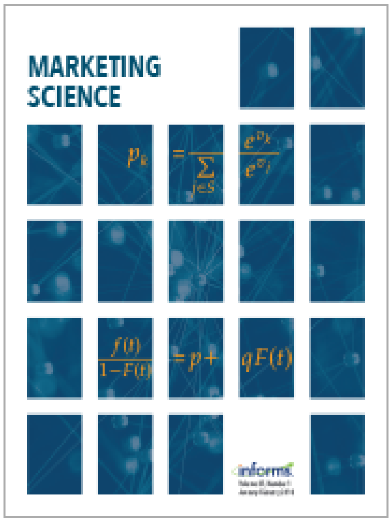

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Nan Xia, S. Rajagopalan,

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Standard vs. Custom Products: Variety, Lead Time, and Price Competition

Nan Xia
Lubar School of Business, University of Wisconsin–Milwaukee,
Milwaukee, Wisconsin 53201, nan.xia.2008@marshall.usc.edu

S. Rajagopalan
Marshall School of Business, University of Southern California,
Los Angeles, California 90089, raj@marshall.usc.edu

In this paper, we study the standardization and customization decisions of two firms in a competitive setting, along with variety, lead time, and price decisions. We incorporate consumer heterogeneity both in firm preference (or store convenience) and in product attribute preferences. We find that the equilibrium outcome depends on the cost efficiencies of the production technologies as well as the consumer sensitivity to product fit and lead time. We develop an index that signifies the relative attractiveness of the standardization and customization strategies, and the potential outcomes. We identify the strategic roles of product variety and lead time in the competition. In contrast to the previous literature, we find that increasing the variety will not intensify the price competition if there is sufficient firm differentiation. Rather, it relieves the price pressure for the firm as it satisfies consumer needs better and enables higher price premiums. We also analyze the impact of asymmetric variable costs, fixed costs, and brand reputation on the equilibrium decisions.

Key words: customization; product differentiation; product variety; competition
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1. Introduction

For the past few decades, there has been an explosion of choices in almost every product category. Furthermore, an increasing number of firms have started making custom products to better meet customers' needs and tastes, competing against traditional firms offering standard products. Examples range from customized footwear (NIKEiD, Digitoe) and apparel (Lands' End) to custom watches (Timissimo). Mass customization has been touted as the next wave and the Holy Grail of manufacturing (Pine 1993), leading to the demise of mass production as a means to meet the growing demand for product variety. Wind and Rangaswamy (2001) point out that many products are being customized, and they offer the notion of "customerization" wherein customers help customize the products by exploiting the power of the Internet. Zipkin (2001), on the other hand, argues that mass customization may not work for many product categories and provides several examples to substantiate his assertion. Huffman and Kahn (1998) point out that increased customization may lead to a confusing set of choices for the consumer and has to be carefully managed.

Two forces seem to be at work here. One is a demand pull—the need for firms to maintain or increase their market share by better meeting customer preferences for various product attributes. Second is a supply push—the ability of firms to offer increased variety without significantly increasing their costs because of more flexible manufacturing capabilities and distribution channels. As the capabilities of firms to fine-tune their products to meet consumer preferences improve, the question that arises is this: Are we more likely to see firms meeting consumer demand for increased variety and personalization by offering several standard products or by offering custom products as claimed by the mass customization advocates?

Let us consider some anecdotal evidence. In many product categories, only standard products are offered—for example, TVs, breakfast cereals, and cameras—whereas only custom products are offered in others, for example—airplanes or industrial products such as tools, dies, etc. The website http://www.madeforone.com provides many instances of existing and new customized products and services. There are a few industries where both custom and standard products are offered, e.g., apparel and furniture, but the proportion of custom product sales is typically small. Sales of catalog apparel retailers, e.g., Lands' End, are only 3%–4% of retail store apparel sales (U.S. Census Bureau 2005), even assuming catalog retailers' entire sales represent custom products, which is not the case. Overall, one finds only a few industries wherein both standard and custom products enjoy substantial market shares. (An example is the personal computer (PC) industry, where Dell has won a large share of the market by offering customized PCs.) This is partly due to key differences in the production process for custom versus standard products (Zipkin 2001) as well as the extent to which consumers care about customization.

As we point out in the next section, because the emergence of mass customization is recent, there have been only a few academic works on this topic. In this paper, we consider a duopoly wherein both firms have the choice of offering either standard or custom products and address the following questions:[1] First, under what market conditions is it profitable for firms to offer custom versus standard products? In equilibrium, will firms always pursue the same product strategies? If it is better to offer standard products, what is the optimal variety to provide and how is it related to market characteristics? When it is optimal to offer custom products, what is the optimal lead time that should be quoted? Finally, what are the effects of product variety and lead time on the market shares and prices?

To address these questions, we construct a game-theoretic duopoly model, where customers are heterogeneous in firm and product preferences. Firms will first choose between providing a limited number of standard products, which do not meet customers' product attribute preferences exactly but are available immediately, and custom products, which meet product attribute preferences exactly but are available only after a certain lead time. Depending on the product-type decisions, the firms then determine variety and lead time and finally set prices. The paper offers several interesting insights. First, we find that in equilibrium the dominance of a product-type strategy depends on its cost efficiencies on the supply side and the attractiveness on the demand side. Specifically, we develop an index for customization and for standardization based on costs and demand sensitivity, and the product strategy that has a smaller index value is the strategic choice of both firms. Second, variety and lead time can influence a consumer's choice of the competing firms. Increasing the variety for standard products or shortening the lead time for custom products can boost the sales and margin with decreasing returns. As a consequence, when the production technology becomes more cost efficient, the firm will be able to provide a larger variety or shorter lead time. Furthermore, in contrast to the previous literature, we find that increasing the variety will not intensify the price competition if there is sufficient firm differentiation. Rather, it relieves the price pressure for the firm as it satisfies consumer needs better and enables higher price premiums. We also find that brand reputation does not affect the product strategy, but a firm with a higher reputation will offer a larger variety or shorter lead time to exploit the consumer surplus and enjoy higher prices and margins.

The remainder of this paper is organized as follows. In the next section, we review the related literature. In §3, we present our model and characterize the equilibrium strategies in terms of production technology, variety, lead time, and prices. In §4, we further analyze the impact of asymmetric variable costs, fixed costs, and brand reputation on the equilibrium strategies. We present our conclusions in §5. All proofs can be found in the appendix.

2. Literature Review

The academic literature in mass customization is sparse but draws upon the literature in product differentiation, specifically, spatial and horizontal differentiation, and can be found in economics, marketing, and management science journals. The product differentiation literature (Gabszewicz and Thisse 1992) is primarily based on Hotelling's (1929) model in which two firms compete in location and price within a linear city. Lancaster (1990) gives a full review of product variety under different market structures. More recent surveys of product differentiation models include Manez and Waterson (2001) and Anderson (2008). Some key ideas from these surveys are that price competition becomes more intense when transport costs become more convex and price discrimination is allowed. Also, firms tend to offer less variety to reduce the intensity of price competition (Martinez-Giralt and Neven 1988). Shugan (1989) explores when and why premium quality producers may provide a smaller assortment than lower quality producers. Our work is broadly related to these works and we discuss these linkages when we present our results, but our focus is on standardization versus customization and not just product variety.

There is also a popular literature focusing on mass customization as a new business strategy (Pine 1993 and Kotler 1989). Mass customization was proposed as a means to offer customers exactly what they desire, with low costs achieved through flexible manufacturing and process technologies (Pine 1993). Piller and Tseng (2003) provide numerous examples of mass customization and personalization strategies by companies such as Procter & Gamble, Lego, Adidas, Lands' End, and BMW. Zipkin (2001) points out that production technologies in many industries may not be cost-effective or flexible enough to achieve mass customization.

[1] Henceforth, we use "production technology," "product type," and "product strategy" interchangeably to refer to the choice of standardization or customization.

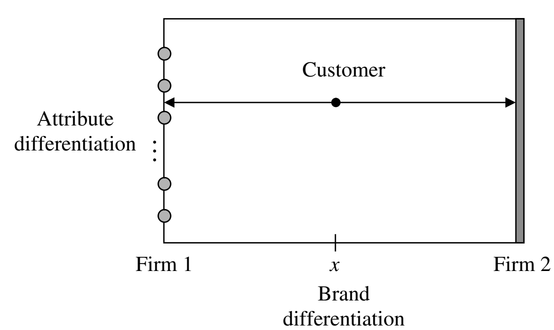
We now review the literature in product customization more closely related to our model, i.e., the ones that deal with the interaction of standard products with custom products. Balasubramanian (1998) considers a model with a direct marketer (who could be seen as a customizer) competing with multiple retailers who are evenly distributed on a circle and develop several interesting results on the price equilibrium and the impact of the direct marketer's entry. Dewan et al. (2003) develop a model of product customization on a circle where the firm chooses a customization scope (an arc segment) with two standard products at the end of the customization scope. In a duopoly, customization reduces the differentiation between the firms' standard products and the firms are worse off compared to a monopolist. When the firms adopt customization sequentially, the early adopter achieves an advantage and may be able to deter subsequent entry by strategically choosing its customization scope. Alptekinoğlu and Corbett (2008) study the competition between a mass customizer offering custom products and a mass producer offering several standard products. They show that the mass producer can survive the competition even if it has a small cost disadvantage. Mendelson and Parlakturk (2005) consider a similar setup, but they model inventory costs for the standard product firm and show conditions that favor customization. Our paper differs from the above papers in several respects: First, we incorporate the disutility of lead time for custom products and allow the custom product firm to choose the lead time—a shorter lead time attracts more customers but incurs a higher cost. More important, we allow each firm to choose either strategy—mass production or mass customization—instead of assuming that one firm adopts mass production and the other adopts mass customization. Finally, we allow for heterogeneity in the preference of consumers for the two firms. These key differences result in interesting new insights, as will be clear later.

Syam et al. (2005) explore the appropriate level of customization in a duopoly setting, where each firm offers one standard product and has to choose whether and which attribute to customize in a two-dimensional attribute space and determine prices. They find that in equilibrium, firms either do not customize or customize along only one and the same attribute. Syam and Kumar (2006) explore similar decisions in a different setup: duopolists can choose the fraction of attributes to customize and there are two consumer segments with different sensitivities to customization. They find that when firms offer custom products, they also offer a standard product and tend to offer partial rather than full customization to reduce price competition. Furthermore, the degree of customization is lower when *both* firms offer customized products. Syam et al. (2008) present an interesting model that blends ideas of uncertain consumer preferences about an ideal product attribute with regret to determine the optimal consumer choice between customized and standard products. They find that when consumers are likely to have high regret levels, they are likely to choose a standard product. Also, the presence of two standard products rather than only one may increase the attractiveness of a custom product. The focus of our work is different, as we model variety and lead time decisions rather than attributes for customization or uncertain consumer preferences or regret. Second, we allow the firm to decide the number of standard products to offer, as is often observed in consumer products such as jeans or cosmetics. Third, we model the lead time decision for custom products because custom products typically require long lead times, and this is a potentially significant drawback of custom products in the minds of consumers (Ahlstrom and Westbrook 1999). Finally, we allow each firm to offer standard or custom products but not both, while they assume that both firms offer *one* standard product and can decide whether to offer a custom product. Our model results in several new insights on the impact of variety and lead time.

3. Model Formulation

We consider a duopoly with two symmetric firms competing with each other for the M customers. The customers are distributed in a rectangular product space with Firm 1's products located at the left end, denoted by $x = 0$, and Firm 2's products at the right end, denoted by $x = 1$ (Figure 1). Each consumer is identified by a point that represents her ideal product and has a unitary demand. The location on the horizontal axis represents the preference for a firm while the vertical axis represents differentiation along a product attribute. For example, if the product category is running shoes, foot size may represent differentiation along the vertical axis while location on the horizontal axis may reflect relative preference for Nike versus Adidas. To make the model tractable and

Figure 1 Product and Customer Space Where Firm 1 Offers Standard Products and Firm 2 Offers Custom Products



focus on product-type decisions, we assume that customers are uniformly distributed along both dimensions. However, the insights obtained extend to the case of other random distributions of customer preferences. A firm may offer standard or custom products. A standard product is available immediately but may not meet the customer's product attribute preference perfectly, while a custom product meets the product attribute preference exactly but is available only after a certain lead time l_i. If a firm i decides to offer standard products, it offers n_i products that are evenly distributed in the product attribute space. If it decides to offer custom products, it offers essentially an infinite number of products targeted at each customer and it has to specify a lead time l_i. The utility for a consumer of getting her ideal product is U and is the same for all consumers.

Suppose Firm 1 offers n_1 standard products at a price p_1. For a customer at location x along the horizontal axis, the net utility of purchasing a standard product from Firm 1 is denoted by $(U - tx - d/n_1 - p_1)$. Note that tx is the loss of utility because of the "distance" of a consumer at x from Firm 1, and t represents the "transportation cost" or the intensity of relative preference for a firm. Thus, higher values of t imply greater firm loyalty and so a customer "closer" to Firm 1 will require a larger price differential to switch to Firm 2's products. The term d/n_1 represents the loss of utility from getting a standard product that does not meet the consumer's product preference exactly.[2] d, the product misfit cost, also represents the degree of substitution between products, and as Firm 1 increases the variety n_1, the disutility decreases because a consumer is more likely to get something close to her ideal product. In the limit, this disutility vanishes as n_1 approaches infinity; i.e., the product offerings meet the customer's preference exactly.

Suppose Firm 2 offers a custom product with a lead time l_2. Then, the net utility of buying the custom product is $(U - t(1-x) - kl_2 - p_2)$, where p_2 is the price charged by Firm 2 and k denotes the sensitivity to lead time. kl_2 is the loss of utility because of the lead time l_2. A higher value of k implies greater sensitivity to lead time.

A consumer buys the product from the firm that provides a higher net utility. We assume that U is large enough so that the net utility is always greater than zero and that all consumers will buy a product from one of the two firms; i.e., the market is fully covered. This assumption is not uncommon in the marketing and economics literature (Balasubramanian 1998, Syam et al. 2005, Doraszelski and Draganska 2006). Also, we assume that the price p_i is the same for all standard products (or all custom products); i.e., there is no price discrimination based on the consumer's location. Price discrimination is not common in horizontal differentiation contexts. For instance, Lands' End charges the same amount for custom dress shirts of the same quality, independent of color, size, etc. Draganska and Jain (2006) point out that firms typically charge the same price for stock keeping units within a product line along characteristics such as scent, color, and flavor that relate to horizontal differentiation. Syam et al. (2005) and Alptekinoğlu and Corbett (2008) also provide persuasive arguments for not considering price discrimination in contexts similar to ours. The unit cost for either type of product is assumed to be c initially for ease of exposition. We point out later how the results change if the unit cost is different for standard and custom products.

Increasing the number of standard products is equivalent to increasing product variety, and there is anecdotal evidence that increased product variety results in higher production and distribution costs. However, the nature of this increase is not clear, and empirical evidence about whether and how production cost increases with variety is inconclusive (Kekre and Srinivasan 1990). We assume that the cost of variety is linear in the number of standard products offered, given by Vn_i, which is a common assumption in the relevant literature (Dobson and Waterson 1996, Alptekinoğlu and Corbett 2008, Doraszelski and Draganska 2006). Each product type produced incurs a fixed cost V, which may also include product development costs.

Custom products require a lead time to produce, as pointed out earlier, unlike standard products. However, because longer lead times create greater disutility for consumers,[3] the custom firm has to carefully choose a lead time. Typically, firms can reduce lead times by incurring additional costs, for instance, by expediting production, shipping by air, or acquiring technologies that can quickly produce customized products. Piller and Tseng (2003) and Pine (1993) provide numerous examples of such technologies that help achieve short lead times with more expensive and flexible technologies. To capture this phenomenon, custom products incur an additional cost β/l in our model, which is convex, decreasing in the lead

[2] We make this assumption because the expected distance between a customer and her nearest standard product is inversely proportional to the variety offered under uniform distribution. Under other distributions, d/n_1 is also a good estimate of the expected disutility because of product misfit, under the assumption that standard products are evenly spread out along the attribute dimension that is shown to be the optimal strategy in a monopoly setting (Gaur and Honhon 2006). Therefore, the results will also apply to the case of nonuniform distributions.

[3] There may be exceptions for certain products and services, e.g., restaurants, where waiting time may signal higher quality.

time l. Note that as $l \to 0$, $\beta/l \to \infty$, and so the cost of offering infinite variety with zero lead time using custom products tends to infinity. This is the same as the cost of offering an infinite number of standard products, which have zero lead time by definition.

Let F_s and F_c denote the fixed cost required to purchase and install the production system necessary to offer standard and custom products, respectively. The production systems or at least some subsystems required to produce customized products may be quite different from that for standard products, and these differences are reflected in the fixed costs. We assume $F_s = F_c$ in this section and discuss how the results change if $F_s \neq F_c$ in the next section.

We allow both firms to offer either standard or custom products but not both. When the fixed cost incurred for offering standard (or custom) products is high, it will not be profitable to offer both product types. Also, the equipment, processes, and labor required for making standard and custom products are likely to be quite different in many industries—typically, production of standard products involves greater automation and thus higher fixed costs. For example, some furniture makers will only produce custom furniture while other firms make only standard furniture. Similarly, firms such as Champion Homes make only manufactured (standard) homes while other manufacturers such as Standard Pacific Homes make only semicustom or custom homes, because the production processes, materials, and technologies are different. Our objective is to understand whether and when the equilibrium solution will have the firms offering standard or custom products. Furthermore, we would like to explore the impact of competition on the firms' variety and lead time decisions as well as prices.

We consider a three-stage game. At stage 1, each firm decides whether to offer standard or custom products. We refer to each subgame at the end of stage 1 as (i, j) with $i, j \in \{S, C\}$, where, for example, (S, C) denotes that Firm 1 offers standard products and Firm 2 offers custom products. At stage 2, a standard product firm decides the product variety n_i while a custom firm decides on the lead time l_i. Finally, the firms choose prices at stage 3.

Because each firm can decide to offer standard or custom products at stage 1, we consider each of the following scenarios first before analyzing the overall game: (1) Both firms offer only standard products. (2) Both firms offer only custom products. (3) One firm offers standard products while the other offers custom products. For convenience, we use the subscript to denote the firm and superscript to denote the subgame. For instance, p_1^{sc} represents the price charged by Firm 1 in the subgame (S, C).

3.1. Standard vs. Standard: Equilibrium Variety and Prices

In the subgame (S, S), where both firms offer standard products, they determine the variety decision at stage 2 and pricing decision at stage 3. We first analyze the pricing game at stage 3, then the equilibrium variety at stage 2.

3.1.1. Price Equilibrium. From the consumer utility functions, we can derive the indifferent customer's location as

$$\bar{x}^{ss} = \frac{t + d/n_2^{ss} - d/n_1^{ss} + p_2^{ss} - p_1^{ss}}{2t}. \tag{1}$$

To focus on the duopoly and exclude the possibility of monopoly scenarios, we impose the condition $\bar{x}^{ss} \in (0, 1)$ in the price equilibrium, which is satisfied if we assume $3t > d$; i.e., there is sufficient firm differentiation. Then, the customers located between 0 and $\bar{x}^{ss}$ will purchase one of the n_1 standard products offered by Firm 1, while customers located within $[\bar{x}^{ss}, 1]$ will purchase one of the n_2^{ss} standard products offered by Firm 2.

Given n_i^{ss}, Firm i's optimization problem at stage 3 is

$$\max_{p_i} \pi_i^{ss} = D_i^{ss}(p_i^{ss} - c) - Vn_i^{ss} \tag{2}$$

for $i = 1, 2$, where $D_1^{ss} = M\bar{x}^{ss}$, $D_2^{ss} = M(1 - \bar{x}^{ss})$.

Using first-order conditions, the optimal pricing strategy for Firms 1 and 2, respectively, is $p_1^{ss} = \frac{1}{2}(p_2^{ss} + c + t + d/n_2^{ss} - d/n_1^{ss})$ and $p_2^{ss} = \frac{1}{2}(p_1^{ss} + c + t + d/n_1^{ss} - d/n_2^{ss})$. We then obtain the price equilibrium at stage 3:

$$\begin{aligned} p_1^{ss} &= c + t + \frac{1}{3}\left(\frac{d}{n_2^{ss}} - \frac{d}{n_1^{ss}}\right), \\ p_2^{ss} &= c + t + \frac{1}{3}\left(\frac{d}{n_1^{ss}} - \frac{d}{n_2^{ss}}\right). \end{aligned} \tag{3}$$

The following proposition follows from Equation (3):

Proposition 1. *If $n_i^{ss} > n_j^{ss}$, then $p_i^{ss} > p_j^{ss}$, $i \neq j$.*

Thus, in the (S, S) subgame, the firm that offers a greater variety charges higher prices as it is more attractive to potential customers in terms of net utility to them. As an example, Moeller et al. (2003) suggests that firms often increase variety so that they can charge higher prices. Retailers demand unique packaging for home DVDs from the studios so as to reduce the intensity of price competition at the retail level. This result is unlike those in the literature where increased variety leads to more intense price competition (see, e.g., Martinez-Giralt and Neven 1988). This is because we allow for firm-specific preferences.

3.1.2. Variety Equilibrium. At stage 2, Firm 1 determines the optimal variety to maximize its profit, anticipating the subsequent equilibrium prices.

Firm 1's market share in the price equilibrium is

$$m_1^{ss} = \frac{t + d/n_2^{ss} - d/n_1^{ss} + p_2^{ss} - p_1^{ss}}{2t} = \frac{t + \frac{1}{3}(d/n_2^{ss} - d/n_1^{ss})}{2t}, \tag{4}$$

and Firm 2's market share is

$$m_2^{ss} = \frac{t + \frac{1}{3}(d/n_1^{ss} - d/n_2^{ss})}{2t}. \tag{5}$$

Therefore, the profit functions of the two firms are

$$\pi_1^{ss} = \frac{M}{2t}\left[t + \frac{1}{3}\left(\frac{d}{n_2^{ss}} - \frac{d}{n_1^{ss}}\right)\right]^2 - Vn_1^{ss}, \tag{6}$$

$$\pi_2^{ss} = \frac{M}{2t}\left[t + \frac{1}{3}\left(\frac{d}{n_1^{ss}} - \frac{d}{n_2^{ss}}\right)\right]^2 - Vn_2^{ss}. \tag{7}$$

The equilibrium variety decisions are stated in the following proposition:

Proposition 2. *If both firms choose standardization, the equilibrium variety and prices are $n_1^{ss} = n_2^{ss} = \sqrt{Md/3V}$, $p_1^{ss} = p_2^{ss} = c + t$. The equilibrium variety is concave increasing in the market potential and degree of product substitution, and convex decreasing in the variety cost. The equilibrium profits are $\pi_1^{ss} = \pi_2^{ss} = Mt/2 - \sqrt{MVd/3}$.*

Thus, in equilibrium, both firms charge a price that exceeds unit variable cost by the amount of transportation cost t. Thus, the greater the differentiation between the firms, the higher the price they can charge. The equilibrium variety is increasing in the market potential but at a slower rate as the market size enlarges, because of the decreasing returns from variety. The same is true for the impact on variety of the sensitivity to product fit. For instance, sensitivity to product fit is likely to be much higher for a personal item such as apparel as compared to, say, a binder. Correspondingly, one is likely to find much greater variety in apparel relative to a binder. Finally, as variety cost increases, the optimal variety would decrease, as expected. For instance, the cost of producing significant variety is likely to be higher for a car as compared to a more modular and less complex product with fewer parts such as a laptop computer, and one correspondingly finds Toyota offering only a few option combinations for a Camry as compared to the number of configurations offered for a laptop. That the equilibrium variety is convex decreasing in the variety cost offers interesting predictions: as the variety cost decreases, the equilibrium variety expands at an ever-faster rate. This may explain the soaring variety for some products such as yogurt, cereals, toothpastes, etc. (Cox and Alm 1998).

3.2. Custom vs. Custom: Equilibrium Lead Time and Prices

In the subgame (C, C), both firms provide custom products that are tailored to each customer's specification but after a lead time l_i^{cc}. The indifferent customer's location is $\bar{x}^{cc} = (t + kl_2^{cc} - kl_1^{cc} + p_2^{cc} - p_1^{cc})/(2t)$. To ensure that $\bar{x}^{cc} \in (0, 1)$ in the price equilibrium, we assume $3t > k\bar{l}$, where $\bar{l}$ is an upper bound on the lead time. That is, we assume sufficient firm differentiation to focus on the case where both firms cover part of the market. The customers located between 0 and $\bar{x}^{cc}$ purchase a custom product from Firm 1 while customers located within $[\bar{x}^{cc}, 1]$ buy a custom product from Firm 2.

3.2.1. Price Equilibrium. Given lead times l_1^{cc} and l_2^{cc}, Firm i's optimization problem at stage 3 is

$$\max_{p_i^{cc}} \pi_i^{cc} = D_i^{cc}(p_i^{cc} - c) - \frac{\beta}{l_i^{cc}} \tag{8}$$

for $i = 1, 2$, where $D_1^{cc} = M\bar{x}^{cc}$, $D_2 = M(1 - \bar{x}^{cc})$.

Using first-order conditions, the two firms' optimal pricing strategies are, respectively, $p_1^{cc} = \frac{1}{2}(p_2^{cc} + c + t + kl_2^{cc} - kl_1^{cc})$ and $p_2^{cc} = \frac{1}{2}(p_1^{cc} + c + t + kl_1^{cc} - kl_2^{cc})$. Therefore, the price equilibrium at stage 3 is given by

$$\begin{aligned} p_1^{cc} &= c + t + \tfrac{1}{3}(kl_2^{cc} - kl_1^{cc}), \\ p_2^{cc} &= c + t + \tfrac{1}{3}(kl_1^{cc} - kl_2^{cc}). \end{aligned} \tag{9}$$

Proposition 3. *If $l_i^{cc} < l_j^{cc}$, then $p_i^{cc} > p_j^{cc}$, $i \neq j$.*

The proof follows easily from Equation (9). Thus, in the subgame (C, C), the firm that offers a shorter lead time charges higher prices. This is because the firm with longer lead time is less attractive to customers and attempts to compensate for this disadvantage by lowering prices. In contrast, the firm offering a shorter lead time will charge a premium to exploit the consumer surplus. This phenomenon is not uncommon in practice. For instance, custom drapery is available from different vendors, with those offering shorter lead times charging higher prices. The same is true for products such as custom windows and doors (Mullet Door) or precision mechanical components (W. M. Berg).

3.2.2. Lead Time Equilibrium. At stage 2, Firm 1 decides on the optimal lead time to maximize its profit.

Firm 1's market share in the price equilibrium is

$$m_1^{cc} = \frac{t + kl_2^{cc} - kl_1^{cc} + p_2^{cc} - p_1^{cc}}{2t} = \frac{t + \frac{1}{3}(kl_2^{cc} - kl_1^{cc})}{2t}, \tag{10}$$

and Firm 2's market share is

$$m_2^{cc} = \frac{t + \frac{1}{3}(kl_1^{cc} - kl_2^{cc})}{2t}. \tag{11}$$

Thus, the profit functions of the two firms are

$$\pi_1^{cc} = \frac{M}{2t}\left[t + \frac{1}{3}(kl_2^{cc} - kl_1^{cc})\right]^2 - \frac{\beta}{l_1^{cc}}, \tag{12}$$

$$\pi_2^{cc} = \frac{M}{2t}\left[t + \frac{1}{3}(kl_1^{cc} - kl_2^{cc})\right]^2 - \frac{\beta}{l_2^{cc}}. \tag{13}$$

The following proposition provides the equilibrium lead time:

Proposition 4. *If both firms choose customization, the lead time and prices offered in equilibrium are* $l_1^{cc} = l_2^{cc} = \sqrt{3\beta/(Mk)}$, $p_1^{cc} = p_2^{cc} = c + t$. *The equilibrium lead time is convex decreasing in the market potential and sensitivity to lead time, and concave increasing in the lead time cost. The equilibrium profits are* $\pi_1^{cc} = \pi_2^{cc} = Mt/2 - \sqrt{M\beta k/3}$.

As one might expect, the equilibrium lead time is increasing in the cost parameter β relating to lead time reduction, but the increase is at a decreasing rate. This is due to price competition, which limits the extent of increase in lead time. Thus, substantial increases in lead time reduction costs will result in a less than proportional increase in lead time. A similar reasoning also holds for increases in the sensitivity to lead time. Finally, the equilibrium lead time is decreasing in the market potential but at a slower rate as the market size enlarges. As the market potential increases, the fixed lead time-related costs can be spread among more customers, and thus the firm can afford to have shorter lead times. Observe that the prices in equilibrium are the same as in the previous subgame, where both firms produce standard products and depend only on the unit variable cost and the transportation cost t.

3.3. Standard vs. Custom: Equilibrium Variety, Lead Time, and Prices

In the subgame (S, C), one firm chooses standardization (assume it is Firm 1 without loss of generality) while the other firm (Firm 2) chooses customization. At stage 2, Firm 1 chooses the number of standard products to offer n_1^{sc}, and Firm 2 chooses the lead time l_2^{sc} for custom products simultaneously. After they both observe n_1^{sc} and l_2^{sc}, they set the prices at stage 3, which we consider next.

3.3.1. Price Equilibrium. The indifferent customer is located at $\bar{x}^{sc} = (t + kl_2^{sc} - d/n_1^{sc} + p_2^{sc} - p_1^{sc})/(2t)$. We have $\bar{x}^{sc} \in (0, 1)$ in the price equilibrium under the previous assumptions $3t > d$ and $3t > k\bar{l}$. The customers located between 0 and $\bar{x}^{sc}$ will purchase Firm 1's standard products, while customers located within $[\bar{x}^{sc}, 1]$ will buy Firm 2's custom products.

Firm 1's optimization problem at stage 3 is $\max_{p_1^{sc}} \pi_1^{sc} = D_1^{sc}(p_1^{sc} - c) - Kn_1^{sc}$, and Firm 2 maximizes $\pi_2^{sc} = D_2^{sc}(p_2^{sc} - c) - \beta/l_2^{sc}$, where $D_1 = M\bar{x}^{sc}$ and $D_2 = M(1 - \bar{x}^{sc})$.

Firm 1's optimal price for standard products is then given by $p_1^{sc} = \frac{1}{2}(p_2^{sc} + c + t + kl_2^{sc} - d/n_1^{sc})$, and Firm 2's optimal price for custom products is $p_2^{sc} = \frac{1}{2}(p_1^{sc} + c + t + d/n_1^{sc} - kl_2^{sc})$. Therefore, the price equilibrium at stage 3, given n_1^{sc} and l_2^{sc}, is

$$\begin{aligned} p_1^{sc} &= c + t + \frac{1}{3}\left(kl_2^{sc} - \frac{d}{n_1^{sc}}\right), \\ p_2^{sc} &= c + t + \frac{1}{3}\left(\frac{d}{n_1^{sc}} - kl_2^{sc}\right). \end{aligned} \tag{14}$$

As we would expect, Firm 1's price is increasing in the variety it can offer to its customers. Furthermore, as Firm 2 increases the lead time for custom products, Firm 1 can afford to charge a higher price and still be competitive. As the disutility from its limited variety decreases relative to disutility from the lead time of the custom products, Firm 1 can charge a higher price and Firm 2 has to charge a lower price. We now determine the equilibrium variety and lead time that will be offered by the two firms.

3.3.2. Variety and Lead Time Equilibrium. In the price equilibrium, Firm 1 and Firm 2's market shares are

$$m_1^{sc} = \frac{t + \frac{1}{3}(kl_2^{sc} - d/n_1^{sc})}{2t} \tag{15}$$

and

$$m_2^{sc} = \frac{t + \frac{1}{3}(d/n_1^{sc} - kl_2^{sc})}{2t}, \tag{16}$$

respectively. At stage 2, Firm 1 chooses the variety that maximizes its profit:

$$\pi_1^{sc} = \frac{M}{2t}\left[t + \frac{1}{3}\left(kl_2^{sc} - \frac{d}{n_1^{sc}}\right)\right]^2 - Vn_1^{sc}. \tag{17}$$

The optimal variety satisfies the first-order condition

$$\frac{\partial \pi_1^{sc}}{\partial n_1^{sc}} = \left(\frac{3t}{d} + \frac{kl_2^{sc}}{d} - \frac{1}{n_1^{sc}}\right)\frac{1}{(n_1^{sc})^2} - \frac{9Vt}{Md^2} = 0. \tag{18}$$

At the same time, Firm 2 chooses the lead time so as to maximize its profit:

$$\pi_2^{sc} = \frac{M}{2t}\left[t + \frac{1}{3}\left(\frac{d}{n_1^{sc}} - kl_2^{sc}\right)\right]^2 - \frac{\beta}{l_2^{sc}}, \tag{19}$$

and the corresponding first-order condition is

$$\frac{\partial \pi_2^{sc}}{\partial l_2^{sc}} = \left(\frac{3t}{k} + \frac{d}{kn_1^{sc}} - l_2^{sc}\right)(l_2^{sc})^2 - \frac{9\beta t}{Mk^2} = 0. \tag{20}$$

The following theorem characterizes the equilibrium variety and lead time in the (S, C) game relative to those in the (S, S) game and (C, C) game. It also provides insights into the prices and market shares of the two firms in equilibrium. For convenience, define an index for standard products I_s and an index for custom products I_c, where

$$I_s = Vd, \qquad I_c = \beta k.$$

Theorem 1. *When one firm offers standard products and the other firm offers custom products, the equilibrium variety, lead time, prices, and market share satisfy the following relationships*:

(i) *if* $I_s > I_c$, *then* $n_1^{sc} < n_1^{ss}$, $l_2^{sc} < l_2^{cc}$, $p_1^{sc} < p_1^{ss} = p_2^{cc} < p_2^{sc}$, $m_1^{sc} < m_1^{ss} = m_2^{cc} < m_2^{sc}$;

(ii) *if* $I_s < I_c$, *then* $n_1^{sc} > n_1^{ss}$, $l_2^{sc} > l_2^{cc}$, $p_1^{sc} > p_1^{ss} = p_2^{cc} > p_2^{sc}$, $m_1^{sc} > m_1^{ss} = m_2^{cc} > m_2^{sc}$; *and*

(iii) *if* $I_s = I_c$, *then* $n_1^{sc} = n_1^{ss}$, $l_2^{sc} = l_2^{cc}$, $p_1^{sc} = p_2^{sc} = p_1^{ss} = p_2^{cc}$, $m_1^{sc} = m_2^{sc} = m_1^{ss} = m_2^{cc}$;

where $n_1^{ss} = \sqrt{Md/(3V)}$, $l_2^{cc} = \sqrt{3\beta/(Mk)}$, $p_1^{ss} = p_2^{cc} = c + t$, $m_1^{ss} = m_2^{cc} = \frac{1}{2}$.

The index for standard products I_s is the product of variety cost and sensitivity to product fit. The index for custom products I_c is the product of lead time cost and lead time sensitivity. Theorem 1 shows that the product strategy that has a smaller index is more attractive for a firm to adopt in the sense that it will incur lower costs or draw more demand. When $I_s > I_c$ in the (S, C) subgame, we find that the custom product firm has a larger market share than the standard product firm despite charging a higher price ($m_1^{sc} < m_2^{sc}$, $p_1^{sc} < p_2^{sc}$). Furthermore, a custom product firm faces less pressure when competing with a standard product firm than when competing with a custom product firm, and thus it can choose a shorter lead time without worrying about price competition ($l_2^{sc} < l_2^{cc}$). The larger market share and prices of the custom firm in the (S, C) subgame imply higher revenues, and so it can afford to incur the higher costs associated with shorter lead times. In contrast, the standard product firm has greater competitive pressure in the (S, C) subgame than in the (S, S) subgame because of the inherent disadvantage implied by $I_s > I_c$; hence, it chooses a smaller variety in the (S, C) subgame ($n_1^{sc} < n_1^{ss}$) and charges a lower price ($p_1^{sc} < p_1^{ss}$). The situation is the opposite when $I_s < I_c$. Only when $I_s = I_c$ and the two production technologies are equivalent do we find that equilibrium variety, lead time, prices, and market shares are the same in all the subgames.

3.4. The Equilibrium Product Type, Variety, Lead Time, and Prices

We finally consider the decisions at the first stage, where the firms choose between standardization and customization. The following theorem characterizes the equilibrium product type and profits:

Theorem 2 (The Equilibrium Product-Type Theorem). (i) *If* $I_s > I_c$, *then* $\pi_1^{sc} < \pi_1^{cc}$, $\pi_2^{ss} < \pi_2^{sc}$, *and* (C, C) *is the equilibrium*;

(ii) *if* $I_s < I_c$, *then* $\pi_1^{sc} > \pi_1^{cc}$, $\pi_2^{ss} > \pi_2^{sc}$, *and* (S, S) *is the equilibrium*; *and*

(iii) *if* $I_s = I_c$, *then* $\pi_1^{sc} = \pi_1^{cc} = \pi_2^{ss} = \pi_2^{sc}$, *and* $(S, S), (S, C), (C, S), (C, C)$ *are all possible equilibria*.

We find that when the sensitivity to product fit or the variety cost is *small* relative to the sensitivity to lead time or lead time reduction cost, i.e., $I_s < I_c$, both firms choose to offer standard products. The situation is reversed if $I_s > I_c$ and both firms offer custom products. Whether it is attractive to offer standard or custom products depends on many factors and is a function of product characteristics, consumer preferences, and production technologies. For example, the sensitivity to product fit d is likely to be higher for apparel or cosmetics as compared to, say, a VCR. Thus, ceteris paribus, one is more likely to see apparel being customized as compared to a VCR, but other factors also play a role. If the cost of lead time reduction β or the sensitivity to lead time k is high for an apparel item, then customization may not be an attractive strategy even for an apparel item. Levi Strauss found the cost and lead time for customized jeans to be high and abandoned the idea (Wagner 2002). Some firms have been successful, such as Lands' End, even though their lead time for custom apparel is 3–4 weeks because they provide a perfect or close-to-perfect fit. For example, Piller (2006) points out that some apparel firms are unable to truly achieve a custom fit for apparel despite the promise of customization, and this leads to consumer disappointment and poor sales.

Even if manufacturing technologies become flexible, transportation lead times are likely to be large unless shipment is by air, in which case the cost of reducing lead time (β) is large. General Mills test-marketed custom cereals but never followed through because of the long lead times (Schlosser 2004). Thus, transportation lead time plays a significant role in determining the lead time for many products, and if the cost of reducing transportation lead time is high (say, shipping by air versus road or ship) relative to the cost of the item, then customization is never an optimal strategy, independent of whether sensitivity to product fit is high or if it is cost-effective to customize, etc.

Because we allow for each firm to offer a standard or custom product, our results provide different and broader insights than those in Alptekinoğlu and Corbett (2008), where one firm pursues a standard and the other a custom strategy. Also, because we allow for firm differentiation through the parameter t, we find that both firms pursuing a custom product strategy need not result in Bertrand competition and zero profits. When we consider a product such as a PC, it is not likely that the sensitivity to product fit d is high for many consumers. However, the modular nature of the product implies that the cost of customization is not high and achieving short lead times does not lead to very high costs. Furthermore, the sensitivity to lead time k may not be high because it is not typically an impulse purchase. Hence, one is more likely to see firms potentially producing custom products, and in fact, we do observe more firms allowing consumers to customize their PCs following Dell's strategy.

Theorem 2 also suggests that the market size does not affect the equilibrium product strategies. However, from Theorem 1, the equilibrium variety increases and the lead time decreases as the market grows larger.

We note that (S, C) is not an equilibrium unless $I_s = I_c$, which is a point rather than a range of parameters. Furthermore, as we point out later, (S, C) is not an equilibrium under most scenarios even if the variable costs of the two products are different. However, we show later that if custom products and standard products have different fixed costs, then (S, C) may be an equilibrium.

4. Extensions

In the previous section, we find that when standard and custom products have the same fixed and variable costs, the equilibrium outcome depends on the index values. Next, we look at the impact of asymmetric variable and fixed costs on the equilibrium. Then, we study the effect of brand reputation on the equilibrium strategies.

4.1. Impact of Variable Costs

Let c_s and c_c denote the unit cost of standard and custom products, respectively. We assume that both products have the same fixed costs to understand the impact of variable costs.

Theorem 3. *When standard and custom products incur different variable costs, the equilibrium outcome is the following*:

(i) *if $I_s \le I_c$ and $c_s < c_c$, then (S, S) is the equilibrium;*

(ii) *if $I_s \ge I_c$ and $c_s > c_c$, then (C, C) is the equilibrium; and*

(iii) *if $I_s \le I_c$ and $c_s \ge c_c$ or if $I_s \ge I_c$ and $c_s \le c_c$, then (C, C) or (S, S) may be the equilibrium.*

In particular, when $I_s = I_c$, then both firms will choose the type of products with smaller variable costs.

Theorem 2 says that when standard and custom products have the same variable costs, both firms choose the products that have a smaller index value. In contrast, Theorem 3 says that when the index value is the same, the equilibrium product type is the one with smaller variable costs. If a product type with smaller variable cost also has a smaller index, then that product type is the one chosen by both firms.

We illustrate the nature of the equilibrium as a function of these parameter values with some numerical results. Table 1 shows the threshold value of I_c for the given values of c_s, c_c, and I_s, such that the equilibrium shifts from (C, C) to (S, S) when I_c exceeds the threshold. We let $M = 100$, $t = 2$.

Table 1 **Threshold Value of I_c Above Which the Equilibrium Shifts from (C, C) to (S, S)**

c_s	c_c	I_s	Threshold of I_c	$\lvert(c_c - c_s)/c_s\rvert$ (%)	$\lvert(I_c - I_s)/I_s\rvert$ (%)	$(\sqrt{I_s} - \sqrt{I_c})/(c_c - c_s)$
1	1.1	10	8.22	10	17.8	2.96
1	1.2	10	6.61	20	33.9	2.96
1	1.3	10	5.18	30	48.2	2.96
1.1	1	10	11.96	9.1	19.6	2.96
1.2	1	10	14.09	16.7	40.9	2.96
1.3	1	10	16.40	23.1	64.0	2.96

We observe that variable costs have a bigger impact on the equilibrium than the index values. For instance, if the variable cost of custom products is 20% higher than for standard products ($c_s = 1$, $c_c = 1.2$), then (S, S) will be the equilibrium unless I_c is 33.9% less than I_s. More specifically, if $d = 1$, $k = 1$, $V = 10$, then (S, S) will be the equilibrium unless $\beta < 6.61$. Interestingly, we find that the ratio of $\sqrt{I_s} - \sqrt{I_c}$ to $c_c - c_s$ is a constant, which also indicates that the effect of index values is less than that of variable costs.

In summary, the equilibrium product type will be the one with smaller variable costs as long as its index value is not far bigger than the other's index value. Therefore, if the custom products have significantly higher variable costs as is true for many product categories (Schlosser 2004), it is unlikely that firms will produce custom products in equilibrium. Interestingly, note that both firms pursue the same product strategy in equilibrium. This need not be the case when fixed costs are different, as we see in the next subsection.

4.2. Impact of Fixed Costs

We now consider the impact of fixed costs on the equilibrium strategies. First, fixed costs do not have any impact on the equilibrium pricing, variety, and lead time decisions, and only impact whether each firm will offer standard or custom products. We first list some observations that follow directly from our analysis in the previous sections but take into account the impact of fixed costs. We assume that the variable costs are the same for both product types to isolate the impact of fixed costs.

Theorem 4. *When the fixed costs of mass production and mass customization are different, the equilibrium outcome is the following*:

(i) *if $I_s > I_c$ and $F_s \ge F_c$, then (C, C) is the equilibrium;*

(ii) *if $I_s > I_c$ and $F_s \ll F_c$, then (S, S) is the equilibrium;*

(iii) *if* $I_s < I_c$ *and* $F_s \le F_c$, *then* (S, S) *is the equilibrium*;
(iv) *if* $I_s < I_c$ *and* $F_s \gg F_c$, *then* (C, C) *is the equilibrium*;
(v) *otherwise*, (S, S) *or* (C, C) *or* (S, C) *may be the equilibrium*.

Thus, even if $I_s > I_c$, (S, S) can be the equilibrium if the fixed costs of customization are substantially larger than the fixed costs of standardization. Conversely, even if $I_s < I_c$, the equilibrium outcome may be for both firms to produce custom products if the fixed costs of standardization are substantially larger than the fixed costs of customization. For instance, Archetype Solutions, the firm that has helped Lands' End, JCPenney, etc., to launch customized products, points out that it takes a lot of effort and cost to create the necessary customization infrastructure for each new retailer (Wagner 2002). In this case, it appears that the (S, S) equilibrium is more likely than the (C, C) equilibrium.

The result also shows that when $I_s > I_c$ and $F_s < F_c$ or $I_s < I_c$ and $F_s > F_c$, then, depending on the relative values of the various costs and other parameters, the equilibrium outcome could be (S, C) or (C, C) or (S, S). In particular, the (S, C) equilibrium will arise only under the following condition:

$$\pi_1^{cc} - \pi_1^{sc} < (F_c - F_s) < \pi_2^{sc} - \pi_2^{ss}, \qquad (21)$$

[4]

where π here represents profits without considering fixed costs. Thus, the (S, C) equilibrium arises only when the difference between the fixed cost of customization and that of standardization is not substantially large. Furthermore, the above condition also implies that the sum of profits of both firms in the (S, C) equilibrium is larger than the sum of profits from following the (S, S) and (C, C) strategies. Hence, the range of possible parameter values wherein (S, C) is an equilibrium is narrower than the ranges for (S, S) and (C, C) strategies.

Theorem 4 implies that a necessary condition for (S, C) to be the equilibrium is

$$(F_c - F_s)(I_s - I_c) > 0. \qquad (22)$$

The product type that has a smaller index needs to have a larger fixed cost, which is unlikely but not impossible.

4.3. Impact of Reputation

We now analyze how differences in reputation or brand equity will affect the equilibrium outcome. Here, the reputation refers to the brand image as perceived by all consumers. For example, the retail stores that offer better store environment and product quality will have a higher reputation in customers' minds. Nordstrom has a higher reputation than JCPenney and Nike has a better reputation than L.A. Gear. We model the higher reputation with a willingness to pay more for that firm's products. Specifically, we assume that the utility for a consumer of getting her ideal product from Firm i is U_i, $i = 1, 2$. We analyze the equilibrium structure when $U_1 \neq U_2$.

To investigate the effect of brand reputation, we assume that both products have the same fixed and variable costs for both firms. However, we comment on how the results would change if the costs are different, specifically if the firm with a higher reputation has a higher variable cost perhaps because of higher quality inputs.

We find that the result of Theorem 2 on equilibrium product types is robust under differences in brand reputation. That is, both firms will choose the products with smaller index value in the equilibrium, regardless of their brand reputation. In particular, when $I_s = I_c$, the equilibrium could be (S, S), (S, C), or (C, C).[5]

However, the brand reputation does affect the variety, lead time, prices, and market shares in equilibrium, as stated in the following proposition:

Proposition 5. *When the two firms have different reputations, the equilibrium strategies have the following properties*:
(i) *if the equilibrium is* (S, S), *the firm with the higher reputation will provide a larger variety than the competitor*; *and*
(ii) *if the equilibrium is* (C, C), *the firm with the higher reputation will provide a shorter lead time*.
In either case, the firm with the higher reputation will enjoy a larger market share, higher retail prices (*and unit margin*), *and greater profitability than the competitor.*

Thus, a firm with a higher reputation in effect provides better product features (greater variety or shorter lead times) but charges correspondingly higher prices. We observe that the Ralphs grocery chain, which offers a better store environment, provides a larger assortment, and charges higher prices for products such as yogurt and shampoo as compared to a lower-tier store such as Food 4 Less.

There may be examples where a higher reputation firm offers less variety. Shugan (1989) points out that in some industries, producers of premium quality

[4] The necessary and sufficient condition for (S, C) to be the equilibrium is

$$\frac{Mt}{2} - \sqrt{\frac{M\beta k}{3}} - \frac{9V^2 t}{2Md^2} n^{SC^4} + V n^{SC} < F_C - F_S < \frac{9\beta^2 t}{2Mk^2}\frac{1}{l^{SC^4}} - \frac{\beta}{l^{SC}} - \frac{Mt}{2} + \sqrt{\frac{MVd}{3}},$$

where n^{SC} and l^{SC} are solutions of Equations (18) and (20).

[5] We ignore the proof here because of the length constraint.

goods offer a smaller assortment; e.g., Häagen-Dazs offers fewer flavors of ice cream than Baskin-Robbins. However, note that in these cases, the quality of the ice cream is different and so are the corresponding variable costs. In fact, higher variable cost of the higher quality firm is a key condition required for the result in Shugan (1989, p. 316). Although our model does not explicitly model differences in quality, it can be shown that higher variable costs (signifying higher quality) can result in a smaller assortment in our model. Using an analysis similar to that used in §4.1, it can be shown that if two firms providing standard products have different variable costs, then the one with higher variable cost will have a smaller variety in equilibrium. However, our model and conclusions are more conditional. Specifically, if the firm with higher quality (and variable costs) also has a higher reputation, then depending on the relative differences in reputations and variable costs, the higher reputation firm may offer a larger or smaller variety.

5. Discussion and Conclusions

In this paper, we have studied competition between two firms to investigate the relative strengths of standardization and customization and conditions under which firms are likely to follow a particular strategy. The two firms compete for customers through their choices of production technology (product type), variety, lead time, and price. Consumers have heterogeneous tastes for the stores or firms and for product attributes.

First, we have shown that in equilibrium, whether customization dominates standardization or not hangs on its relative cost efficiencies and attractiveness to the consumers, as consumers base their store choice on product variety and lead time in addition to the price offered. The firm that chooses a superior product strategy, represented by a smaller index value or smaller variable costs, can gain a larger market share and charge higher prices and thus achieve higher profitability. Hence, we find that (S, S) or (C, C) are the equilibrium strategies for a wide range of parameter values, and (S, C) is the equilibrium only over a relatively narrow range. This is true when variable or fixed costs are different for the two product types and even when reputations of the two firms are different. Furthermore, our analysis showed that if the fixed or variable costs for custom products are likely to be higher as one might expect, then the (S, S) equilibrium is far more likely. This perhaps explains why we tend to see only standard products in many industries such as consumer electronics, office supplies, etc., while custom products are thriving in a few industries such as PCs. Furthermore, the proportion of customized product sales is small even in product categories such as apparel, where several firms offer customization. The cost of achieving flexibility and consumer sensitivity to lead time play an important role, and depending on the product category, it is sometimes a cost issue (e.g., consumer electronics) while in other categories it may stem from sensitivity to lead time (e.g., toothpaste). In general, as car manufacturers have discovered (Schlosser 2004), the cost of achieving customization with lead times acceptable to consumers is quite high for many product categories. Customers have to wait several weeks or months to get a customized car, which reduces the potential demand substantially. Therefore, only a negligible proportion of cars sold are customized. For many impulse purchase products where sensitivity to lead time k is likely to be high, customization is not a feasible strategy. In general, items with a high value density (such as PCs or furniture) are more likely to have a smaller k, but whether such products are customized depends on the cost parameter β. As time goes by and the costs of customization decrease, customization may become a dominant strategy in more product categories, but this is not imminent.

Second, we have shown the strategic roles of product variety and lead time under competition. Increasing variety or decreasing lead time can both increase market share and margin, but has diminishing returns and incurs higher costs. Therefore, the firm should carefully choose the variety and lead time that balance the costs and benefits.

Third, we find that with sufficient firm differentiation, increasing variety will *not* intensify the price competition. Previous literature has found that increasing the product variety would force the firm itself to lower the price because of intensified price competition (e.g., Martinez-Giralt and Neven 1988, Alptekinoğlu and Corbett 2008), where there is no firm differentiation. In contrast, we find that when there is sufficient firm differentiation (or, equivalently, high enough transportation cost), increasing the variety would allow the firm to increase the market share as well as charge a higher price, while the competitor would lower the price. Therefore, increasing the variety actually relieves the price pressure for itself as it better caters to consumer needs and enables higher price premiums.

Furthermore, we find that the reputation of a firm does not impact its product strategy and thus it is not more likely that a firm with a better brand or quality image will necessarily offer customization, for instance. However, such firms do offer greater product variety and shorter lead time, depending on whether it offers standard or custom products, respectively, and charges higher prices. Thus, the product type offered appears to be largely a function of the costs and sensitivity of consumers to product fit and lead time, and not a function of a firm's brand image. Furthermore, it appears that symmetric product strategies are the most likely ones in most scenarios.

Our model has some limitations that suggest future research ideas. First, we assumed that the market is fully covered. Relaxing this assumption may generate more insights on the role of variety and lead time under competition. For example, the equilibrium variety may increase and lead time decrease as they can attract more customers to purchase the product. Second, we could have heterogeneity in the sensitivity of consumers to the product fit and lead time. Then, it may become more likely that firms adopt different product strategies trying to capture different customer segments. Finally, we could allow one firm to be an incumbent and study entry-deterrent strategies by analyzing sequential move games.

Appendix

Proof of Proposition 2. When both firms offer standard products, Firm 1's profit is $\pi_1^{ss} = (M/(2t))[t + \frac{1}{3}(d/n_2^{ss} - d/n_1^{ss})]^2 - Vn_1^{ss}$, which has the first-order condition with respect to its variety:

$$\frac{\partial \pi_1^{ss}}{\partial n_1^{ss}} = \left(\frac{3t}{d} + \frac{1}{n_2^{ss}} - \frac{1}{n_1^{ss}}\right)\frac{1}{(n_1^{ss})^2} - \frac{9Vt}{Md^2} = 0. \tag{23}$$

The corresponding first-order condition for Firm 2 is

$$\frac{\partial \pi_2^{ss}}{\partial n_2^{ss}} = \left(\frac{3t}{d} + \frac{1}{n_1^{ss}} - \frac{1}{n_2^{ss}}\right)\frac{1}{(n_2^{ss})^2} - \frac{9Vt}{Md^2} = 0. \tag{24}$$

Subtracting (24) from (23), we have $(1/n_1^{ss} - 1/n_2^{ss})[(1/n_1^{ss}) \cdot (3t/d - 1/n_1^{ss}) + (1/n_2^{ss})(3t/d - 1/n_2^{ss})] = 0$. The second term is positive using $3t > d$, thus we have $1/n_1^{ss} - 1/n_2^{ss} = 0$. We then get $n_1^{ss} = n_2^{ss} = \sqrt{Md/(3V)}$ from (23) and $p_1^{ss} = p_2^{ss} = c + t$ from (3). □

Proof of Proposition 4. When both firms offer custom products, Firm 1 maximizes its profit $\pi_1^{cc} = (M/(2t)) \cdot [t + \frac{1}{3}(kl_2^{cc} - kl_1^{cc})]^2 - \beta/l_1^{cc}$, which has the first-order condition

$$\frac{\partial \pi_1^{cc}}{\partial l_1^{cc}} = \left(\frac{3t}{k} + l_2^{cc} - l_1^{cc}\right)(l_1^{cc})^2 - \frac{9\beta t}{Mk^2} = 0. \tag{25}$$

The corresponding first-order condition for Firm 2 is

$$\frac{\partial \pi_2^{cc}}{\partial l_2^{cc}} = \left(\frac{3t}{k} + l_1^{cc} - l_2^{cc}\right)(l_2^{cc})^2 - \frac{9\beta t}{Mk^2} = 0. \tag{26}$$

Subtracting (26) from (25), we have $(l_1^{cc} - l_2^{cc})[l_1^{cc}(3t/k - l_1^{cc}) + l_2^{cc}(3t/k - l_2^{cc})] = 0$. Using $3t > k\bar{l}$, which leads to $l_1^{cc}(3t/k - l_1^{cc}) + l_2^{cc}(3t/k - l_2^{cc}) > 0$, we have $l_1^{cc} - l_2^{cc} = 0$. Then, from (25) and (9) we get $l_1^{cc} = l_2^{cc} = \sqrt{3\beta/(Mk)}$ and $p_1^{cc} = p_2^{cc} = c + t$. □

Proof of Theorem 1. For convenience, we rewrite n_1^{sc} as d/kl_1^{sc}, where l_1^{sc} is a variable representing the equivalence lead time. Then, (18) and (20) become

$$\left(\frac{3t}{k} + l_2^{sc} - l_1^{sc}\right)(l_1^{sc})^2 - \frac{9Vdt}{Mk^3} = 0 \tag{27}$$

and

$$\left(\frac{3t}{k} + l_1^{sc} - l_2^{sc}\right)(l_1^{sc})^2 - \frac{9\beta t}{Mk^2} = 0, \tag{28}$$

respectively. Subtracting (28) from (27) yields

$$(l_1^{sc} - l_2^{sc})\left[l_1^{sc}\left(\frac{3t}{k} - l_1^{sc}\right) + l_2^{sc}\left(\frac{3t}{k} - l_2^{sc}\right)\right] = \frac{9t(Vd - \beta k)}{Mk^3}. \tag{29}$$

Because the second term is positive using $3t > k\bar{l}$, $Vd > \beta k$ if and only if $l_1^{sc} > l_2^{sc}$.

Alternatively, we rewrite l_2^{sc} as d/kn_2^{sc}, where n_2^{sc} is a variable representing the equivalence variety. In a similar way, we can show that $Vd > \beta k$ if and only if $1/n_1^{sc} > 1/n_2^{sc}$.

If $Vd > \beta k$, (29) $\Rightarrow l_1^{sc} > l_2^{sc}$. Rewrite (28) as $(l_2^{sc})^2 = 9\beta t/(Mk^2(3t/k + l_1^{sc} - l_2^{sc})) < 3\beta/(Mk)$; i.e., $l_2^{sc} < \sqrt{3\beta/(Mk)} = l_2^{cc}$. Similarly, we get $l_1^{sc} > \sqrt{3\beta/(Mk)}$ from (27). Following the same logic, we can show that $n_1^{sc} < \sqrt{Md/3V} = n_1^{ss}$. Now, we compare the price and market share. From (14), $p_1^{sc} = c + t + \frac{1}{3}(kl_2^{sc} - d/n_1^{sc}) < c + t + \sqrt{\beta k/(3M)} - \sqrt{Vd/(3M)}$ (using $l_2^{sc} < \sqrt{3\beta/(Mk)}$ and $n_1^{sc} < \sqrt{Md/(3V)}$) $< c + t$ (using $Vd > \beta k$) $= p_1^{ss}$. Similarly, we can show that $p_2^{sc} > p_2^{cc}$. Market share

$$\begin{aligned} m_1^{sc} &= \frac{t + \frac{1}{3}(kl_2^{sc} - d/n_1^{sc})}{2t} \\ &< \frac{t + \frac{1}{3}(\sqrt{\beta k/(3M)} - \sqrt{Vd/(3M)})}{2t} \\ &< \frac{1}{2} = m_1^{ss}. \end{aligned}$$

The results for the cases $Vd < \beta k$ and $Vd = \beta k$ can be shown following the same logic. □

Proof of Theorem 2.

Case 1. $Vd > \beta k$. From Theorem 1, we have $n_1^{sc} < \sqrt{Md/(3V)}$. Rewriting (18) as $t + \frac{1}{3}(kl_2^{sc} - d/n_1^{sc}) = (3Vt/(Md))(n_1^{sc})^2$ and substituting it into (17), we have

$$\begin{aligned} \pi_1^{sc} &= Vn_1^{sc}\left[\frac{9Vt}{2Md^2}(n_1^{sc})^3 - 1\right] < V\sqrt{\frac{Md}{3V}}\left[\frac{9Vt}{2Md^2}\sqrt{\frac{Md}{3V}}^3 - 1\right] \\ &= \frac{Mt}{2} - \sqrt{\frac{MVd}{3}} < \frac{Mt}{2} - \sqrt{\frac{M\beta k}{3}} = \pi_1^{cc}; \quad \text{i.e., } \pi_1^{sc} < \pi_1^{cc}. \end{aligned}$$

Similarly, rewriting (20) as $t + \frac{1}{3}(d/n_1^{sc} - kl_2^{sc}) = (3\beta t/(Mk))(1/(l_2^{sc})^2)$ and substituting it into (19), we have

$$\begin{aligned} \pi_2^{sc} &= \frac{\beta}{l_2^{sc}}\left[\frac{9\beta t}{2Mk^2}\frac{1}{(l_2^{sc})^3} - 1\right] \\ &> \frac{\beta}{\sqrt{3\beta/(Mk)}}\left[\frac{9\beta t}{2Mk^2}\frac{1}{\sqrt{3\beta/(Mk)}^3} - 1\right] \\ &\qquad \left(\text{using } l_2^{sc} < \sqrt{\frac{3\beta}{Mk}}\right) \\ &= \frac{Mt}{2} - \sqrt{\frac{M\beta k}{3}} > \frac{Mt}{2} - \sqrt{\frac{MVd}{3}} = \pi_2^{ss}. \end{aligned}$$

Because $\pi_1^{sc} < \pi_1^{cc}$ and $\pi_2^{sc} > \pi_2^{ss}$, in equilibrium both firms choose to offer custom products.

The cases $Vd < \beta k$ and $Vd = \beta k$ can be shown through a similar way. □

Proof of Theorem 3. (i) $Vd \le \beta k$ and $c_s < c_c$. When both firms choose standard or custom products, they incur the same variable costs so the equilibrium is the same as before. Only the equilibrium of (S, C) game is affected. Suppose Firm 1 chooses standard products and Firm 2 chooses custom products. Then, Firm 1's optimal price for standard products is $p_1^{sc} = \frac{1}{2}(p_2^{sc} + c_s + t + kl_2^{sc} - d/n_1^{sc})$ and Firm 2's optimal price for custom products is $p_2^{sc} = \frac{1}{2}(p_1^{sc} + c_c + t + d/n_1^{sc} - kl_2^{sc})$. The equilibrium prices at stage 3 are $p_1^{sc} = t + \frac{1}{3}(2c_s + c_c + kl_2^{sc} - d/n_1^{sc})$ and $p_2^{sc} = t + \frac{1}{3}(c_s + 2c_c + d/n_1^{sc} - kl_2^{sc})$. At stage 2, Firm 1's profit

$$\pi_1^{sc} = (M/(2t))\left[t + \tfrac{1}{3}(kl_2^{sc} - d/n_1^{sc} + c_c - c_s)\right]^2 - Vn_1^{sc}$$

with the first-order condition $\partial\pi_1^{sc}/\partial n_1^{sc} = ((3t + c_c - c_s)/d + kl_2^{sc}/d - 1/n_1^{sc})(1/(n_1^{sc})^2) - 9Vt/(Md^2) = 0$. Similarly, the first-order condition for Firm 2 is $\partial\pi_2^{sc}/\partial l_2^{sc} = ((3t + c_s - c_c)/k + d/(kn_1^{sc}) - l_2^{sc})(l_2^{sc})^2 - 9\beta t/(Mk^2) = 0$. Rewriting l_2^{sc} as $d/(kn_2^{sc})$, the above two equations become

$$\left(\frac{3t + c_c - c_s}{d} + \frac{1}{n_2^{sc}} - \frac{1}{n_1^{sc}}\right)\frac{1}{(n_1^{sc})^2} - \frac{9Vt}{Md^2} = 0 \tag{30}$$

and

$$\left(\frac{3t + c_s - c_c}{d} + \frac{1}{n_1^{sc}} - \frac{1}{n_2^{sc}}\right)\frac{1}{(n_2^{sc})^2} - \frac{9\beta kt}{Md^3} = 0, \tag{31}$$

respectively. Subtracting (31) from (30), we get

$$\left(\frac{1}{n_1^{sc}} - \frac{1}{n_2^{sc}}\right)\left[\frac{1}{n_1^{sc}}\left(\frac{3t}{d} - \frac{1}{n_1^{sc}}\right) + \frac{1}{n_2^{sc}}\left(\frac{3t}{d} - \frac{1}{n_2^{sc}}\right)\right] + \frac{c_c - c_s}{d}\left(\frac{1}{n_1^{sc}} + \frac{1}{n_2^{sc}}\right) = \frac{9t(Vd - \beta k)}{Md^3}. \tag{32}$$

Using $3t > d$, we have

$$\frac{1}{n_1^{sc}}\left(\frac{3t}{d} - \frac{1}{n_1^{sc}}\right) + \left(\frac{1}{n_2^{sc}}\right)\left(\frac{3t}{d} - \frac{1}{n_2^{sc}}\right) > 0.$$

Therefore, if $Vd \le \beta k$ and $c_s < c_c$, then $1/n_1^{sc} - 1/n_2^{sc} < 0$; i.e., $n_1^{sc} > n_2^{sc}$. From (30), $(n_1^{sc})^2 = (Md^2/(9Vt))((3t + c_c - c_s)/d + 1/n_2^{sc} - 1/n_1^{sc}) > Md/(3V)$ (using $c_s < c_c$ and $1/n_1^{sc} - 1/n_2^{sc} < 0$); i.e., $n_1^{sc} > \sqrt{Md/(3V)} = n_1^{ss}$. Using a similar approach as in the proof of Theorem 2, we can show that $\pi_1^{sc} > \pi_1^{cc}$ and $\pi_2^{sc} < \pi_2^{ss}$, which imply that both firms offer standard products in equilibrium if $Vd \le \beta k$ and $c_s < c_c$.

Similarly, we can show that when $Vd \ge \beta k$ and $c_s > c_c$, both firms offer custom products in equilibrium. □

Proof of Proposition 5. Proof of (i). If both firms choose to offer standard products, then for a customer at location x, the net utility of purchasing a standard product from Firm 1 and Firm 2 is $(U_1 - tx - d/n_1^{ss} - p_1^{ss})$ and $(U_2 - t(1 - x) - d/n_2^{ss} - p_2^{ss})$, respectively. The indifferent customer is located at $\bar{x}^{ss} = (t + U_1 - U_2 + d/n_2^{ss} - d/n_1^{ss} + p_2^{ss} - p_1^{ss})/(2t)$. The equilibrium prices at stage 3 are

$$\begin{aligned} p_1^{ss} &= c + t + \frac{1}{3}\left(U_1 - U_2 + \frac{d}{n_2^{ss}} - \frac{d}{n_1^{ss}}\right), \\ p_2^{ss} &= c + t + \frac{1}{3}\left(U_2 - U_1 + \frac{d}{n_1^{ss}} - \frac{d}{n_2^{ss}}\right). \end{aligned} \tag{33}$$

At stage 2, Firm 1's profit is

$$\pi_1^{ss} = \frac{M}{2t}\left[t + \frac{1}{3}\left(U_1 - U_2 + \frac{d}{n_2^{ss}} - \frac{d}{n_1^{ss}}\right)\right]^2 - Vn_1^{ss} \tag{34}$$

with the first-order condition

$$\frac{\partial\pi_1^{ss}}{\partial n_1^{ss}} = \left(\frac{3t + U_1 - U_2}{d} + \frac{1}{n_2^{ss}} - \frac{1}{n_1^{ss}}\right)\frac{1}{(n_1^{ss})^2} - \frac{9Vt}{Md^2} = 0. \tag{35}$$

Obtaining the first-order condition for Firm 2 and subtracting it from (35), we get $(1/n_1^{ss} - 1/n_2^{ss})[(1/n_1^{ss})(3t/d - 1/n_1^{ss}) + (1/n_2^{ss})(3t/d - 1/n_2^{ss})] + ((U_1 - U_2)/d)(1/n_1^{ss} + 1/n_2^{ss}) = 0$. If $U_1 > U_2$, then $1/n_1^{ss} - 1/n_2^{ss} < 0$; i.e., $n_1^{ss} > n_2^{ss}$. Then, from (33), we know that $p_1^{ss} > p_2^{ss}$. The market share

$$\begin{aligned} m_1^{ss} &= \frac{t + U_1 - U_2 + d/n_2^{ss} - d/n_1^{ss} + p_2^{ss} - p_1^{ss}}{2t} \\ &= \frac{t + \frac{1}{3}(U_1 - U_2 + d/n_2^{ss} - d/n_1^{ss})}{2t} = \frac{p_1^{ss} - c}{2t}, \end{aligned}$$

and $m_2^{ss} = (p_2^{ss} - c)/2t$, therefore, we have $m_1^{ss} > m_2^{ss}$. From (34) and (35), $\pi_1^{ss} = (9V^2t/(2Md^2))(n_1^{ss})^4 - Vn_1^{ss} = Vn_1^{ss}[(9Vt/(2Md^2))(n_1^{ss})^3 - 1]$, similar for π_2^{ss}, so we have $\pi_1^{ss} > \pi_2^{ss}$ using $n_1^{ss} > n_2^{ss}$. The result when $U_1 < U_2$ is the opposite.

Proof of (ii) can be shown following the same logic. □

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