MARKETING SCIENCE
Vol. 24, No. 4, Fall 2005, pp. 569–584
ISSN 0732-2399 | EISSN 1526-548X | 05 | 2404 | 0569

DOI 10.1287/mksc.1050.0128

Customized Products: A Competitive Analysis

Niladri B. Syam, Ranran Ruan, James D. Hess
Department of Marketing, C. T. Bauer College of Business, University of Houston, 4800 Calhoun Road, Houston, Texas 77204
{nbsyam@uh.edu, ruanranran@hotmail.com, jhess@uh.edu}

This paper investigates the competitive market for mass-customized products. Competition leads to surprising conclusions: Manufacturers customize only one of a product's two attributes, and each manufacturer chooses the same attribute. Customization of both attributes cannot persist in an equilibrium where firms first choose customization and then choose price, because effort to capture market with customization makes a rival desperate, putting downward pressure on prices.

Equilibrium involves partial or no customization. In partial customization, rival firms do not differentiate their mass-customization programs: If firms customize different attributes, many more consumers are indifferent between the two firms. The elasticity of demand is increased and the resulting price war makes differentiated customization unprofitable. If firms customize the same attribute of a two-attribute product, they should concentrate on the attribute with the smaller heterogeneity in consumers' preferences.

We incorporate consumers' effort in portraying their preferences as a cost of interaction and provide public policy findings on the well-being of these consumers: When this cost is low, consumers are better off with customization than with standard goods, but firms choose too little customization. The loss in consumer surplus is sometimes captured by the firms, but for low interaction costs, firms' profit-driven behavior is economically inefficient.

Key words: customization; product differentiation; competition; game theory; personalization
History: This paper was received February 23, 2004, and was with the authors 1 month for 2 revisions; processed by Duncan Simester.

1. Introduction

Increasingly, academics and practitioners view marketing as an interactive process where sellers and buyers rely on each other to co-create better value in the exchange. Concepts such as individual marketing, one-to-one marketing, and interactive marketing center on this view (e.g., Fournier et al. 1998, Pine and Gilmore 2000, Peppers et al. 1999). Advances in flexible manufacturing and Internet-based information and communication technology will only accelerate this trend.

One emerging marketing strategy is mass customization, which is a flexible process designed to provide consumers a product matched to their individually stated needs in one or more product dimensions (*Business Week* 2000, p. 130). The concept of mass customization has drawn considerable attention in the fields of operations management and management information systems, where the focus is on the information and manufacturing systems needed for quick and flexible manufacturing (Gillenson et al. 1999, Nicholas 1998). However, despite its growing popularity in marketing practice and the resulting attention paid it by the trade press, mass customization and consumer co-creation of ideal products has hardly been investigated by academic marketers (Wind and Rangaswamy 2001).

This paper partially fills this gap by analytically modeling the strategic provision of customized products in a competitive situation. Our contribution answers five questions. First, what is the impact of customization on profits and prices for firms that previously provided only standard products? Second, given that competing firms can choose the specific product attributes to customize, how many attributes will be customized? Third, will competing firms customize different attributes to enhance brand differentiation, or will the marketplace drive them to common customization? Fourth, do consumers benefit from mass customization, recognizing that as co-creators of their custom products they bear interaction costs? Fifth, is the economy better off with mass customization?

To foreshadow our major conclusions, L. L. Bean and REI (Recreational Equipment, Inc.) sell sleeping bags for backpacking, characterized by two attributes: "length" and "temperature comfort rating." Length corresponds to the hiker's height, and temperature comfort rating corresponds to the outdoor temperature at night (lower temperature ratings are not always desirable, especially when doing desert hiking in the summer). Both firms can choose whether or not to customize these attributes. Each firm could customize neither of these attributes (that is, offer one size and comfort rating to all consumers), customize only the length, customize only the comfort rating, or customize both length and comfort rating, creating "segments-of-one" (Pine and Gilmore 2000). The prices and profits in a particular customization situation are determined by the competition for consumers, whose details are provided in the following section.

Surprisingly, the Nash equilibrium is characterized by partial customization—only one attribute is customized, while the other is offered at a standard level for all consumers. In addition, the specific attribute that is customized is the same for both firms, say comfort rating of sleeping bags—there is no differentiation by the two sellers. The basic intuition behind both of these findings (partial customization and matched customization) has the same source: designing products to take advantage of the consumers' desire for ideal products while avoiding a disastrous price war. Partial, but not complete, customization is reasonable because if *both* firms offer completely customized products, the sellers are identical in the eyes of the consumer, and the only way the competitive firms can attract consumers is by price reductions. The resulting price war between identical brands would transfer all the benefits of customization to the consumers. Thus, partial but not complete customization is the equilibrium outcome.

The same logic applies for asymmetric strategic choices. For example, L. L. Bean will not switch from the customized "comfort rating" equilibrium to complete "customize both length and comfort rating" product strategy because that would leave REI in a very unfavorable situation. Specifically, REI would have an inferior product in the eyes of the consumers because it offers only one length sleeping bag. Given its product decision, the only weapon REI has to make up for its product's deficiency is price, and it will wield this with a vengeance to protect a minimal market share.

Why do the firms not differentiate themselves by customizing different attributes; say, L. L. Bean customizes length of sleeping bags while REI customizes comfort rating? As detailed below, with differentiated partial customization many more consumers are indifferent between the differentiated offers than would be if the customization was matched. This gives both differentiated firms a stronger incentive to reduce price. The competition when more consumers are in play leads to price cuts without corresponding changes in equilibrium market share. By customizing the same attribute and thus softening the price sensitivity of demand, the firms can avoid price wars. We can contrast our model, in which the desire to avoid price competition induces firms not to differentiate their customization strategies, with that of Liu et al. (2004). In a model of competition between television broadcasters, they show that the absence of price competition does not always imply minimum differentiation, especially if competition on other factors such as quality induces firms to take differentiated positions.

Our model may be extended to address other issues such as how firms coordinate on the attribute to customize. We find that if consumers have different preference heterogeneities for the two attributes, then it is optimal for both the firms to customize the attribute with the *lower* preference heterogeneity. This counterintuitive result is a consequence of attempts to avoid price wars.

Finally, variations of our model can tell when customization is likely to be used. The trade literature suggests that customization is more likely to happen in markets with a higher level of consumer preference heterogeneity than in markets with lower consumer heterogeneity (Wayland and Cole 1998, p. 28). However, if heterogeneity is sufficiently high, firms could also earn quasi-monopoly rents by providing differentiated standard products and might not have any incentives to provide customized products even if consumers desire it. Our analysis supports this line of reasoning by showing that, in a world where competing firms choose whether or not to offer customized goods, they earn similar profits with either strategy if consumer preference heterogeneity is high enough. This illustrates potentially ambiguous relationships between high preference heterogeneity and customization, which our analytic model resolves.

Our theory focuses on the strategic role of competition in answering the question, "Should I customize, and if so, what aspect?" Manufacturing costs are set to zero and no form of price discrimination occurs. Obviously, these are important factors in customization, but by setting them aside in our logical experiments, we avoid confounding them with our focal driving force, competition. This approach to controlling for other factors is conventional in analytic modeling (Moorthy 1993).

Furthermore, customized pricing issues have been studied elsewhere in marketing and economics (Shaffer and Zhang 1995, Bester and Petrakis 1996, Villas-Boas 2003, Fudenberg and Tirole 2000, Chen and Iyer 2002). Many customizers do not price discriminate, however. Reflect.com manufactures custom-made cosmetics, but all variants of customized lipsticks, say, are priced at $17.00 regardless of what color and what type of finish (glossy, matte, or a combination) is chosen. Of course, L'Oreal Colour Riche Lipstick is available at the local pharmacy in 48 shades of red, all at the same price: $7.99 per tube. LandsEnd.com offers customized-fit jeans (with over 100,000 fit variants), all at the same price of $54. This also differentiates our basic model from studies of a limited product-line assortment because these studies typically would involve different prices for different elements in the assortment.

Dewan et al. (2003) address product customization and price competition on the Internet. They are concerned mainly with the cost efficiencies of flexible manufacturing, while our paper sets this issue aside while treating the configuration of the customized product itself in greater detail than theirs. The customized products offered by rival firms in Dewan et al. do not compete head to head, but this is precisely the focus of our paper. We assume that there is no cost difference associated with customization (e.g., mixing colors of house paint). In an empirical approach Zhang and Krishnamurthi (2004) provide a decision support system for customized online promotions and derive the optimal price discount for each household for each shopping trip.

Other studies have modeled consumer preferences distributed on a two-dimensional space (Ben-Akiva et al. 1989, Anderson et al. 1992, Ansari et al. 1998). These models are concerned with the optimal choice of a single product rather than the extensive assortment of products implied by customization. Given that firms can choose only one product, a central finding in these papers is that firms chose identical levels of one attribute and maximally different levels on the other. This foreshadows our result when firms make decisions on assortments rather than single products: We find that rival firms identically customize one of the attributes (offering a huge assortment), but maximally differentiate themselves with a single level of the other. They partially but identically customize. Of course, in the single-product models, a firm cannot offer a product that totally dominates its rival's product in the minds of all consumers, while in our model firms may select product strategies preferred by all consumers. It is not obvious that complete customization is a poor reply to a rival that customizes only one attribute, and for this reason the equilibrium derived below is not a foregone conclusion, even given the previous results on single-product competition.

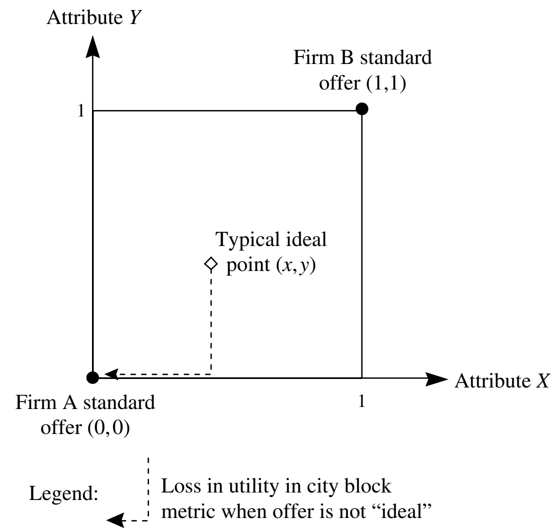
2. A Model of Customization

Consider a market with two Firms A and B producing a product with two attributes labeled X and Y that they could offer either as standard features or as customized options. This is consistent with the conceptualization of a product as a bundle of attributes and is also consistent with practice where firms are able to choose the attributes that they are willing to customize.

2.1. Consumer Choice of Standard Products

Consumers have heterogeneous but independent preferences for the two attributes and their ideal values of the two attributes (x, y) are distributed uniformly over the unit square $[0,1] \times [0,1]$. In the baseline case, each firm offers a single standard product whose attributes are also located in the unit square. We assume that firms are maximally differentiated with respect to both attributes X and Y, and the standard products are located at $(0,0)$ and $(1,1)$ for A and B, respectively. Each firm's location in attribute space and the ideal vector of a typical consumer are displayed in Figure 1.

Figure 1 **Ideal Point in Attribute Space**



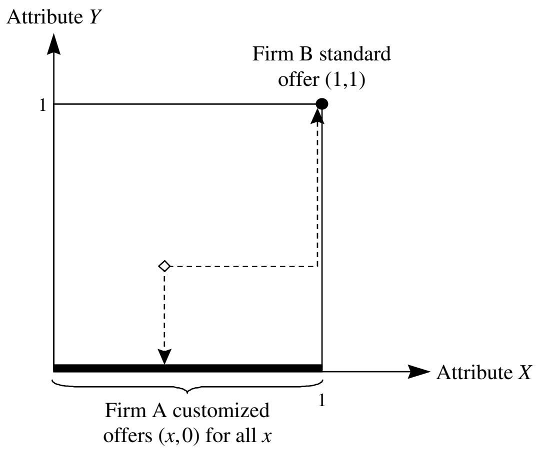
Each consumer has a maximum demand of one unit of the ideal product for which she has reservation value V, which we assume is large enough that all consumers buy the product from one of the firms. The effective reservation price (or gross utility before price) associated with Firm A's standard product for a consumer located at (x, y) is $U_A = V - x - y$. For Firm B's standard product, it is $U_B = V - (1-x) - (1-y)$. This utility uses the "city block" distance as a measure of how far a given consumer's ideal location is from the location of a firm, as seen in Figure 1. The city block metric is consistent with our assumption of independent attributes because the utility is additive in the two attributes (Anderson et al. 1992).

2.2. Customization and Consumer's Cost of Interaction

If a firm offers to customize an attribute, then it will provide a product that exactly matches a given consumer's ideal level of that attribute. In other words, if a firm customizes Attribute X, then it has a continuum of "virtual" products, with the typical one being $(x, 0)$.[1] As seen in Figure 2, if Firm A customizes

[1] The continuum assumption is for mathematical convenience, of course, but some firms offer this level of customization (paint colors

Figure 2 Partial vs. No Customization



Attribute X, then the loss in utility for a nonideal location is just the vertical distance; while for the standard location of Firm B, there is both a horizontal and vertical discrepancy from the ideal point.

To get the ideal level of the attribute, the consumers must interact with the firm, and this may be costly to the consumer. As a recent article in *Business Week* pointed out:

> One problem with customization is that it requires customers to do a lot of the initial legwork. That means filling out forms, picking choices, standing in scanning booths, and otherwise going through the hassle of helping manufacturers take the guesswork out of serving their needs. (*Business Week* 2000)

The "legwork" creates resistance to customization by consumers. In our paper, we highlight the critical role of consumers' interaction cost for customized products in the market. The interaction costs could include time diverted from other activities. Even after a consumer communicates her preferences to the firm, there can be delay in consumption as the manufacturer produces and delivers the customized product. This might go through multiple iterations before just the right product is provided to the consumer. There is also the extra cognitive burden of having to know preferences accurately enough to convey them to potential manufacturers, and there is the risk that a customized product might differ from the ideal.

Because we are not concerned with the exact nature of the costs or with what causes them, we lump all of them under the umbrella of *interaction cost*, which is denoted by z. Initially, we assume the interaction cost is the same for all consumers. We also assume that the interaction cost is proportional to the number of attributes that a consumer must describe; that is, if the consumer must interact with the seller for both X and Y, then the interaction cost is $2z$. If Firm A customizes Attribute X and offers a standard Attribute Y, then the consumer located at (x, y) has gross utility $U_A = V - z - y$. If the consumer cost of interaction is too high, then customization will not be offered; the critical threshold (as shown below) is $z = 1/2$, which is the discrepancy of the standard product for the average consumer's ideal level of a noncustomized attribute.

It is important to distinguish between two types of consumer input into customizing. First, consumers provide information that improves the quality of the product for all consumers (e.g., beta testers for software products or lead users). Second, consumers describe their personal tastes for attribute levels and features of a product. We analyze only the second type of consumer input, variety, setting aside the first, quality. In other words, we concentrate on horizontal rather than vertical product differentiation. Specifically, we do not model customization where more of an attribute is better.

This model presents a stylized version of the tradeoff that consumers face when they contemplate the purchase of customized products. On one hand, they can purchase the standard product and receive some disutility from not being able to get exactly what they want. On the other hand, they can purchase the customized product and get what they want, but they have to bear some cost of interacting with the firm.[2]

2.3. Customization Alternatives

The interaction among firms is analyzed as a two-stage game, where in the first stage firms choose the level of customization, and in the second stage the firms set prices and consumers make their product choice. In this section, we consider each of the customization options and outline the method of analysis of the second-stage price game. Details are found in Appendix A.

A consumer's input does not improve the product for anyone else but only brings the product closer to the consumer's ideal. As a result, we assume that firms operate in a regime of posted prices where all consumers see the same price for the customized product. The model deals exclusively with product customization, and assumes away customized pricing.[3] Moreover, to focus on strategic effects and to

can be mixed in any way the buyer wants). As mentioned above, some lipstick brands offer 48 different shades of red; continuity is a limiting case of such illustrations.

[2] Other consumer behaviors with customization are found in Huffman and Kahn (1998) and Liechty et al. (2001).

[3] This differentiates customization from a deep product line. Though each consumer gets a product tailored to his/her needs, all versions of the product have the same objective quality, so the firm posts an identical price for all customized products. Deep product-line assortment typically would involve different prices for different elements in the line. Later in the paper we relate our model to the work of Chen and Iyer (2002) on customized prices.

ensure that our results are not driven by costs, we assume the marginal cost of manufacturing each attribute is zero.

The analysis of the price equilibrium when there is no customization is very standard and we relegate the details to Appendix A. Both firms charge identical prices, which equal 1 in equilibrium, and split the market evenly. More interesting cases occur with customization.

We conceive of *complete customization* as a firm's decision to customize both attributes of the product and *partial customization* as its decision to customize only one of the two attributes. Because each firm can customize completely, partially, or not at all, our analysis must consider several strategic scenarios. When both firms offer partially customized products, two situations arise, depending on whether they customize different attributes—*differentiated partial customization*—or the same identical attribute—*matched partial customization*. We address the case of differentiated partial customization first.

Because like all analytical models the results of our analysis are also dependent on the assumptions made, we briefly summarize the critical assumptions made about firms, consumers, and the interactions between firms and between firms and consumers.

2.4. Discussion of Assumptions About Firms and Consumers

Our model assumes two symmetric Firms A and B that sell costless two-attribute products. To begin with the simplest scenario, both firms are put on a level playing field, and we defer to future research the analysis of markets with a dominant and a fringe firm. Our firms can offer neither attribute, one of the two attributes, or both the attributes as customized options. In this duopoly, there ought to be at least two attributes to allow each firm a unique strategy, and we limit the model to just two attributes for analytic convenience. To hold costs constant, the marginal cost of providing both standard products and customized options is assumed to be zero for all firms; our results are not sensitive to this cost assumption. When a firm customizes, we assume a continuum of products are available to take advantage of the mathematics of continuity. We assume the strategic decisions (customization) are made first, while the tactical decisions (price) are made subsequently; this is traditional in such models. Moreover, we assume simultaneous revelation of customization strategies by both firms, although leader-follower models could be explored in future research.

Consumers have heterogeneous and independent preferences for the two attributes. Ideal values of attributes are assumed to be distributed uniformly over the unit square $[0, 1] \times [0, 1]$, and all utility functions use the "city block" distance to measure of how far an ideal location is from a firm's product. This uniform distribution is standard in the literature on product differentiation employing the Hotelling (1929) framework because of its analytical tractability. Naturally, other specifications of consumer heterogeneity could yield different results; for example, Hauser and Shugan (1983) show that bimodal distributions of preference can result in dramatically different price responses of a defender brand. The city block metric implies that a consumer's valuation of one attribute is independent of the level of the other attribute. This is technically usefully because the market areas of the firms thus have linear boundaries, making the formulation of demand analytically straightforward. Finally, we assume that consumers have a homogeneous per-attribute cost of communicating their ideal attribute level.

2.5. Differentiated Partial Customization

Let Firm A customize Attribute X and Firm B customize the other Attribute Y. If Firm A charges p_A and Firm B charges p_B for their partially customized products, then the consumer at ideal point (x, y) will prefer Firm A to B if $V - z - y - p_A > V - z - (1-x) - p_B$, or equivalently $y < -x + 1 + p_B - p_A$. The market shares of the firms are shown graphically in Figure 3 under the assumption that Firm B has the lowest price. The line where $x + y = 1 + p_B - p_A$ is the collection of consumers for which the firms compete most vigorously. We refer to this as the combat zone.

This differentiated partial customization strategy makes the two firms more similar on average compared to no customization. For consumers with ideal points near the lower-right corner, the two firms offer almost identical products. As a result, the prices are driven lower than in the no-customization case (see Appendix A for details). Because both the firms and the attributes are symmetric, the equilibrium prices of both firms equal 1/2 and the market divides along the downward-sloping diagonal referred to as the combat zone in Figure 4. It is interesting to note that this is the same combat zone that occurs when neither firm customizes.

Figure 3 **Differentiated Partial Customization**

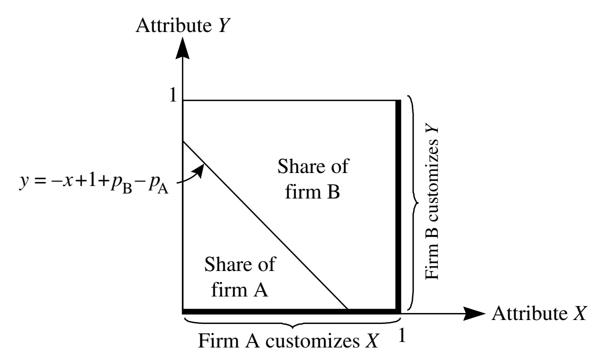
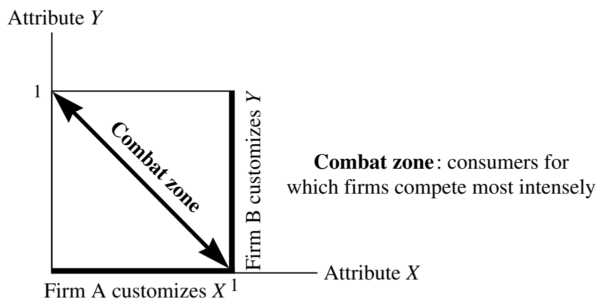


Figure 4 Combat Zone for Differentiated Partial Customization

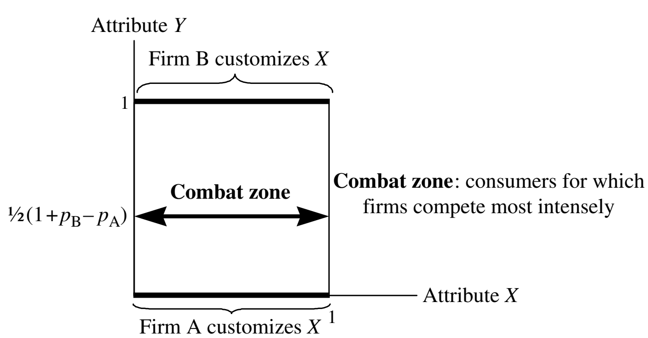


2.6. Matched Partial Customization

Now suppose both firms customize only Attribute X and offer Attribute Y with a standard feature. This is called "matched" customization because the firms select the same attribute. Consumers at (x, y) prefer Firm A to Firm B if $V - z - y - p_A > V - z - (1 - y) - p_B$, or equivalently, $y < (1 + p_B - p_A)/2$. Because both firms offer all consumers their customized ideal level of x, this no longer enters the calculation of which consumers pick Firm A. As seen in Figure 5, the combat zone is a horizontal line, involving only ideal levels of the standardized Attribute Y. The symmetry of the game implies that prices and market shares are identical in equilibrium.

From Figures 4 and 5 it is clear that the consumers that the two firms most vigorously compete for—the combat zone—is larger in the case where they customize different attributes: $\sqrt{2}$ as compared to 1. In differentiated partial customization, a price cut by a small amount brings in roughly 40% more consumers than under matched partial customization. This makes the firms more aggressive in their price competition under differentiated customization. Intuitively speaking, when firms customize the same attribute they compete on one front—the standardized attribute—rather than on both fronts. This intuition is made formal in Appendix A, where it is shown that the price for both matched customizing firms is 1 and they split the market in half along the horizontal line at 1/2.

Figure 5 Combat Zone for Matched Partial Customization



2.7. Complete Customization

If both firms customize completely, then all consumers can have their ideal product from either firm. The only way a firm can attract consumers is with price discounts, and the Bertrand equilibrium occurs where the prices are driven to cost, which in this model is 0. On the other hand, if only one firm offers complete customization, the analysis of the Nash equilibrium prices is somewhat more complicated, but straightforward. Details are provided in Appendix A.

3. Strategic Customization

Now that we have analyzed the pricing at the second stage of the game, let us step back to first-stage customization strategies. A firm can customize none of the product attributes (denoted by "None"), Attribute X, Attribute Y, or both attributes (denoted by "Both"). Detailed derivations of profits are in Appendix A, and the results are summarized in Figure 6.

3.1. Matched Partial Customization Is the Equilibrium for Low Interaction Cost

What is the Nash equilibrium in customization strategies? It depends on how costly it is for the consumer to specify the ideal level of an attribute to the firm. Obviously, if consumers find it very difficult to explain the exact type of attribute they want from

Figure 6 Customization Game with Interaction Costs

Cell entries: A's profit, B's profit / Firm A's customized attribute	Firm B's customized attribute: None	X	Y	Both
None	½,½	*	*	*
X	$\frac{1}{2}\left(\frac{7}{6}-\frac{z}{3}\right)^2$, $\frac{1}{2}\left(\frac{5}{6}+\frac{z}{3}\right)^2$	½,½	*	*
Y	$\frac{1}{2}\left(\frac{7}{6}-\frac{z}{3}\right)^2$, $\frac{1}{2}\left(\frac{5}{6}+\frac{z}{3}\right)^2$	¼,¼	½,½	*
Both	π_A, π_B	$\left(\frac{2-z}{3}\right)^2$, $\left(\frac{1+z}{3}\right)^2$	$\left(\frac{2-z}{3}\right)^2$, $\left(\frac{1+z}{3}\right)^2$	0,0

*The game is symmetric.
$\pi_A = ((\sqrt{z^2+2}+z)^3)/32 + (\sqrt{z^2+2}+z)/2 - 2z$, $\pi_B = ((\sqrt{z^2+2}+z)^3)/32$ when $z \le 1/2$, $\pi_A = ((\sqrt{(1-z)^2+2}+1-z)^3)/32$, $\pi_B = ((\sqrt{(1-z)^2+2}+1-z)^3)/32 + (\sqrt{(1-z)^2+2}+1-z)/2 - 2(1-z)$ when $z > 1/2$, where z is the consumers' cost of interaction.

a seller, customization is very unattractive. The consumers would be better off just accepting a nonideal product than dealing with the hassle of interacting with the firm. If interaction is cheap, what form of customization will be found in equilibrium?

Primary Theorem. *Consider two symmetric firms that have to decide whether and how much to customize before they choose their prices. Matched partial customization is the strategic Nash equilibrium if consumer interaction cost is low* ($z \le 1/2$), *and no customization is the Nash equilibrium if consumer interaction cost is large* ($z > 1/2$).

There are two (essentially identical) matched partial customization strategies, depending on which attribute is customized: $\langle X, X\rangle$ and $\langle Y, Y\rangle$. In §5.3 we discuss what determines which attribute is customized. If we suppose that the customized attribute is X, in Figure 6 the pair of strategies $\langle X, X\rangle$ is the matched partial customization equilibrium to be studied. Intuition for the theorem is given below; the proof is given in Appendix B.

A well-touted strategic principle advises firms to create a unique perceptual position in the minds of consumers. Should not Firm A switch from customizing the Attribute X to customizing Y to differentiate itself from its rival? Surprisingly, no. Recall that differentiated customization brings significantly more consumers into the combat zone, and this greatly intensifies price competition. Any consumer with identical ideal values for both attributes is a target for differentiated sellers, and there are 41% more of such consumers than ones with ideal value equal to 1/2 for the matched customized attribute strategy. The above principal presumes that unique perceptual positioning mitigates price competition, but in the customization game it doubles price elasticities and drives equilibrium prices down 50%. This is unprofitable.

Another way that Firm A could create a distinct perceptual position would be to drop its customization. However, if consumers find customization interaction easy to do, $z \le 1/2$, this is also unprofitable because scores of consumers will defect to Firm B, which continues to customize Attribute X. Even after discounting price to hold the losses in market share to a minimum, it is easily shown that profits for Firm A fall from 1/2 to $(1/2)(5/6 + z/3)^2$.

Finally, could Firm A benefit from uniquely expanding the customization program to include both Attributes X and Y, and thus attract a large number of consumers? The problem with this strategy is that it puts its rival in a desperate strait, because Firm A will be offering a personally ideal product to each consumer. The only weapon available to Firm B to defend its turf is price, and it must wield it with a vengeance, discounting its price between 33% and 66% depending upon the consumer interaction cost. This compels the complete customizer to mark down its prices between 33% and 50%, and even though Firm A's superior product strategy improves its market share from 50% to as much as 66%, its profits fall from 0.50 to between 0.25 and 0.44. Complete customization is not a good response to a rival's partial customization. Is complete customization ever profitable? We address this next.

3.2. Complete Customization Never Occurs in Equilibrium

Are we certain that there are no other equilibria when $z < 1/2$? Specifically, is the differentiated complete customization strategy $\langle \text{Both}, \text{None}\rangle$ an equilibrium of this game? In differentiated complete customization, one firm offers a uniformly superior assortment but the other firm remains "different but inferior" in the mind of the consumers. Consider Figure 7, which graphs the profits of Firm A as a function z for various customization strategies. The profit for Firm A with $\langle \text{Both}, \text{None}\rangle$ is highest only when the consumer interaction cost is very low, $z < 0.131$.

However, as seen in Figure 8, Firm B has an incentive to deviate from the strategy pair $\langle \text{Both}, \text{None}\rangle$ by adopting a partial customization strategy as long as $z < 1/2$. Therefore, for all values of per-unit consumer interaction cost, one or the other of the firms has an incentive to deviate from the differentiated complete customization strategy $\langle \text{Both}, \text{None}\rangle$.

We have already seen that complete customization is not the best reply to partial customization. Obviously, matched complete customization $\langle \text{Both}, \text{Both}\rangle$ cannot be a strategic equilibrium because it results in a disastrous Bertrand price war that dissipates all profits; a unilateral switch by either firm to any other strategy improves profits. In summary, complete customization of all attributes will never be observed in equilibrium.

Corollary. *If symmetric firms compete for consumers whose tastes are uniformly distributed, then complete*

Figure 7 **Profits of Firm A Against No Customization**

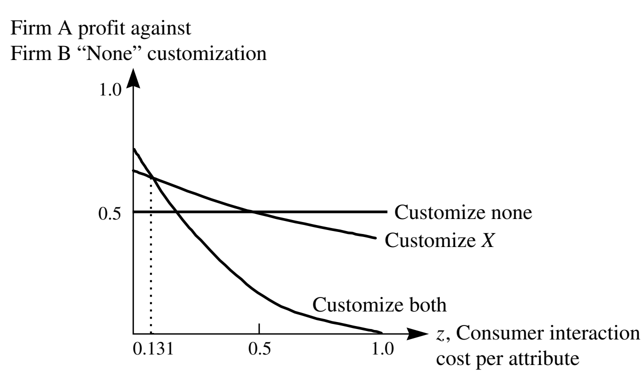
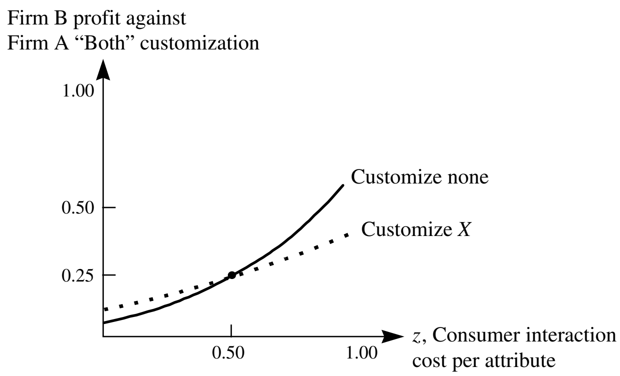


Figure 8 Profits of Firm B Against Complete Customization



customization of both attributes is never an equilibrium strategy in the customization game.

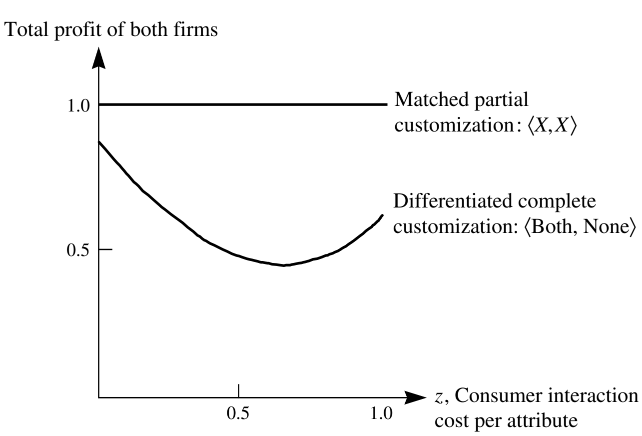
As seen in Figure 7, there are some values of consumer interaction costs such that one firm has higher profits with complete customization than with any other strategy, assuming that its rival is not customizing. Not only is this strategic situation not an equilibrium, but the total profits for both sellers is less than that obtained in the matched partial customization equilibrium (see Figure 9).

In differentiated complete customization, the firm with an inferior product assortment becomes an intense price discounter, and some profits are dissipated in the resulting price war. However, because all consumers buy the product, there is no loss in economic efficiency, and firm profits are merely transferred to consumer surplus, as we will analyze in §4.

3.3. Product Customization vs. Price Customization

Chen and Iyer (2002), Shaffer and Zhang (1995), Bester and Petrakis (1996), Villas-Boas (2003), and Fudenberg and Tirole (2000) have investigated customized pricing. In Chen and Iyer (2002), for example, firms endogenously choose the "addressability" of consumers, which is taken as a proxy for customized prices, and they find that it is not optimal for both firms to choose full addressability. In other words, just as these authors find that two competing firms are worse off choosing fully customized prices, we find that competing firms are worse off choosing fully customized products. However, the mechanisms (as reflected in equilibrium outcomes) by which firms pursue partial customization of prices in Chen and Iyer (2002) and the partial customization of products in our paper are very different and deserve careful consideration.

Figure 9 Total Profit of Both Firms



In their model, firms customize prices, a continuous variable, as compared to our model where firms make a discrete choice of which attribute(s) to customize. The most salient aspect of competing with discrete strategies, and one that is absent with continuous strategies, is the issue of whether it is desirable for the firms to coordinate on some "better" choices and, more interestingly, if there are any mechanisms that will allow them to do so. We are able to answer both these questions. Firms in our model not only choose partial customization over complete customization, they customize the same attribute.

Because in Chen and Iyer (2002) firms choose the extent of price customization in the first stage and also compete on prices in the second, enormous pressure is placed on a firm's pricing strategy. For low levels of consumer heterogeneity/product differentiation, firms face intense price competition, and thus differentiate themselves through an asymmetric choice of price customization. In our model, symmetric firms could adopt symmetric choices of product customization. Because they compete by choosing the degree of product customization in the first stage and price competition in the second, not too much pressure is placed on their pricing strategy, and firms are able to sustain a symmetric equilibrium in the first stage. Moreover, in Chen and Iyer the second-stage price equilibrium cannot exist in pure strategies, whereas we find a pure-strategy price equilibrium corresponding to every scenario of first-stage choice of customization.

The general finding in this literature is that customized pricing tends to intensify competition as firms' promotional efforts are simply neutralized by their rivals. While a complete extension of our model to include price discrimination is beyond the scope of this paper, one can easily see that this general finding is likely to reappear.

Specifically, suppose that the firms are committed to the differentiated partial customization $\langle X, Y\rangle$, where Firm A customizes Attribute X and Firm B customizes Attribute Y. Because the customers place an order for a specific value of x (or y), this allows the firm to charge different prices for different attribute levels. It is possible to show[4] that the Nash equilibrium two-part tariffs are

$$P_A = \tfrac{1}{2} - \tfrac{1}{2}(x-0) \quad \text{and} \quad P_B = \tfrac{1}{2} - \tfrac{1}{2}(1-y).$$

The price falls as the customized attribute moves away from its most distinct level (0 for X and 1 for Y). The intuition for this is that as x moves from 0 toward 1, A's customized product $(x, 0)$ approaches one of the many products offered by Firm B: $(1, 0)$. Hence, as x increases, the attractiveness of the rival firm rises and competitive prices must fall. Contrast this to differentiated partial customization with uniform prices ($P_A = 1/2 = P_B$). The prices are uniformly lower when price-customizing firms compete, and in equilibrium, the partially differentiated customizers divide the market in half as in Figure 4. Profits drop from the value 1/4 seen in Figure 6 to 1/6. This matches the general finding of other studies of price customization mentioned above.

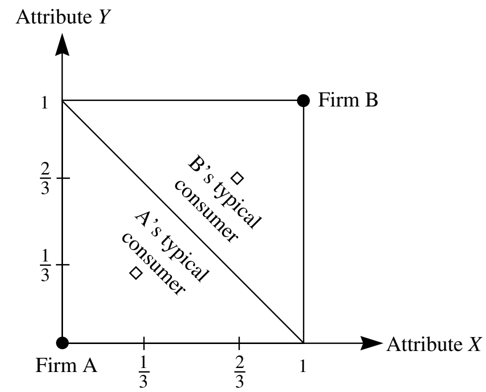
4. Consumer Surplus and Economic Welfare of Customization

Studies of economic benefits and costs of the provision of product variety date back over seventy years to the work of Hotelling (1929) and Chamberlin (1933). Our model assumes that firms can provide the most appropriate product variety at no cost, yet market forces lead to less than complete customization. Also, we assume that providing information to guide the design of the customized product is difficult for consumers. It is not at all clear that the marketing decisions of the firms correctly account for the consumers' cost of interacting with them. In this section, we analyze the costs and benefits of customization to all parties involved in the co-creation of product varieties.

Consumers' surplus and economic welfare can be most easily studied by identifying the "typical consumer." For example, when neither seller offers customization, $\langle\text{None}, \text{None}\rangle$, the consumers divide between the firms so that consumers in the lower triangle buy from Firm A and those in the upper triangle buy from Firm B (see Figure 10). The typical consumer in the lower triangle has an ideal vector $(1/3, 1/3)$, so her consumer surplus is $CS = V - 1/3 - 1/3 - p_A$. In equilibrium, both firms have a price of 1, so the total consumer surplus is $V - 5/3$.

The typical consumer in Figure 10 is also the typical consumer when the sellers use differentiated partial customization, $\langle X, Y\rangle$, because the market divides along the same diagonal (see Figure 4). The consumer

Figure 10 **Location of Typical Consumers**



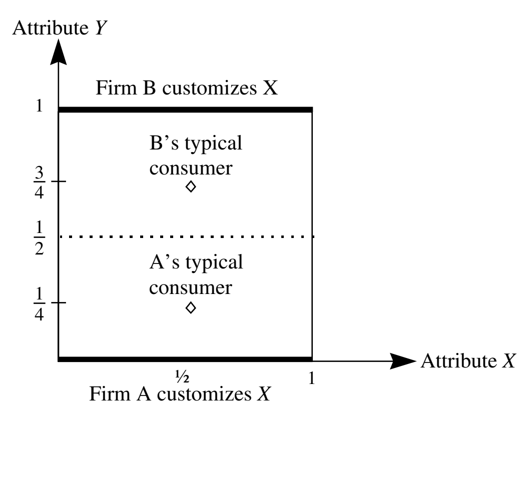
surplus is $CS = V - z - 1/3 - p_A$, and because the equilibrium price is 1/2, the total consumer surplus is $V - 5/6 - z$. In the strategic case $\langle X, X\rangle$, the typical consumer of Firm A has an ideal vector $(1/2, 1/4)$, as seen in Figure 11, so the typical consumer's surplus is $CS = V - 1/4 - z - p_A$. Because the equilibrium prices are 1, the total consumer surplus is $V - 5/4 - z$.

The computation of consumer surplus for the differentiated complete customization equilibrium $\langle\text{Both}, \text{None}\rangle$ is more complicated because it is not symmetric. As shown in Appendix C, the total consumer surplus is

$$V - 3\frac{\sqrt{z^2+2}+z}{4} + \frac{4}{3}\left(\frac{\sqrt{z^2+2}+z}{4}\right)^3.$$

As can be seen in Figure 12, in aggregate consumers would be better off with differentiated customization, either partial $\langle X, Y\rangle$ or complete $\langle\text{Both}, \text{None}\rangle$. This is because the consumers would benefit from the ideal attribute offering of the customizer, while getting very low prices from both sellers. Notice that when the consumers' cost of interaction is moderate, between 5/12 and 1/2, the market pressures lead to matched partial customization but this is the worst situation from consumers' perspective. In this range, even no customization is preferred by the buying public, because they can avoid substantial interaction costs.

Figure 11 **Typical Consumers for Matched Partial Customization**



[4] Details are available in a technical appendix found at http://mktsci.pubs.informs.org.

Figure 12 **Consumer Surplus**

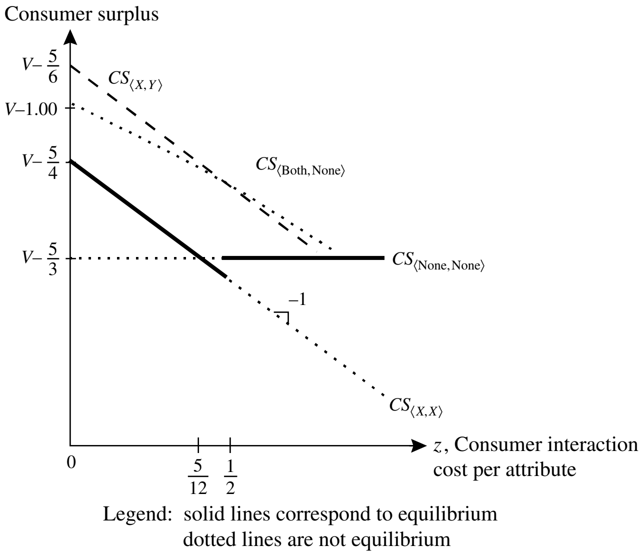
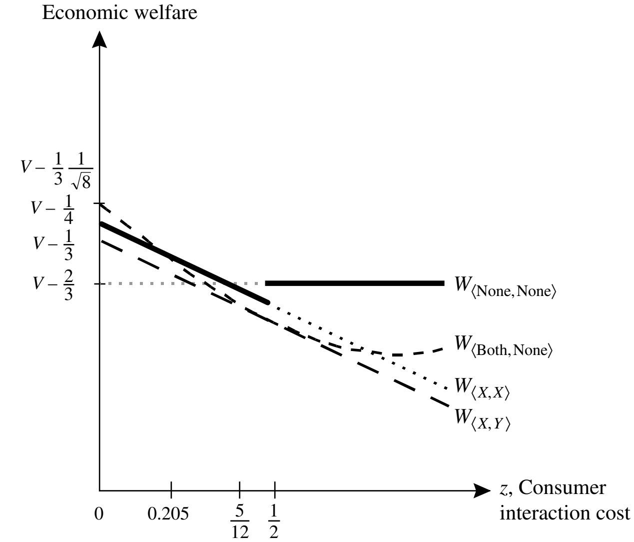


Figure 13 **Economic Welfare**



Consumer Surplus Theorem. (a) *Aggregate consumer surplus is always higher for differentiated customization* (*partial* ⟨X, Y⟩ *or complete* ⟨*Both, None*⟩) *compared to matched customization* (*partial* ⟨X, X⟩).

(b) *Comparing just matched strategies, if cost of interaction is very low, consumers prefer partial to no customization.*

(c) *At moderate levels of interaction costs, matched partial customization is the worst of all customization strategies for consumers, although it is the Nash equilibrium for firms.*

Perhaps the losses to consumers are transferred as gains to the owners of the firms. What is the total economic welfare, the sum of profits and consumer surplus? We have assumed that the valuation of the ideal product, V, is large enough that all consumers buy from either Firm A or B. Moreover, we have assumed that the cost of manufacturing the products is zero. As a result, transfers of money from the bank accounts of consumers to the bank accounts of the owners of the firms create no net wealth. This makes the computation of economic welfare simple in most strategic cases. For ⟨None, None⟩, the welfare is just $W = V - 2/3$, because the typical consumer gets a product that is less than ideal by an amount of 1/3 for each attribute. The welfare under matched partial customization ⟨X, X⟩ is also simple, $W = V - 1/4 - z$, because the consumer only has a nonideal attribute for one of the attributes and the discrepancy is 1/4 for the typical consumer; of course, the interaction cost must be accounted for, too. The case of differentiated partial customization ⟨X, Y⟩ is similar, but the average discrepancy is 1/3, so total welfare is $V - 1/3 - z$. The case of differentiated complete customization ⟨Both, None⟩ is more complex, but the economic welfare is

$$W = V - 2z - \frac{\sqrt{z^2+2}+z}{4} + \frac{16}{3}\left(\frac{\sqrt{z^2+2}+z}{4}\right)^3.$$

All four of these economic welfares are drawn as functions of the consumer interaction cost in Figure 13.

When the consumer cost of interaction is low, below $5/12 = 0.417$, some form of partial or complete customization is economically efficient compared to no customization, but it is entirely possible that the sellers match their partial customization because they are focusing only on their profits. Differentiated complete customization is better for the entire economy when consumer interaction costs are below 0.205. For values of z in the set $[0.205, 0.417] \cup [0.5, 1.0]$, the equilibrium strategies are economically efficient.

Economic Welfare Theorem. *Aggregate economic welfare* (*the sum of profits and consumer surplus*) *is maximized by the invisible hand of marketing for many values of consumer interaction costs, but for very low interaction costs and some moderate levels, the behavior of firms is economically inefficient.*

5. Variations on the Main Theme

In the following subsections, we consider variations on other aspects of the marketing environment and their influence on customization. Formal derivations are found in Appendix D.

5.1. Heterogeneity in Consumer Interaction Cost

Suppose that consumers are heterogeneous with respect to their interaction cost z. Let z be distributed uniformly on $[0, \theta]$. The optimal prices and profits in the ⟨None, None⟩, ⟨X, X⟩, and ⟨X, Y⟩ are unaffected by this change and are the same as in Figure 6. The derivation of optimal prices and profits for the ⟨X, None⟩, ⟨Both, X⟩, and ⟨Both, None⟩ cases are given in Appendix D. As in the case with a homogeneous interaction cost, here too we find that only a symmetric first-stage equilibrium involving partial customization can prevail, generalizing the Primary Theorem to heterogeneous interaction costs.

Result 1. Matched partial customization is the Nash equilibrium if consumer interaction cost heterogeneity is low ($\theta < 1$), and no customization is the Nash equilibrium if consumer interaction cost heterogeneity is large ($\theta > 1$).

5.2. Greater Heterogeneity in Consumer Preferences

Assume that consumer preferences for the ideal values of the two attributes are distributed uniformly over the general square $[0, d] \times [0, d]$, where the parameter d is not necessarily 1. The Primary Theorem can be generalized to account for the parameter d.

Result 2. Matched partial customization is the Nash equilibrium if consumer preference heterogeneity is high compared to interaction cost ($d/2 > z$), and no customization is the Nash equilibrium if consumer preference heterogeneity is low ($d/2 < z$).

That is, customization is more likely to occur when the consumers have greater diversity in opinions as to what constitutes the ideal product. It is worth noting that the profit without customization is the same as that with matched partial customization; both equal $d/2$. However, the only equilibrium for large preference heterogeneity is matched partial customization.

5.3. Different Attribute Heterogeneity

Assume the heterogeneity in consumer preferences for Attribute X is larger than that for Attribute Y. Specifically, let consumer preferences for Attributes X and Y be uniformly distributed on $[0, d]$ and $[0, k]$, respectively, where $d > k$. One can show that under matched partial customization of X, the prices of both firms equal k and the equilibrium profits are $k/2$. Matched partial customization of Y, strategy pair $\langle \mathrm{Y}, \mathrm{Y} \rangle$, yields higher prices and profits, d and $d/2$. Clearly, if firms have asymmetric attributes with different preference heterogeneities, they would like to conspire to customize the attribute with the *smaller* preference heterogeneity. There need not be conspiracy, for if k is less than 29% of d, the unique Nash equilibrium in the game is matched customization of the attribute with smaller preference heterogeneity.

Result 3. If the heterogeneity in consumers' preferences for one attribute is less than 29% of the other, then the unique Nash equilibrium is for both firms to customize the attribute with smaller heterogeneity. If the difference in heterogeneity is not too large, however, either attribute may be matched in Nash equilibrium. In all cases, the profits of the firms are higher when they both customize the less heterogeneous attribute.

This result is not intuitively obvious. If the ideal temperature comfort rating of sleeping bags is similar across the population, but there is wide disagreement between consumers on the ideal length of a sleeping bag, intuition might suggest (wrongly) it would be useful to customize length and offer a standard comfort rating. This seems to be a consumercentric tactic, but it ignores the competitive environment of the sellers. If both sellers customize the heterogeneous sleeping bag length, then they would only be distinguished in the minds of the consumers on their particular comfort ratings. By assumption, that distinction is not critical to the consumers, so the firms would be forced to fight for market share by vigorously discounting prices, and this price war is unprofitable. The Nash strategy that anticipates this price war is to offer customization for the relatively homogenous temperature comfort rating and to offer a standard but distinct sleeping bag length.

5.4. Products with Three Attributes

Our primary result that matched partial customization is the equilibrium strategy is not an artifact of having two attributes in the product. Consider a three-attribute product. Let consumer preferences for their ideal levels of three attributes W, X, and Y be uniformly distributed on the unit cube $[0, 1] \times [0, 1] \times [0, 1]$. There can be many partial customization scenarios, but consider the following matched partial customization scenario: Both firms customize X and Y and offer W at a standard level. If $V - 2z - w - p_{\mathrm{A}} > V - 2z - (1 - w) - p_{\mathrm{B}}$, then consumers prefer Firm A to B where z is the per-attribute interaction cost. The demands are exactly the same as the case $\langle \mathrm{X}, \mathrm{X} \rangle$ analyzed above and the optimal profits are 1/2 each. Suppose Firm B deviates by customizing X and W and offering Y as a standard feature. Then Firm A is preferred to B if $V - z - z - w - p_{\mathrm{A}} > V - z - (1 - y) - z - p_{\mathrm{B}}$. The demands are exactly the same as the case $\langle \mathrm{X}, \mathrm{Y} \rangle$ above and the optimal profits are 1/4 each. No firm will deviate from matched partial customization by switching one of the customized attributes for the standard attribute.

6. Conclusions

Our paper analyzes the market for customized products. We set aside the issue of cost of flexible manufacturing and price discrimination to focus on brand competition and consumers' cost of interacting with a customizing firm.

Surprisingly, we find that rival firms will customize only one attribute of a two-attribute product, and each firm will choose the same attribute. This is surprising in part because customizing, in our model, is costless, so it seems reasonable for firms to go all the way and engage in complete customization. If firms do not customize completely, then intuition might also suggest that firms actively differentiate themselves in the minds of consumers by customizing different attributes. These hunches fail to account for competitive forces and the number of consumers that are jointly targeted by both competitors.

Complete customization of all attributes will not persist in equilibrium because competition to be the leading one-to-one marketer leads to desperation on the part of the rival. This desperation takes the form of severe downward pressure on prices, which makes complete customization a fool's game for the firm. The only equilibrium in our model involves partial or no customization.

Because customization is partial at most, should not the firms pick different attributes to customize to avoid looking like twins in the minds of the shoppers? We find that the answer to this question is, "No." When firms choose to customize different attributes, then many consumers are indifferent between the two firms; they think, "I can have the perfect length of sleeping bag from L. L. Bean but I can have the perfect temperature comfort rating from REI, so I'll choose the one with the lower price." Had both firms provided the ideal level of a common attribute, fewer consumers would say, "I get the ideal length from either firm, and the REI has too low a temperature rating and L. L. Bean too high a temperature rating in equal amounts compared to my ideal, so I'll choose the one with the lower price." The elasticity of demand can be diminished and price wars pacified by customizing the same attribute.

Both these findings have obvious managerial insights for firms considering customizing their products in a competitive environment. In addition, extensions of our model provide managerial guidance of which attribute to customize. The trade literature has speculated that firms should identify attributes in which there are large differences in consumers' opinion of which variety is best and then customize that attribute. This does not account for competitive rivals in the market. We find that customizing an attribute without much consumer variegation in ideal levels is the best strategy because it mitigates the incentive to price discount. Ignoring this fact leads to unprofitable, and avoidable, price wars.

Our baseline model assumes that if a firm customizes an attribute, it does not offer a standard product because it is just one of the customized products. We do not assume that the firm has a preexisting standard product, but it would be worthwhile to analyze a model with competing firms offering both their standard and customized products. Such a model should also allow firms to endogenously determine the "degree of customization," which is interpreted as the fraction of meaningful attributes of the product that are customized. This is a considerably more complex model: There are four prices (for the standard and customized products of each firm) and the two degrees of customization (one for each firm). In addition, such a model will have to determine how the customized product cannibalizes sales of the standard product. We encourage others to study this interesting, but challenging problem. Furthermore, a detailed analysis of firms competing by customizing three-attribute products is also left for future research.

Finally, in addition to these managerial implications, our paper provides public policy findings on the well-being of consumers who co-create customized products by explaining in detail to the manufacturer precisely what they desire. Our paper incorporates the consumer cost of interaction as an important parameter. We find that consumers might be better off with customization than with standard goods, but generally the firms' choice to avoid complete customization leaves much consumer surplus on the table. The loss in consumer surplus is often captured by the firms, but for very low levels of consumer interaction costs and some moderate levels, the profit-driven behavior of customizer firms is economically inefficient.

Appendix A. Nash Equilibrium Prices and Profits

A.1. Customization Strategy $\langle \text{None}, \text{None} \rangle$, Both Firms Offer Two Standard Attributes

If Firm A charges p_A and Firm B charges p_B for their standard products, then the consumer with ideal attribute (x, y) will prefer Firm A's standard product over Firm B's standard product if $V - x - y - p_A > V - (1-x) - (1-y) - p_B$, or equivalently,

$$x + y < 1 + \frac{p_B - p_A}{2}.$$

The demand for Firm A is the consumers in the triangle bounded by the lines

$$x = 0, \quad y = 0, \quad \text{and} \quad y = -x + 1 + \frac{p_B - p_A}{2}$$

in the lower-left corner of Figure 14. Such a triangle has area $q_A = (2 - p_A + p_B)^2/8$. The rest of the consumers buy from Firm B, so $q_B = 1 - (2 - p_A + p_B)^2/8$. The first-order condition for the maximization of Firm A's profits

$$\pi_A = \frac{(2 - p_A + p_B)^2}{8} p_A$$

with respect to its price is

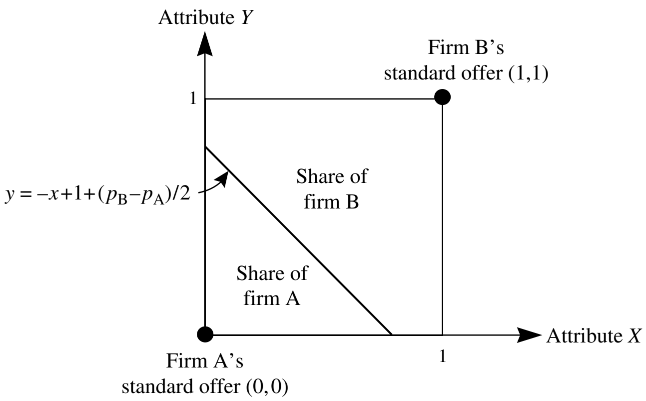
$$\frac{\partial \pi_A}{\partial p_A} = -\frac{(2 - p_A + p_B)}{4} p_A + \frac{(2 - p_A + p_B)^2}{8} = 0.$$

The corresponding first-order condition for Firm B is

$$\frac{\partial \pi_B}{\partial p_B} = 1 - \frac{(2 - p_A + p_B)^2}{8} - \frac{(2 - p_A + p_B)}{4} p_B = 0.$$

Simultaneously solving the two first-order conditions, the prices of the two firms are the same in the unique equilibrium and equal 1; the other solution has negative prices, $p_A = -0.5$ and $p_B = -3.5$. Because the demand divides evenly, the resulting profit for each firm is 1/2.

Figure 14 **Market Shares with No Customization**



A.2. Customization Strategy $\langle \mathrm{X}, \mathrm{X}\rangle$, Matched Partial Customization of Attribute X

Suppose both firms customize Attribute X and offer Attribute Y as standard. Consumers with interaction cost z will prefer Firm A to Firm B if $V - z - y - p_{\mathrm{A}} > V - z - (1-y) - p_{\mathrm{B}}$ or, equivalently, $y < (1 + p_{\mathrm{B}} - p_{\mathrm{A}})/2$. The number of consumers that satisfy this is $q_{\mathrm{A}} = (1 - p_{\mathrm{A}} + p_{\mathrm{B}})/2$, given the uniform distribution of ideal points. The price of Firm A that maximizes its profit $\pi_{\mathrm{A}} = [(1 - p_{\mathrm{A}} + p_{\mathrm{B}})/2]p_{\mathrm{A}}$ must satisfy the first-order condition

$$\frac{\partial \pi_{\mathrm{A}}}{\partial p_{\mathrm{A}}} = -\frac{1}{2}p_{\mathrm{A}} + \frac{1 - p_{\mathrm{A}} + p_{\mathrm{B}}}{2} = 0.$$

By simultaneously solving the two firm's first-order conditions, we obtain the unique common price for the firms as 1. Because the demand divides evenly, the resulting profit for each firm is 1/2.

A.3. Customization Strategy $\langle \mathrm{X}, \mathrm{Y}\rangle$, Differentiated Partial Customization

Suppose that Firm A customizes Attribute X and Firm B customizes Y. The consumer with ideal point (x, y) will prefer Firm A to B if $V - z - y - p_{\mathrm{A}} > V - z - (1-x) - p_{\mathrm{B}}$, or equivalently $y < -x + 1 + p_{\mathrm{B}} - p_{\mathrm{A}}$. The mathematical expression for the demand of Firm A illustrated in Figure 4 is $q_{\mathrm{A}} = (1 + p_{\mathrm{B}} - p_{\mathrm{A}})^2/2$. To maximize Firm A's profits $\pi_{\mathrm{A}} = [(1 - p_{\mathrm{A}} + p_{\mathrm{B}})^2/2]p_{\mathrm{A}}$ with respect to its price requires

$$\frac{\partial \pi_{\mathrm{A}}}{\partial p_{\mathrm{A}}} = -(1 - p_{\mathrm{A}} + p_{\mathrm{B}})p_{\mathrm{A}} + \frac{(1 - p_{\mathrm{A}} + p_{\mathrm{B}})^2}{2} = 0.$$

There is a corresponding first-order condition for Firm B. By simultaneously solving the two first-order conditions, the unique valid solution for the price is the same for the two firms and equals 1/2 in equilibrium (the other solution yields negative prices). Notice that this is lower than the prices when no customization is offered. Because the demand divides evenly, the resulting profit for each firm is $(1/2)(1/2) = 1/4$, which is less than when the firms differentiate themselves with standard products.

A.4. Customization Strategy $\langle \mathrm{X}, \mathrm{None}\rangle$, Partial Customization by A, Standardization by B

Suppose that Firm A customizes Attribute X and Firm B neither attribute. The consumer with ideal point (x, y) will prefer Firm A to B $V - z - y - p_{\mathrm{A}} > V - (1-x) - (1-y) - p_{\mathrm{B}}$ or equivalently

$$y < -\frac{x}{2} + 1 + \frac{p_{\mathrm{B}} - p_{\mathrm{A}} - z}{2}.$$

The demand for Firm A is the lower trapezoid in Figure 15, which equals

$$q_{\mathrm{A}} = \frac{3}{4} + \frac{p_{\mathrm{B}} - p_{\mathrm{A}} - z}{2}.$$

The demand for B is the upper trapezoid, which equals

$$q_{\mathrm{B}} = \frac{1}{4} - \frac{p_{\mathrm{B}} - p_{\mathrm{A}} - z}{2}.$$

The first-order condition for Firm A is

$$\frac{\partial \pi_{\mathrm{A}}}{\partial p_{\mathrm{A}}} = -\frac{1}{2}p_{\mathrm{A}} + \frac{3}{4} + \frac{p_{\mathrm{B}} - p_{\mathrm{A}} - z}{2} = 0,$$

and the first-order condition for Firm B is

$$\frac{\partial \pi_{\mathrm{B}}}{\partial p_{\mathrm{B}}} = -\frac{1}{2}p_{\mathrm{B}} + \frac{1}{4} - \frac{p_{\mathrm{B}} - p_{\mathrm{A}} - z}{2} = 0.$$

Solving the first-order conditions simultaneously gives the equilibrium prices

$$p_{\mathrm{A}} = \frac{7}{6} - \frac{z}{3} \quad \text{and} \quad p_{\mathrm{B}} = \frac{5}{6} + \frac{z}{3}.$$

Back substituting these into the profit functions gives equilibrium profits

$$\pi_{\mathrm{A}} = \frac{1}{2}\left(\frac{7}{6} - \frac{z}{3}\right)^2 \quad \text{and} \quad \pi_{\mathrm{B}} = \frac{1}{2}\left(\frac{5}{6} + \frac{z}{3}\right)^2.$$

A.5. Customization Strategy $\langle \mathrm{Both}, X\rangle$, Complete Customization by A, Partial Customization by B

Suppose that Firm A customizes both Attributes X and Y and Firm B customizes only Attribute X. Consumers will prefer Firm A to Firm B if $V - 2z - p_{\mathrm{A}} > V - z - (1-y) - p_{\mathrm{B}}$, or equivalently, $y < 1 - z + p_{\mathrm{B}} - p_{\mathrm{A}}$. The demand for A is $q_{\mathrm{A}} = 1 - z + p_{\mathrm{B}} - p_{\mathrm{A}}$, and for B is $q_{\mathrm{B}} = z - p_{\mathrm{B}} + p_{\mathrm{A}}$. The first-order condition for Firm A is

$$\frac{\partial \pi_{\mathrm{A}}}{\partial p_{\mathrm{A}}} = -p_{\mathrm{A}} + 1 + p_{\mathrm{B}} - p_{\mathrm{A}} - z = 0,$$

and the first-order condition for Firm B is

$$\frac{\partial \pi_{\mathrm{B}}}{\partial p_{\mathrm{B}}} = -p_{\mathrm{B}} + z - p_{\mathrm{B}} + p_{\mathrm{A}} = 0.$$

Solving the first-order conditions simultaneously, we get the equilibrium prices $p_{\mathrm{A}} = (2-z)/3$, $p_{\mathrm{B}} = (1+z)/3$. Back

Figure 15 **Market Shares with $\langle \mathbf{X}, \mathrm{None}\rangle$**

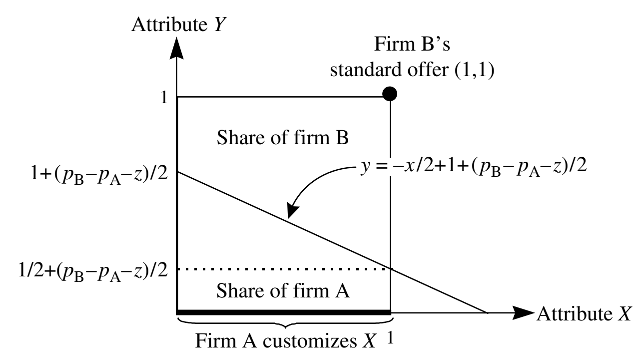
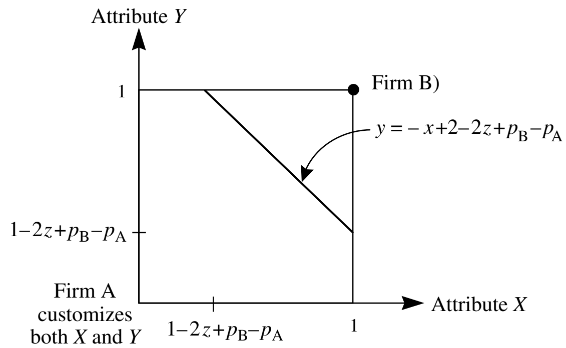


Figure 16 **Market Shares with** $\langle$Both, None$\rangle$



substituting gives equilibrium profits

$$\pi_A = \left(\frac{2-z}{3}\right)^2 \quad \text{and} \quad \pi_B = \left(\frac{1+z}{3}\right)^2.$$

A.6. Customization Strategy $\langle$Both, None$\rangle$, Complete Customization by A, Standard by B

Suppose that Firm A customizes both Attributes X and Y and Firm B customizes neither, and that $z < 1/2$. Consumers will purchase from Firm A if $V - 2z - p_A > V - (1-x) - (1-y) - p_B$ or equivalently $x + y < 2 - 2z + p_B - p_A$. The demand for Firm B come from the consumers in the upper-right triangle in Figure 16, $q_B = 0.5(2z + p_A - p_B)^2$, and demand for A is the residual $q_A = 1 - q_B$.

The first-order conditions for profit maximization are

$$\frac{\partial \pi_A}{\partial p_A} = 1 - 0.5(2z + p_A - p_B)^2 - (2z + p_A - p_B)p_A = 0,$$

$$\frac{\partial \pi_B}{\partial p_B} = 0.5(2z + p_A - p_B)^2 - (2z + p_A - p_B)p_B = 0.$$

Solving these for equilibrium prices gives

$$p_A = \frac{(3\sqrt{2+z^2} - 5z)}{4}, \quad \text{and} \quad p_B = \frac{(\sqrt{2+z^2} + z)}{4},$$

and equilibrium profits are

$$\pi_A = \frac{(\sqrt{z^2+2}+z)^3}{32} + \frac{\sqrt{z^2+2}+z}{2} - 2z, \qquad \pi_B = \frac{(\sqrt{z^2+2}+z)^3}{32}.$$

The analysis for the case $z > 1/2$ follows a similar pattern and is left to the reader.

Appendix B

Proof of Primary Theorem and Corollary. Consider deviations from $\langle$None, None$\rangle$. Firm A will not deviate to $\langle$X, None$\rangle$ or $\langle$Y, None$\rangle$ if

$$\frac{1}{2}\left(\frac{7}{6} - \frac{z}{3}\right)^2 < \frac{1}{2},$$

which holds if $z > 1/2$. Firm A will not deviate from $\langle$None, None$\rangle$ to $\langle$Both, None$\rangle$ if

$$\frac{(\sqrt{z^2+2}+z)^3}{32} + \frac{\sqrt{z^2+2}+z}{2} - 2z < \frac{1}{2}.$$

This is true for $z > 0.243$. So, when $z > 1/2$ the strategy pair $\langle$None, None$\rangle$ is a Nash equilibrium. Is it the unique Nash equilibrium in this scenario? The only other possibility for equilibria are $\langle$X, X$\rangle$, $\langle$X, Y$\rangle$, $\langle$Both, X$\rangle$, and $\langle$Both, Both$\rangle$. Consider each in sequence. $\langle$X, X$\rangle$ cannot be an equilibrium because when $z > 1/2$, then

$$\frac{1}{2}\left(\frac{5}{6} + \frac{z}{3}\right)^2 > \frac{1}{2},$$

and hence Firm B would defect to $\langle$X, None$\rangle$. $\langle$X, Y$\rangle$ cannot be an equilibrium because Firm B would defect to $\langle$X, X$\rangle$. $\langle$Both, X$\rangle$ cannot be an equilibrium because

$$\left(\frac{2-z}{3}\right)^2 < \frac{1}{2} \quad \text{for all } z < 1,$$

so Firm A would defect to $\langle$X, X$\rangle$. Finally, $\langle$Both, Both$\rangle$ cannot be an equilibrium because Firm B would defect to $\langle$Both, X$\rangle$, which results in positive profit. In summary, when the interaction cost exceeds one-half, $z > 1/2$, the "no-customization" strategy pair $\langle$None, None$\rangle$ is the unique Nash equilibrium.

Suppose instead that $z < 1/2$. The Nash equilibrium is either $\langle$X, X$\rangle$ or $\langle$Y, Y$\rangle$. We will analyze the former. If Firm A were to deviate from $\langle$X, X$\rangle$ to $\langle$Y, X$\rangle$, its profits would drop from 1/2 to 1/4, so that will not be done. Nor will Firm A deviate to $\langle$None, X$\rangle$ because its profits would drop to $(1/2)(5/6+z/3)^2$, which is less than 1/2 when $z < 1/2$. Finally, A would not deviate to $\langle$Both, X$\rangle$ because its profits would drop to $((2-z)/3)^2$, which are at most $4/9 < 1/2$. By symmetry, Firm B will not unilaterally deviate from the strategy pair $\langle$X, X$\rangle$, so it is a Nash equilibrium when $z < 1/2$.

Is the set of symmetric strategy pairs {$\langle$X, X$\rangle$ and $\langle$Y, Y$\rangle$} the only equilibria when $z < 1/2$? We need to check only that the pairs $\langle$None, None$\rangle$, $\langle$Both, None$\rangle$, and $\langle$Both, Both$\rangle$ are not equilibria; the others were eliminated from contention above. Consider them in sequence. We analyzed $\langle$None, None$\rangle$ previously, so recall that deviations to $\langle$X, None$\rangle$ are profitable when $z < 1/2$. In $\langle$Both, None$\rangle$, Firm B's profits are

$$\frac{(\sqrt{z^2+2}+z)^3}{32},$$

but if B defected to $\langle$Both, X$\rangle$ its profits would be $((1+z)/3)^2$. A little algebra shows that this defection is profitable as long as $z < 1/2$. Finally, $\langle$Both, Both$\rangle$ cannot be an equilibrium because any unilateral deviation produces positive profits. In summary, when $z < 1/2$, the only Nash equilibria are the matched partial customization pairs, $\langle$X, X$\rangle$ and $\langle$Y, Y$\rangle$.

Appendix C

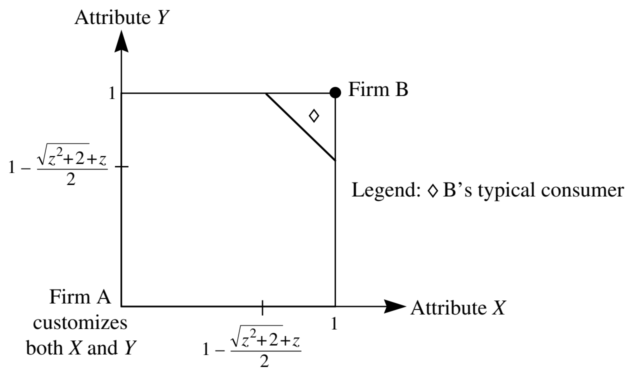
In Figure 17, Firm B with only a single standard product can only sell to consumers whose ideal vectors are in the triangle in the upper-right corner of the space (they buy Firm B's slightly inferior product because B's price is very low and their ideal attributes are close to B's offer). Using elementary properties of triangles, the average consumer of Firm B has an X-coordinate that is 1/3 of the way between the corner (1, 1) and the corner $(1 - (\sqrt{z^2+2}+z)/2, 1)$, and similarly for the Y-coordinate.

As a consequence, the typical consumer of Firm B has consumer surplus

$$V - \frac{7}{12}(\sqrt{z^2+2}+z).$$

All consumers of A take advantage of the complete customization offered by Firm A. Because they get their

Figure 17 **Typical Consumer for** $\langle$Both, None$\rangle$



personal ideal product from A, each one has a surplus $V-2z-p_A$ regardless of the specific value of their ideal vector. The market shares of A and B are

$$1-\frac{(\sqrt{z^2+2}+z)^2}{8} \quad \text{and} \quad \frac{(\sqrt{z^2+2}+z)^2}{8},$$

so the total consumer surplus is

$$V-3\frac{\sqrt{z^2+2}+z}{4}+\frac{4}{3}\left(\frac{\sqrt{z^2+2}+z}{4}\right)^3.$$

Appendix D

Proof of Result 1. We start by deriving optimal prices and profits for cases $\langle$X, None$\rangle$, $\langle$Both, X$\rangle$, and $\langle$Both, None$\rangle$ with heterogeneous interaction costs.

(a) *Derivation of Profits: Customization Strategy* $\langle$X, None$\rangle$, *A Customizes X, B Customizes None.* Consumers will prefer Firm A to Firm B if $V-z-y-p_A > V-(1-x)-(1-y)-p_B$. This implies that

$$y < -\frac{x}{2}+1+\frac{p_B-p_A-z}{2}.$$

The market divides similarly to in Figure 15. Because z is uniformly distributed on $[0,\theta]$, the demand for Firm A is

$$q_A=\int_0^\theta \frac{3-2p_A+2p_B-2z}{4}\frac{1}{\theta}\,dz,$$

where $1/\theta$ is the density of the uniform distribution. The demand for Firm A's product is

$$q_A=\frac{3}{4}-\frac{p_A-p_B+\theta/2}{2},$$

and the demand for B is $1-q_A$. The first-order condition for the optimal price of Firm A is

$$\frac{\partial\pi_A}{\partial p_A}=-\frac{1}{2}p_A+\frac{3}{4}+\frac{p_B-p_A-\theta/2}{2}=0,$$

and the first-order condition for Firm B is

$$\frac{\partial\pi_B}{\partial p_B}=-\frac{1}{2}p_B+\frac{1}{4}-\frac{p_B-p_A-\theta/2}{2}=0.$$

Solving the first-order conditions simultaneously gives the equilibrium prices

$$p_A=\frac{7-\theta}{6} \quad \text{and} \quad p_B=\frac{5+\theta}{6}.$$

Back substituting these into the profit functions gives equilibrium profits

$$\pi_A=\frac{1}{2}\left(\frac{7-\theta}{6}\right)^2 \quad \text{and} \quad \pi_B=\frac{1}{2}\left(\frac{5+\theta}{6}\right)^2.$$

(b) *Derivation of Profits: Customization Strategy* $\langle$*Both*, X$\rangle$, *A Customizes Both, B Customizes X.* Consumers will prefer Firm A to Firm B if $V-2z-p_A > V-z-(1-y)-p_B$, or $y<1-z+p_B-p_A$. The demand for A is

$$q_A=\int_0^\theta (1-z+p_B-p_A)\frac{1}{\theta}\,dz=(1+p_B-p_A)-\frac{\theta}{2}$$

and for B is $q_B=1-q_A$. The first-order condition for Firm A is

$$\frac{\partial\pi_A}{\partial p_A}=-p_A+1+p_B-p_A-\frac{\theta}{2}=0,$$

and the first-order condition for Firm B is

$$\frac{\partial\pi_B}{\partial p_B}=-p_B+\frac{\theta}{2}-p_B+p_A=0.$$

Solving the first-order conditions simultaneously, we get the equilibrium prices $p_A=(4-\theta)/6$, $p_B=(2+\theta)/6$. Back substituting gives equilibrium profits

$$\pi_A=\left(\frac{4-\theta}{6}\right)^2 \quad \text{and} \quad \pi_B=\left(\frac{2+\theta}{6}\right)^2.$$

(c) *Derivation of Profits: Customization Strategy* $\langle$*Both*, *None*$\rangle$, *A Customizes Both, B None.* Consumers will purchase from Firm A if $V-2z-p_A > V-(1-x)-(1-y)-p_B$ or $y<-x+2-2z+p_B-p_A$. Because z is uniformly distributed on $[0,\theta]$, the demand for Firm A is

$$q_A=\int_0^\theta \frac{(p_A-p_B+2z)^2}{2}\frac{1}{\theta}\,dz.$$

The demand for Firm B come from the consumers in the upper-right triangle as in Figure 16, $q_B=0.5(\theta+p_A-p_B)^2$ and demand for A is the residual $q_A=1-q_B$. The first-order conditions for profit maximization are

$$\frac{\partial\pi_A}{\partial p_A}=1-0.5(\theta+p_A-p_B)^2-(\theta+p_A-p_B)p_A=0, \quad \text{and}$$
$$\frac{\partial\pi_B}{\partial p_B}=0.5(\theta+p_A-p_B)^2-(\theta+p_A-p_B)p_B=0.$$

Solving these for equilibrium prices gives

$$p_A=\frac{3\sqrt{2+(\theta/2)^2}-5\theta/2}{4}, \quad \text{and} \quad p_B=\frac{\sqrt{2+(\theta/2)^2}+\theta/2}{4},$$

and equilibrium profits are

$$\pi_A=\frac{\left(\sqrt{(\theta/2)^2+2}+\theta/2\right)^3}{32}+\frac{\sqrt{(\theta/2)^2+2}+\theta/2}{2}-2z,$$
$$\pi_B=\frac{\left(\sqrt{(\theta/2)^2+2}+\theta/2\right)^3}{32}.$$

Equilibrium. From the derivations above, we can see that the formulas for profits with heterogeneous interaction costs are almost identical to those when interaction cost is a single value: The symbol z has been replaced by $\theta/2$. Thus, all the mathematics of Appendix B applies with that change of variable. In particular, if $\theta > 1$, then the Nash equilibrium is $\langle \text{None}, \text{None} \rangle$ and when $\theta < 1$ the equilibria are $\langle \text{X}, \text{X} \rangle$ or $\langle \text{Y}, \text{Y} \rangle$.

Proof of Results 2 and 3. Consider the general case on the rectangle $[0, d] \times [0, k]$, where $d > k$.

The derivation of equilibrium prices and profits shown in Figure 18 follows the process in Appendix A. When $k = d$, the game matrix in Figure 18 becomes symmetric. It is easy to show that if $z < d/2$, then

$$\frac{d}{2} < \frac{1}{2d}\left(\frac{7}{6}d - \frac{z}{3}\right)^2,$$

and firms will switch customization from None to X, leading to matched partial customization in equilibrium, as stated in Result 2.

It is possible to show that when $2z < d$ and $k/d < 7 - 3\sqrt{5} \approx 0.29$, the unique Nash equilibrium in this game is $\langle \text{Y}, \text{Y} \rangle$, where the firms match customization on the attribute with the least consumer heterogeneity. We will not demonstrate Result 3 completely because the method is similar to that of Appendix B, but to give a flavor of the analysis, let us show that $\langle \text{X}, \text{X} \rangle$ is not an equilibrium. If Firm A deviated to $\langle \text{Y}, \text{X} \rangle$, then its profits would change from $k/2$ to

$$d\left(\frac{1}{3} + \frac{1}{6}\frac{k}{d}\right)^2.$$

This deviation is profitable if

$$\left(2 + \frac{k}{d}\right)^2 > 18\frac{k}{d}, \quad \text{or} \quad \left(7 - \frac{k}{d}\right)^2 > 45,$$

so under the assumption that $k/d < 7 - 3\sqrt{5} \approx 0.29$, it is in the self-interest of Firm A to deviate to a customization of the attribute with less consumer heterogeneity, Attribute Y.

Figure 18 Customization Game with Different Heterogeneities

Cell entries: A's profit, B's profit

Firm B's customized attribute

Firm A's customized attribute	None	X	Y	Both
None	$d/2, d/2$	*	*	*
X	$\frac{1}{2k}\left(\frac{6k+d}{6} - \frac{z}{3}\right)^2$, $\frac{1}{2k}\left(\frac{6k-d}{6} + \frac{z}{3}\right)^2$	$k/2, k/2$	*	*
Y	$\frac{1}{2d}\left(\frac{6d+k}{6} - \frac{z}{3}\right)^2$, $\frac{1}{2d}\left(\frac{6d-k}{6} + \frac{z}{3}\right)^2$	$d\left(\frac{1}{3} + \frac{1}{6}\frac{k}{d}\right)^2$, $d\left(\frac{2}{3} - \frac{1}{6}\frac{k}{d}\right)^2$	$d/2, d/2$	*
Both	π_A, π_B	$\frac{1}{k}\left(\frac{2k-z}{3}\right)^2$, $\frac{1}{k}\left(\frac{k+z}{3}\right)^2$	$\frac{1}{d}\left(\frac{2d-z}{3}\right)^2$, $\frac{1}{d}\left(\frac{d+z}{3}\right)^2$	0,0

* The game is symmetric.
$\pi_A = (1/dk)((\sqrt{z^2 + 2dk} + z)^3)/32 + ((\sqrt{z^2 + 2dk} + z2)/2) - 2z$,
$\pi_B = (1/dk)((\sqrt{z^2 + 2dk} + z)^3)/32$
when $z < k - d/2$, where z is the consumers' cost of interaction. We assume that $d > k$.

References

Anderson, Simon P., Andre de Palma, Jacques-Francois Thisse. 1992. *Discrete Choice Theory of Product Differentiation*. MIT Press, Cambridge, MA and London, England.

Ansari, A., Nicholas Economides, Joel Steckel. 1998. The max-min-min principle of product differentiation. *J. Regional Sci.* **38**(2) 207–230.

Ben-Akiva, Moshe, Andre de Palma, Jacques-Francois Thisse. 1989. Spatial competition with differentiated products. *Regional Sci. Urban Econom.* **19** 5–19.

Bester, H., E. Petrakis. 1996. Coupons and oligopolistic price discrimination. *Internat. J. Indust. Organ.* **14** 227–242.

Business Week. 2000. Customizing for the masses (March 20), 130.

Chamberlin, Edward. 1933. *The Theory of Monopolistic Competition*. Harvard University Press, Cambridge, MA.

Chen, Yuxin, Ganesh Iyer. 2002. Consumer addressability and customized pricing. *Marketing Sci.* **21**(2) 197–208.

Dewan, Rajiv, Bing Jing, Abraham Seidmann. 2003. Product customization and price competition on the Internet. *Management Sci.* **49**(8) 1055–1071.

Fournier, Susan, Susan Dobscha, David Glen Mick. 1998. Preventing the premature death of relationship marketing. *Harvard Bus. Rev.* **76**(1) 42–44.

Fudenberg, Drew, Jean Tirole. 2000. Customer poaching and brand switching. *RAND J. Econom.* **31**(4) 634–657.

Gillenson, M. L., D. L. Sherrell, L. Chen. 1999. Information technology as the enabler of one-to-one marketing. *Comm. Assoc. Inform. Systems* **2**(September) 18.

Hauser, John R., Steven Shugan. 1983. Defensive marketing strategies. *Marketing Sci.* **2**(4) 319–360.

Hotelling, Harold. 1929. Stability in competition. *Econom. J.* **39**(15) 41–57.

Huffman, C., Barbara Kahn. 1998. Variety for sale: Mass customization or mass confusion. *J. Retailing* **74**(4) 491–513.

Liechty, J., Venkatram Ramaswamy, Steven H. Cohen. 2001. Choice menus for mass customization: An experimental approach for analyzing customer demand with an application to a Web-based information service. *J. Marketing Res.* **38** 183–196.

Liu, Yong, Daniel Putler, Charles Weinberg. 2004. Is having more channels really better? A model of competition among commercial television broadcasters. *Marketing Sci.* **23**(1) 120–133.

Moorthy, Sridhar. 1993. Theoretical modeling in marketing. *J. Marketing* **57**(April) 92–106.

Nicholas, John M. 1998. *Competitive Manufacturing Management: Continuous Improvement, Lean Production, Consumer-Focused Quality*. McGraw Hill, New York.

Peppers, Don, Martha Rogers, Bob Dorf. 1999. Is your company ready for one-to-one marketing? *Harvard Bus. Rev.* **77**(1) 151–160.

Pine, Joseph B., James H. Gilmore. 2000. *Markets of One: Creating Customer-Unique Value Through Mass Customization*. HBS Press, Boston, MA.

Shaffer, Greg, John Zhang. 1995. Competitive coupon targeting. *Marketing Sci.* **14**(4) 395–416.

Villas-Boas, J. Miguel. 2003. Price cycles in markets with customer recognition. *RAND J. Econom.* **35**(3) 486–501.

Wayland, Robert E., Paul M. Cole. 1998. *Customer Connections: New Strategies for Growth*. Harvard Business School Press, Boston, MA.

Wind, Jerry, Arvind Rangaswamy. 2001. Customerization: The next revolution in mass customization. *J. Interactive Marketing* **15**(1) 13–32.

Zhang, Jie, Lakshman Krishnamurthi. 2004. Customizing promotions in online stores. *Marketing Sci.* **23**(4) 561–578.