices that vary by the locations of the consumers in the attribute space. Furthermore, unlike Shaffer and Zhang (1995), this paper examines imperfect addressability of consumers. Chen et al. (2001) analyze the competitive impact of the classification accuracy (depth), rather than the addressability (width) of firms' individual-level customer information. In other words, they assume that all consumers are addressable but that firms cannot accurately identify and target consumers by their loyalty type. Here we assume that firms can perfectly identify the consumers that are reached, but that they have imperfect reach. Moreover, the idea of addressability and customized pricing in this paper integrates the loyalty-based consumer heterogeneity with spatial heterogeneity of consumers.

Fudenberg and Tirole (1997) and Villas-Boas (1999) study the dynamics of competition in an infinite-horizon framework when firms can indulge in behavior-based price discrimination. Firms are able to recognize its purchasers from its nonpurchasers (in a previous period) and offer specialized prices accordingly. The price discrimination in our paper is based on differences in horizontal consumer (demographic or psychological) characteristics, rather than on previous purchase behavior.

2. The Model

We first develop the assumptions and the implications of the basic model that captures the idea of addressable competition using customer databases in a market where consumers are heterogeneous along a horizontal attribute of differentiation.

2.1. The Consumer Market

Two firms ($i = 1, 2$) compete in an end consumer market. The firms produce their products at a constant marginal cost of production, which we normalize without any loss of generality to zero. The market has a unit mass of consumers who are uniformly distributed on a standard hotelling line of unit length, with the two firms located at each end. The line represents a horizontal attribute of product differentiation between the firms. A consumer's location on the line represents her ideal preference for the attribute, and the consumer has disutility for consuming a product that is not at her ideal location. Let t represent the per-unit distance disutility incurred by consumers. The total disutility incurred by a consumer who is at distance x from, say, firm i is tx. Note that t is a measure of the degree of consumer heterogeneity preferences along the attribute, with larger values of t representing greater consumer heterogeneity. In other words, t implies consumer heterogeneity in the willingness to pay for the product. It also represents market differentiation between competing firms, because product differentiation in the model is based on the heterogeneity in consumer preferences.

Each consumer has a maximum demand of one unit for which he/she has a reservation value of r. Thus the surplus ϕ_i that the consumer at x gets from firm i is $\phi_i = r - tx - p_i(x)$, where $p_i(x)$ is firm i's price at location x. A consumer buys from the firm that gives him or her larger surplus. If a consumer gets a surplus less than zero (her reservation surplus), she will not buy the product. Finally, we assume that the reservation price is large enough to ensure that a monopoly firm will have the incentive to serve all the customers it can reach. Obviously, this means that all consumers will be served under competition. In the model, this implies the condition $r \geq 2t$.

2.2. Firms' Addressability (Database) Technology

Firms have access to technology that can be used to address individual consumers. Such a technology can be available from internal sources (for example, a firm's transactional databases or the use of the Internet as a selling medium) or from external sources such as syndicated vendors of information. We capture Firm i's addressability through a measure $a_i \in [0, 1]$. This measure can be thought of as the proportion of consumers at each point on the line who are in Firm i's database. Consequently, the firm can offer these consumers personalized prices. Thus a_i can be thought of as the "reach" of the firm's database. This also means that $(1 - a_i)$ of the consumers in the market are not in the firm's database. We assume that while a firm can identify which consumers are in its database, it cannot observe whether or not a consumer is in its competitor's database. The databases of the two firms are assumed to be independent (i.e., the probability of a consumer belonging to a firm's database is independent of the probability that the consumer will belong to its competitor's database).[4]

2.3. The Game

We analyze a two-stage game. In the first stage, the two firms simultaneously invest in addressability a_i. The cost of investing in addressability is convex and of the form $c(a_i) = (½)ka_i^2$. In the second stage, each firm simultaneously chooses a pricing strategy that is contingent on the addressability choices. One can also interpret the first stage investment as giving each firm a maximum or potential ''capacity'' to address consumers. Then each firm can choose how much of this potential capacity to actually utilize in the pricing stage of the game. This captures the fact that a firm can, in the second stage of price competition, choose not to use all its potential addressability. However, as our analysis will show, given the ''capacity'' of the databases that firms invest in the first stage, each firm will choose to address all consumers it has in the database because it can always generate more profits by selling to more customers conditional on the other firm's strategy.

In the price competition stage, Firm i chooses a price profile $p_i(x)$ that is dependent on the location, x, on the line. Thus consumers at each point on the line can potentially get customized prices. In this manner the model captures the essential features of information-rich markets where firms are equipped with database technology and compete with each other using customized pricing strategies that are tailored to individual consumer preferences. Examples of this include competition among mainstream catalog operations, direct-marketing firms, and Internet retailers.

3. Customized Price Competition in Addressable Markets

We now start with the second stage price competition for given levels of addressability. To begin the analysis, we need to construct the profit function of each firm. Without loss of generality, we will assume Firm 1 as the left-side firm (at $x = 0$) and Firm 2 as the right-side firm (at $x = 1$).

Through the device that consumers can be reached by either one or both firms, imperfect consumer addressability creates four distinct segments at each location x: A competitive segment of a_1a_2 consumers can be targeted and therefore competed for by both firms. At every point on the line, the effect of this segment is similar to the switching segment in models of promotional price competition. Two ''monopoly'' segments each of size $a_i\bar{a}_{(3-i)}$ consist of consumers who are in one firm's database but not the other, and therefore there is no competition for these consumers. The effect of these segments is similar to the loyal/uninformed segments in Varian (1980) and Narasimhan (1988). Finally, a segment of size $(1 - a_1)(1 - a_2)$ consists of consumers who are not in any database and thus are not served by either firm.

Because a firm cannot identify whether or not a consumer is in its competitor's database, each firm's pricing strategy will have to trade off between competing for the segment of the a_1a_2 consumers and extracting surplus from the segment of $a_i\bar{a}_{3-i}$ consumers that it alone reaches. This implies that the price equilibrium, in general, will be one in mixed strategies.[5] Mixed strategies here can be interpreted as different customized promotions offered to consumers by the firms over time, which is consistent with the interpretation in the literature of mixed strategies as temporal sales/promotions.

The model of this paper is constructed to capture two aspects of the addressability phenomenon: (i)

[4]This assumption represents a situation where the competing firms independently develop ''internal'' databases. However, an important source of addressability is the emergence of sophisticated vendors of information. For example, several national level household database vendors, such as Equifax or Metromail, provide firms with consumer addressability information. Thus, it is possible for the databases of competing firms to be correlated. We have formally analyzed a model with correlated databases, and the basic result from this analysis is that greater correlation leads to more intense price competition.

[5]In fact, a price equilibrium in pure strategies does not exist unless the market is perfectly addressable ($a_1 = a_2 = 1$).

Firms can have imperfect addressability/reach, and (ii) firms are able to customize prices along the line for the consumers they reach. At each point (except at $x = 0.5$) the effective reservation prices (net of the disutility tx) for the two firms are different, and the firms face consumer segments whose effect is akin to the loyal and switching segments. Thus at every point on the line, we will have a mixed price equilibrium similar to Narasimhan (1988) when the reservation prices for the two firms are different. The asymmetric reservation prices in our model result from the presence of the per-unit distance disutility t. The differences in the effective reservation prices along the line are systematically linked through the disutility parameter. Consumers at x will have effective reservation prices $r - tx$ and $r - t(1 - x)$ for firms 1 and 2, respectively. In addition, in our model there is also a second dimension of consumer heterogeneity along the spatial dimension. Thus not only are consumers heterogeneous in terms of whether they are addressed by one or both firms (which is akin to the loyalty-based heterogeneity at each point), but also there is spatial (horizontal) heterogeneity among consumers across different points in the linear attribute space. It is incorporating this spatial/horizontal dimension that helps us to capture the location-based pricing aspect of the phenomenon. In sum, combining these two dimensions helps represent the two aspects of the phenomenon examined in the paper (i.e., imperfect addressability of consumers as well as location-based pricing).

To establish the mixed-strategy equilibrium of this model let $p_1(x)$ denote the price strategy of Firm 1 for location x. Define the range of $p_1(x)$ as $R_1(x) = (p_{1min}(x), p_{1max}(x))$. Note that $p_{1max}(x = 0)$ is nothing but the reservation price r. At any point, x, the maximum price that firms can charge has to account for the disutility tx. Therefore, $p_{1max}(x) = r - tx$. The segment of consumers who are addressed only by one firm will always be served, even at the highest possible price given $r \geq 2t$. For the segment of a_1a_2 consumers who are addressable by both firms, the incentive compatibility constraint is $p_1(x) + tx = p_2(x) + t(1 - x)$. Note that this implies that while consumers get customized prices, they incur (and not the firms) the disutility cost for not consuming an ideal product. In this sense, our model analyzes price customization and not product customization. A model where firms fully or partially bear consumer disutility costs can be thought of as a model of product customization. Thisse and Vives (1988) consider a spatial model with the physical location interpretation of space in which firms bear the cost of physical transportation of the good.[6] Our analysis is suitable for interpretation of the spatial model as a product attribute space where the travel cost represents the disutility for not consuming an ideal product. Note also that given the price range for firm 1 shown above, the associated price range for firm 2 is $R_2(x) = (p_{1min}(x) - y, p_{1max} - y)$, where $y = t(1 - 2x)$.

The profit functions of the two firms at each point x can now be defined as

$$\pi_1(x) = p_1(x)[a_1(1 - a_2) + a_1a_2H_2(p_1(x) - y)],$$
$$\pi_2(x) = p_2(x)[a_2(1 - a_1) + a_1a_2H_1(p_2(x) + y))], \quad (1)$$

where $H_i(p_{3-i}(x)) = 1 - F_i(p_{3-i}(x))$, and $F_i(\cdot)$ is the *c.d.f* of Firm i's price distribution. The first term in the square brackets in each expression represents the demand at x from each firm's monopoly segment, while the second term is the expected demand from the consumers who are addressable by both firms (given the other firm's pricing strategy). Using these profit functions we can solve for the pricing equilibrium (for a given pair (a_1, a_2)), as shown in the appendix. We then integrate the profits of the firms at each point x over the entire range [0, 1] to derive each firm's total profits as functions of a_1 and a_2. This leads to the following proposition (all proofs are in the appendix).

PROPOSITION 1. *In equilibrium we have that $\pi_1/\pi_2 = a_1/a_2$. The nature of price competition is determined by the following distinct cases:*

Case 1. If the two firms are relatively similar in their addressabilities, $((r - t)/r \leq a_1/a_2 \leq r/(r - t))$, then

[6]We thank the area editor for comments on this point.

$$\pi_1 = a_1(1 - a_2)\left(r - \frac{t}{2}\right) + \frac{a_1(a_1 + a_2)t}{2}\left[\frac{(a_2 - a_1)r + a_1 t}{(a_1 + a_2)t}\right]^2;$$

$$\pi_2 = a_2(1 - a_1)\left(r - \frac{t}{2}\right) + \frac{a_2(a_1 + a_2)t}{2}\left[\frac{(a_1 - a_2)r + a_2 t}{(a_1 + a_2)t}\right]^2.$$

Case 2. If the two firms have sufficiently different addressabilities, i.e., if Firm i has sufficiently higher level of addressability than Firm j ($j \neq i$), ($a_i/a_j > r/(r - t)$), then

$$\pi_i = a_i(1 - a_j)\left(r - \frac{t}{2}\right);$$

$$\pi_j = a_j(1 - a_j)\left(r - \frac{t}{2}\right).$$

The first result in Proposition 1 highlights the role of consumer addressability as a driver of competitive advantage in information intensive markets. Note that the ratio of firms' equilibrium profits are exactly identical to the ratio of their addressability. Higher addressability translates to greater equilibrium profits, underlining the importance of investments in addressability for firms.

Case 1 of Proposition 1 represents the equilibrium profits when the two firms are relatively similar in terms of their addressability. The equilibrium profits of the firms have two distinct terms. The first term represents the profits from the segment of consumers over which that firm has monopoly power to extract all consumer surplus. For example, for Firm 1 the size of this segment is $a_1(1 - a_2)$ and the effective reservation price (i.e., the monopoly price) at any point x is $r - tx$. Thus the total profit from this segment over the entire market $[0, 1]$ is $a_1(1 - a_2)(r - t/2)$.

The second term represents the equilibrium profits of the firms from the competitive segment reached by both firms (a_1a_2). This is most clearly seen in the symmetric case of $a_1 = a_2 = a$. Then this term reduces to $a^2t/4$. Now note that if this segment was the only segment in the market, then firms will engage in local Bertrand competition at every point of the line. Therefore, Firm 1 can get all the customers in $[0, \frac{1}{2}]$ and charge a price of $p_1(x) = t(1 - 2x)$ but get no customers on the other half of the line. Consequently, $\pi_1 = \int_0^{1/2} a^2t(1 - 2x)\, dx = a^2t/4$ (and similarly for Firm 2).

The analysis highlights two distinct effects resulting from consumer addressability: a "surplus extraction" effect and a "competitive" effect. The surplus extraction effect results from the segment of $a_i(1 - a_{3-i})$ consumers who can be addressed by the firm but not by its competitor. Thus the firm has monopoly power over these consumers in the sense that even if it charges the highest possible price it will be assured these consumers. Note that the size of this segment, and consequently the gain from the surplus extraction effect for each firm, is increasing in its own addressability but decreasing in the other firm's addressability. This can be seen from the first terms in the equilibrium profits of Case 1.

The competitive effect results from the firms competing on the segment of a_1a_2 consumers who can be addressed by both firms. The impact of addressability on firms profits because of this effect can be seen from the second term of the equilibrium profit in Case 1. Note that the profits represented by the second term first increases and then decreases with the level of a firm's own addressability but is always increasing in its competitor's addressability. An increase in a firm's, say Firm 1's, own addressability increases the size of the competitive segment, leading to an increase in the profit from that segment. However, increase in a_1 also increases the size of Firm 1's monopoly segment, which reduces its incentive to compete in the a_1a_2 segment, leading to lower profits from this segment. Consequently, the overall relationship between a firm's own addressability and its profits from the competitive segment is in the form of an inverse U. However, with an increase in a_2, the size of the competitive segment increases, while the size of Firm 1's monopoly segment reduces. This gives Firm 1 more incentive but Firm 2 less incentive to compete for the a_1a_2 consumers, resulting in greater profits for Firm 1 from this segment.

Finally, the next case in Proposition 1 characterizes the situations where the addressability levels of the two firms are sufficiently different. For example, if a_1 is sufficiently larger than a_2 (when $i = 1$ and $j = 2$), the surplus extraction effect for Firm 1 overwhelms the competitive effect, and thus Firm 1 has no incentive to compete for the a_1a_2 consumers who are addressed by both firms. Effectively its profits are as if they are from the monopoly segment of $a_1(1 - a_2)$ consumers. In contrast, for Firm 2 the competitive effect overwhelms the surplus extraction effect. Therefore, following the same intuition as in the last paragraph, Firm 2's profits are in an inverse $-$U relationship in a_2.

4. Addressability Choice

In the previous section we solved for the second stage price equilibrium given a pair (a_1, a_2). Consider now the choice of addressability by the firms. We start with the special case where the marginal cost of addressability is zero and solve for the subgame perfect Nash equilibrium. This helps us highlight the incentives of firms to strategically pursue consumer addressability under competition. In particular, we are interested in understanding whether both firms would commit to full addressability even when such addressability is costless.

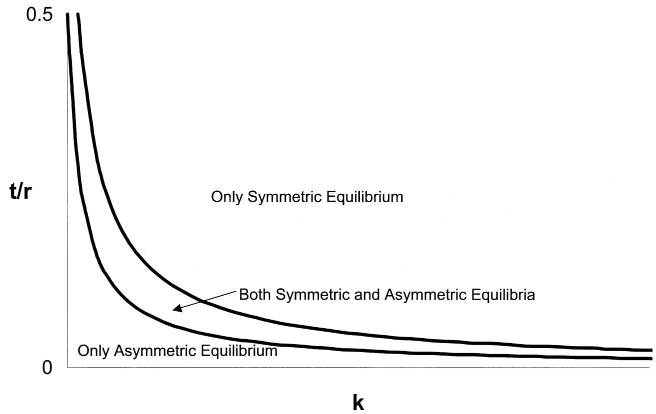
PROPOSITION 2. *When firms choose addressability and the marginal cost of addressability is zero,*

(1) The equilibrium can never involve both firms choosing full addressability;

(2) In equilibrium, $a_i = 1$, $a_{-i} = 0.5$.

This result reveals a strong motivation for firms to differentiate in the choices of addressability. Thus even if incremental addressability comes at zero marginal cost, one of the competing firms will choose less than full addressability. The intuition for this is as follows. Given that one firm, say Firm 1, has full addressability, Firm 2 will not enjoy any benefit of surplus extraction (as the size of its monopoly segment will be $a_2(1 - a_1) = 0$). Therefore, its profits are from the competitive segment only, and as discussed in the previous section, these profits are inverse $-$U in its own addressability a_2. Therefore, even if addressability is costless, Firm 2 will be better off not choosing full addressability at the first stage. In doing so, Firm 2 is able to strategically avoid the head-to-head price competition that full addressability would otherwise have entailed. This is reminiscent of the vertical differentiation models of competition (e.g., Shaked and Sutton 1982, Moorthy 1988) where otherwise symmetric firms endogenously differentiate in quality to avoid head-to-head competition. This provides a rationale for why the major firms in competitive industries such as bank-issued credit cards and long-distance telephone might not all end up pursuing increased addressability.

Figure 1 Equilibrium Partitions with Endogenous Addressability



4.1. Positive Marginal Costs

We now examine how the choice of addressability is affected when addressability has positive marginal costs. Let the cost of incremental addressability be increasing and strictly convex, $c(a_i) = (½)ka_i^2$ (detailed derivations for this case are also provided in the appendix). In establishing the equilibrium, it can be shown that there are three possible cases. The first case pertains to the symmetric choice of addressability in equilibrium where $a_1^* = a_2^* = a = (8r - 4t)/(12r - 9t + 8k)$. The other two cases pertain to the asymmetric equilibria where the equilibrium choices are $a_i^* = \min[(2r - t + 2k)(r - 0.5t)/k(4r - 2t + 2k), 1]$ and $a_{(3-i)}^* = (2r - t)/(4r - 2t + 2k)$.

In Figure 1 we show the partition of the parameter space between the symmetric and asymmetric equilibria. The horizontal axis represents the cost parameter k, while the vertical axis represents the extent of market differentiation/consumer heterogeneity. The symmetric equilibrium obtains when the marginal cost of addressability as well as market differentiation are sufficiently high. With higher marginal costs, firms will choose low addressability levels. Lower addressability levels leads to less intense competition in the $a_1^* a_2^*$ segment. Furthermore, a higher level of market differentiation also helps the firms to mitigate price competition. Therefore, firms make symmetric addressability choices in equilibrium.

Next, as shown in Figure 1, when market differentiation and marginal cost of addressability are small, firms face the prospect of destructive price competition if they adopt symmetric strategies. Consequently, the firms differentiate in their choices of addressability to mitigate this competition. Finally, in the intermediate range of t and k both symmetric and asymmetric equilibria are possible. These results indicate that firms might pursue asymmetric addressability strategies even if they are ex-ante symmetric. Differentiating in the choices of addressability helps firms to mitigate competition. Even firms that potentially have access to the same technology might therefore adopt different database policies.

It is interesting to note the impact of market differentiation/consumer heterogeneity parameter t on equilibrium profits. The comparative statics suggest that the equilibrium profits can actually go down with increasing consumer heterogeneity when the marginal cost of addressability is sufficiently high. In this case, firms will invest in sufficiently small levels of addressability, and in the equilibrium the firms will make symmetric investments. Given this, the size of the monopoly segment of consumers who are reached by only one firm will be relatively large (as compared to the competitive segment). Therefore, more consumer heterogeneity or higher t is "bad" in the sense that it reduces the willingness to pay of consumers in the monopoly segment. In other words, a firm will have to charge lower prices to attract the consumers over whom it has monopoly power but are far away from it on the line. Thus the firm's ability to extract surplus goes down with t, which makes equilibrium profits go down with t. As the marginal cost of addressability becomes smaller, firms will have the incentive to invest in greater levels of addressability. This increases the size of the competitive segment of consumers, leading to more intense competition in this segment. The negative impact of this on profits outweighs the benefits of surplus extraction. Consequently, greater consumer heterogeneity is "good" in the sense that it is equivalent to greater market differentiation between firms. This helps a firm to better withstand competition in the segment of consumers who are reached by both firms.

It is also interesting to note what happens when firms invest in addressability sequentially. If addressability is costless, similar to the result in Proposition 2, the first mover will choose full addressability while the follower will choose $a_2^* = 0.5$. The first mover will make greater profits. When addressability involves positive marginal costs, these results hold as long as the marginal costs are sufficiently small. An implication that follows is that as the costs of addressability decline over time (because of better technology), firms that move ahead of competition in establishing customer databases will stand to enjoy a sustainable first-mover advantage.

4.2. Consumer Welfare

Until now we have analyzed the effect of addressability on firm strategies. Another interesting issue is the consumer welfare implications of advances in database technology. Total consumer surplus is the gross reservation surplus generated in the market minus the equilibrium profits (excluding the cost of addressability) of both firms. The gross reservation surplus can be computed by integrating along the line the reservation price of all consumers served less the disutility costs. We derive the gross reservation surplus to be $(a_1^* + a_2^* - 2a_1^* a_2^*)(r - t/2) + a_1^* a_2^*(r - t/4)$, where a_1^* and a_2^* are the equilibrium choices. For both the symmetric and the asymmetric equilibria, we find that the equilibrium consumer surplus decreases with t/r. Thus the overall consumer surplus is lower in markets with greater consumer heterogeneity. In addition, a decrease in the marginal cost implies that firms invest in higher levels of addressability. A higher level of addressability not only intensifies the competition between firms, but it also implies that more consumers will be served in equilibrium. Therefore, total consumer surplus always increases with a decrease in the marginal cost of addressability.

5. Extensions, Caveats, and Future Research

In this section we list some caveats to our current analysis, provide some preliminary discussion of model extensions and directions for future research.

Incorporating Posted Prices

We have analyzed the case of pure addressable pricing as a representation of direct/database marketing operations. In our analysis firms cannot sell to the $(1 - a_i)$ consumers who are not in their databases. However, in many cases firms do serve these consumers through posted price mechanisms. Suppose firms simultaneously choose posted prices and then choose addressable pricing strategies that are contingent on the previously chosen posted prices. In this case we find that when the level of addressability is sufficiently high (i.e., $(2r - 2t)/(2r - t) \leq a \leq 1$), the equilibrium involves incomplete coverage of the market wherein some consumers who are in the middle of the line and who are not in either database do not buy. Otherwise, there is full coverage of the market along the line. We also find that the equilibrium posted price unambiguously increases in the level of addressability. The equilibrium posted price under the full-coverage case is $p_i^* = t/(1 - a)$ and under the incomplete-coverage case is $r/(2 - a)$. When addressability is zero, we recover the standard hotelling uniform price outcome $p_i^* = t$. When addressability is perfect ($a = 1$), we have that $p_i^* = r$. In other words, when all consumers are addressable, the posted prices become irrelevant for consumer decision making and all consumers buy at the addressable prices. In the case of the choice of addressability, we find a similar result to that of Proposition 2 when addressability comes at zero marginal cost. In other words, both firms choosing full addressability is not an equilibrium. We leave the analysis of the costly choice of addressability for the case of posted plus addressable pricing for future work.

Location-Specific Choice of Addressability

Our analysis assumes that firms choose a uniform level of addressability along the entire market. However, it is plausible that information-intensive firms might differentially invest in addressability, depending upon the location on the line. Thus one can consider a model wherein both firms first invest in location-specific addressability $a_i(x)$ and then compete in addressable prices $p_i(x)$. In such a model the equilibrium choice of addressability for a firm would decrease with the distance from the firm. In other words, the firm invests in greater levels of addressability for consumers who have a higher willingness to pay for its product. Thus firms might endogenously have the incentive to enhance their database in defending their part of the market (see also Iyer and Soberman 2000 for a similar result in the context of targeted product modification investments).

Another interesting issue that we have not analyzed here is what would happen when the choice of addressability becomes less strategic and easier to change as markets evolve and become more information intensive. We can model this as a game where firms make simultaneous choices in both prices and addressability. Analysis of this model is complicated by the fact that there is no pure-strategy equilibrium in the choices of addressability. The reason is similar to that in the vertical differentiation literature where no pure strategy equilibrium in price and quality exists when they are simultaneously chosen because of "jockeying" by the firms in both these variables (see Stokey 1980 for details). There are several other possibilities for future research. Many syndicated vendors of addressable information now exist. It would be interesting to understand the selling strategies that such vendors should use and this would add to the literature on information selling (Sarvary and Parker 1997, Iyer and Soberman 2000). Finally, it would be useful to examine the use of addressable databases for product customization. Here we focused on the use of databases to offer customized prices to customers. We believe that the competitive and strategic implications of product customization provide a worthwhile topic for investigation.

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Appendix

PROOF OF PROPOSITION 1. Let γ_i ($i = 1, 2$) to be the proportion of "monopoly" customers that are addressable by Firm i but not by Firm j ($j = 3 - i$) and α to be the proportion of customers that are addressable by both firms. We have that $\gamma_1 = a_1(1 - a_2)$ and $\alpha = a_1a_2$. Also, we denote $p_i(x)$ to be the price of Firm i at location x, $\pi_i(x)$ to be Firm i's profit at location x, and π_i to be Firm i's total profit. If $a_2 = 0$, Firm 1 is a monopoly and will charge $p_1(x) = r - tx$, customers' effective reservation price at x. Therefore, $\pi_2 = 0$ and $\pi_1 = \int_0^1 a_1p_1(x)\,dx = a_1(r - t/2)$. Similarly, if $a_1 = 0$, we have that $\pi_1 = 0$ and $\pi_2 = a_2(r - t/2)$.

If $a_1 = a_2 = 1$, both firms can perfectly address all customers. Thus firms engage in local Bertrand competition at every point of the unit line. In $0 \le x \le ½$, Firm 1 can charge a maximum price of $p_1(x) = t(1 - 2x)$ and not lose any customers even if the other firm prices at marginal cost. Similarly, in $½ \le x \le 1$, Firm 2 can charge $p_2(x) = t(2x - 1)$ and not lose any customers to Firm 1, even if it prices at marginal cost. Following arguments similar to that in Thisse and Vives (1988), we can show that $\pi_1(x) = p_1(x) = t(1 - 2x)$ and $\pi_2(x) = p_2(x) = 0$ if $0 \le x \le ½$; and $\pi_2(x) = p_2(x) = t(2x - 1)$ and $\pi_1(x) = p_1(x) = 0$ if $½ \le x \le 1$. Consequently, $\pi_i = \int_0^1 \pi_i(x)\,dx = t/4$.

If $0 < a_1 < 1$ and $0 < a_2 < 1$, there is no pure-strategy equilibrium in $p_1(x)$ and $p_2(x)$. The argument is similar to that in Varian (1980) and Narasimhan (1988) and is as follows: (a) To get the α size of customers who are addressable by both firms, Firm 1 (Firm 2) has incentive to set $p_1(x)$ ($p_2(x)$) to undercut $p_2(x)$ ($p_1(x)$) if the latter value is not too low, and (b) If not, Firm 1 (Firm 2) would set $p_1(x)$ ($p_2(x)$) to $r - tx$ ($r - t(1 - x)$) to only sell to its γ_i size of the monopoly customers who are not addressable by the other firm. The mixed-strategy equilibrium at location x of this game can then be solved through the following procedure.

Using proofs similar to Varian (1980) or Narasimhan (1988), it can be shown that the support of $p_i(x)$ is continuous, that $p_i(x)$ cannot have a mass point below the upper bound of its support and that at most one of $p_i(x)$ can have a probability mass, q_i, at the upper bound of its support. In addition, it can be shown that $p_1(x)$'s support is from p_{bx} to $p_{tx} = r - tx$ and $p_2(x)$'s support is from $p_{bx} - t(1 - 2x)$ to $p_{tx} - t(1 - 2x) = r - t(1 - x)$, where p_{bx} is to be determined from the equilibrium conditions.

Now define $H_{ix}(p) = \Pr(p_i(x) \ge p)$, and $y = t(1 - 2x)$. We have that in the equilibrium

$$\pi_1(x) = [\gamma_1 + \alpha H_{2x}(p - y)]p, \qquad p_{bx} \le p \le p_{tx},$$

$$\pi_2(x) = [\gamma_2 + \alpha H_{1x}(p + y)]p, \qquad p_{bx} - y \le p \le p_{tx} - y. \tag{2}$$

Equation (2) results from the requirements that (a) each price at Firm i's price support should generate the same profit for the firm in the mixed-strategy Nash equilibrium, and (b) a customer from α buys from Firm 1 (Firm 2) if and only if $p_1(x) + tx < (>)\ p_2(x) + t(1 - x)$. The equilibrium can be solved by using $H_{1x}(p_{bx}) = 1$, $H_{2x}(p_{bx} - y) = 1$, $H_{1x}(p_{tx}) = q_1$, $H_{2x}(p_{tx} - y) = q_2$, and $q_1q_2 = 0$. Solving for the equilibrium we have

(i) if $0 \le x \le \bar{x}$ $\left(\text{where } \bar{x} = \max\left[0, \dfrac{(a_2 - a_1)r + a_1t}{t(a_2 + a_1)}\right]\right)$,

$$\text{then } \pi_2(x) = \gamma_2(p_{tx} - y), \qquad p_{bx} = \frac{\pi_2(x)}{\gamma_2 + \alpha} + y,$$

$$\pi_1(x) = p_{bx}(\gamma_1 + \alpha), \qquad q_1 = 0, \qquad q_2 = \frac{a_2 - a_1}{a_2} + \frac{a_1 y}{a_2 p_{tx}},$$

$$H_{1x}(p) = \frac{\pi_2(x)}{\alpha(p - y)} - \frac{\gamma_2}{\alpha}, \qquad H_{2x}(p) = \frac{\pi_1(x)}{\alpha(p + y)} - \frac{\gamma_1}{\alpha};$$

(ii) if $\bar{x} \le x \le 1$, then $\pi_1(x) = \gamma_1 p_{tx}$, $\quad p_{bx} = \dfrac{\gamma_1 p_{tx}}{\gamma_1 + \alpha}$,

$$\pi_2(x) = (p_{bx} - y)(\gamma_2 + \alpha), \qquad q_1 = \frac{a_1 - a_2}{a_1} - \frac{a_2 y}{a_1(p_{tx} - y)},$$

$$q_2 = 0, \qquad H_{1x}(p) = \frac{\pi_2(x)}{\alpha(p - y)} - \frac{\gamma_2}{\alpha},$$

$$H_{2x}(p) = \frac{\pi_1(x)}{\alpha(p + y)} - \frac{\gamma_1}{\alpha}.$$

Then π_i can be obtained from $\pi_i = \int_0^1 \pi_i(x)\,dx$, which leads to the results in Proposition 1. □

PROOF OF PROPOSITION 2. To prove part 1 of Proposition 2, suppose that $a_1 = 1$. Given this the profit function of Firm 2 after solving for the price competition subgame is $\pi_2(a_1 = 1; a_2) = a_2[a_2(r - t) - r]^2/[2t(1 + a_2)]$. Thus $(d\pi_2/da_2)|_{a2\to 1} < 0$. Therefore, both firms choosing full addressability can never be an equilibrium when the choice of addressability is endogenous. To prove part 2, suppose that $a_i = 1$. Then using the profit functions π_i above we can solve for a_{3-i}. There are two possible cases. The first case is one in which $0 < \bar{x} < 1$. Here, solving for the optimum a_{3-i} we get that

$$a_{3-i} = \frac{\sqrt{\dfrac{17r - 9t}{r - t}} - 3}{4}.$$

However, substituting this value of a_{3-i} back into $\bar{x}$ implies that $\bar{x} < 0$, which means that this case cannot be an equilibrium solution. Thus the equilibrium must involve the case of $\bar{x} = 0$. Now solving for the best response of Firm $3 - i$ to $a_i = 1$ we find the $a_{3-i} = 0.5$.

Finally, given $a_{3-i} = 0.5$, we can show that the best response for Firm i is indeed $a_i = 1$. To show this let $a_{3-i} = 0.5$ and $a_i = a$, then $\pi_i = \int_0^{\bar{z}} \pi_{i1}\,dx + \int_{\bar{z}}^1 \pi_{i2}\,dx$, where $\pi_{i1} = (1 - a)ar + a^2t - a(1 + a)tx$, $\pi_{i2} = 0.5a(r - tx)$, and $z = [(1 - 2a)r + 2at]/t(1 + 2a)$. Now because (a) $\pi_{i1|x=z} = \pi_{i2|x=z}$, (b) $\partial\pi_{i1}/\partial a = 0$ at $x = z$ and $\partial\pi_{i1}/\partial a > 0$ for x

$< z$, (c) $\partial\pi_{i1}/\partial a > 0$, and (d) $\partial z/\partial a < 0$, we have that π_i increases with a. Thus, $a_i = a = 1$ is the optimal value. Therefore, the pair $a_i = 1$, $a_{-i} = 0.5$ is an equilibrium.

Costly Addressability

In the case where addressability is costly to obtain, Firm i's total profit is $\Pi_i = \pi_i - (½)ka_i^2$, where π_i is $\int_0^1 \pi_i(x)\,dx$ and $\pi_i(x)$ is obtained in results (i) and (ii) in this appendix. From results (i) and (ii), there are three possible scenarios of $\bar{x}$: (1) $0 \le \bar{x} \le 1$ (both firms have mass points at some part of the line); (2) $\bar{x} < 0$ (only Firm 1 has mass points on the line); or (3) $\bar{x} > 1$ (only Firm 2 has mass points on the line). In each scenario, the optimal a_i^* can be obtained by solving $\partial\Pi_1/\partial a_1 = 0$ and $\partial\Pi_2/\partial a_2 = 0$ simultaneously. The results are as follows:

- $a_1^* = a_2^* = \dfrac{8r - 4t}{12r - 9t + 8k}$

  corresponding to the scenario of $0 \le \bar{x} \le 1$.
- $a_1^* = \dfrac{2r - t}{4r - 2t + 2k}$ and $a_2^* = \min\left[\dfrac{(2r - t + 2k)(r - 0.5t)}{k(4r - 2t + 2k)}, 1\right]$

  corresponding to the scenario of $\bar{x} > 1$.
- $a_1^* = \min\left[\dfrac{(2r - t + 2k)(r - 0.5t)}{k(4r - 2t + 2k)}, 1\right]$ and $a_2^* = \dfrac{2r - t}{4r - 2t + 2k}$

  corresponding to the scenario of $\bar{x} < 0$.

Scenario (1) pertains to a possible symmetric equilibrium, and Scenarios (2) and (3) pertain to possible asymmetric equilibria. The final equilibrium results can then be obtained by examining if in each scenario either firm would have the incentive to deviate to another scenario. This can be done by numerical analysis on a dense grid of t/r and k, which leads to Figure 1 in the paper.

References

Borenstein, Severin. 1985. Price discrimination in free-entry markets. *RAND J. Econ.* **16** 380–397.

Blattberg, Robert C., John Deighton. 1991. Interactive marketing: exploiting the age of addressability. *Sloan Management Rev.* **Fall** 5–14.

Chen, Yuxin, Chakravarthi Narasimhan, Z. J. Zhang. 2001. Individual marketing with imperfect targetability. *Marketing Sci.* **20** 23–41.

Fudenberg, Drew, Jean Tirole. 2000. Customer poaching and brand switching. *RAND J. Econom.* **31** 634–657.

Holmes, Thomas. 1989. The effects of third-degree price discrimination in oligopoly. *Amer. Econom. Rev.* **79** 244–250.

Iyer, Ganesh, David Soberman. 2000. Markets for product modification information. *Marketing Sci.* **19** 203–225.

Moorthy, K. S. 1988. Price and product competition in a duopoly. *Marketing Sci.* **7** 141–168.

Narasimhan, Chakravarthi. 1988. Competitive promotional strategies. *J. Bus.* **61** 427–449.

Salop, Steven. 1979. Monopolistic competition with outside goods. *Bell J. Econom.* **10** 141–156.

Sarvary, Miklos, Philip M. Parker. 1997. Marketing information: A competitive analysis. *Marketing Sci.* **16** 24–38.

Shaffer, Greg, Z. J. Zhang. 1995. Competitive coupon targeting. *Marketing Sci.* **14** 395–416.

Shaked, Avner, John Sutton. 1982. Relaxing price competition through product differentiation. *Review Econom. Stud.* **49** 3–13.

Stokey, N. 1980. Job differentiation and wages. *Quart. J. Econom.* **95** 431–449.

Thisse, Jacques-Francois, Xavier Vives. 1988. On the strategic choice of spatial price policy. *Amer. Econom. Rev.* **78** 122–137.

Varian, R. Hal. 1980. A model of sales. *Amer. Econom. Rev.* **70** 651–659.

Villas-Boas, Miguel J. 1999. Dynamic competition with customer recognition. *RAND J. Econom.* **30** 604–631.

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