Competitive Effects of Mass Customization

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Abstract

The existing theoretical literature on mass customization maintains that customization reduces product differentiation and intensifies price competition. In contrast, operations management studies argue that customization serves primarily to differentiate a company from its competitors. Interactive involvement of the customer in product design creates an affective relationship with the firm, relaxing price competition. This paper provides a model that incorporates consumer involvement to explain the phenomena described in the operations management literature.

Two firms on the Hotelling line compete for a continuum of consumers with heterogeneous brand preferences. An exogenously given fraction of consumers is potentially interested in customization. Consumer benefits from customization are the rewards from a special shopping experience and the value of product customization (a better fitting product); these benefits are higher for consumers located closer to the customizing brand. When a consumer purchases a customized product, he/she incurs waiting costs. Each firm simultaneously decides whether to offer standard products, customized products, or both, and then engage in price competition. I show that customization increases product differentiation, leading to less intense price competition. Depending on the parameter values, in equilibrium either both firms offer customized products, one firm offers customized products and the other standard and customized products, or one firm offers customized products and the other standard products. I perform comparative statics analysis with respect to the fraction of consumers interested in customization, the waiting costs, and the fixed cost of customization.

Keywords: product differentiation, price competition, customization, brand loyalty
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1 Introduction

Mass customization is the capability to produce individually tailored goods and services for a relatively large market with near mass production efficiency. Advances in Internet-based information technologies and improvements in manufacturing flexibility have made customization a reality in many product categories. For example, Dell builds to order notebook and desktop computers; Nike and Adidas allow consumers to create their most preferred athletic pair of shoes; apparel vendor Lands’ End offers custom-crafted pants and shirts; Timbuk2 customizes messenger bags and backpacks; MiniUSA.com provides a “build a new MINI” option where the consumer can construct a MINI Cooper car of his/her dreams.

Theoretical studies of mass customization draw upon earlier literature in horizontal product differentiation. Customization enables firms to take advantage of consumers’ desires for ideal varieties, but reduces product differentiation and intensifies price competition (Dewan, Jing, and Seidmann, 2003, Syam, Ruan, and Hess, 2005, Syam and Kumar, 2006, Bernhardt, Liu, and Serfes, 2007, Mendelson and Parlaktürk, 2008a, 2008b, Loginova and Wang, 2011). Indeed, if two or more firms offer a consumer the product that completely matches the consumer’s tastes, then competition leads to marginal cost pricing.

Customization differs from the strategy of offering as many variants as possible. For true customization to take place, the customer must be involved in specifying the characteristics of his/her ideal product during the product design, fabrication, and assembly. This important aspect of customization has never received direct attention in the theoretical literature.

Operations management and information system scholars, on the other hand, have thoroughly described the economic implications of consumer co-design activities. They argue that customization serves primarily to differentiate a company from its competitors. The interactive involvement of the customer in the product design process creates a stronger affective relationship with the firm that subsequently leads to firm loyalty.

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2 The study of horizontal differentiation dates back to Hotelling (1929) and was extended by Lancaster (1966, 1979) and Salop (1979).

3 This type of customization is sometimes referred to as collaborative customization, a term introduced by Gilmore and Pine in The Four Faces of Mass Customization (1997). The other three “faces” of customization are adaptive (standard products can be altered by customers during use), cosmetic (standard products are packaged specially for each consumer), and transparent (products are adapted for individual needs). The term “mass customization” is most often associated with collaborative customization.
High loyalty, in turn, relaxes price-based competition (Gommans, Krishnan, and Schef­fold, 2001, Broekhuizen and Alsem, 2002, Grewal, Iyer, Krishnan, and Sharma, 2003, Arora et al., 2008), which is incompatible with the findings in the theoretical studies.

The present paper attempts to reconcile the conflicting implications of the theoretical and the qualitative operations management literatures regarding the effect of mass customization on the intensity of price competition. Namely, it formalizes the arguments put forth in the operations management literature and proposes a model that successfully captures the effect of relaxed price competition due to consumer interactive involvement.

Overview of the Model and Results

I adopt the standard Hotelling model with two firms competing for a continuum of consumers. Consumers are heterogeneous in two dimensions. First, each consumer is identified by a point on the unit interval that represents his/her brand preferences. Second, consumers differ in their “readiness” for customization. Specifically, I assume that a fraction of consumers never buys customized products for exogenous reasons like privacy, lack of computer literacy, or general resistance to change. The rest of the consumers are potentially interested in customization.

If a firm chooses to offer customization, it must incur sunk costs associated with achieving high levels of manufacturing technology and flexibility (Broekhuizen and Alsem, 2002). I also account for non-zero lead time. When a consumer purchases a customized product, he/she suffers the cost of waiting for the product to be assembled and delivered (Tu, Vonderembse, and Ragu-Nathan, 2001, Zipkin, 2001).

I assume a positive relationship between consumers’ benefits from customization and their valuations of the brand. That is, consumers located “closer” to the brand gain more from customization. This central assumption finds strong support in the operations management literature. Customization benefits are the rewards from a special shopping experience such as satisfaction with the fulfilment of a co-design task (Piller and Müller, 2004, Franke and Piller, 2004) and the value of product customization (i.e., the increment of utility a consumer gains from a product that fits better to his/her needs than the best standard product available). The rewards from an enjoyable shopping experience are, obviously, higher for consumers who are dedicated to the customizing firm. Also, consumers who favor a certain brand possess more knowledge of this brand. Knowledgeable consumers can more easily transfer their needs into appropriate characteristics of the brand than less knowledgeable ones, and the products they co-design better match their needs (Jiang, 2004, Piller, Schubert, Koch, and Möslein, 2005). As a result, for
these consumers the value of product customization is higher than for consumers located “farther away” from the brand.

The timeline of the game is as follows. First, the firms simultaneously decide whether to offer standard products, customized products, or both. After the choices of product strategies are made, the firms engage in price competition. Consumers decide which products to purchase, and the profits are realized.

The main driver of the equilibrium analysis results is that the firms’ customized products are more differentiated than their standard products. I show that, depending on the parameter values, the following three scenarios can occur in equilibrium: (1) both firms offer customized products; (2) one firm offers customized products and the other firm offers standard and customized products; and (3) one firm offers customized products and the other firm offers standard products. In the first scenario the firms’ customized products compete head-to-head (relaxed price competition), in the second and third scenarios the competition is between one firm’s standard products and the other firm’s customized products (moderate price competition). The scenario in which both firms offer standard and customized products cannot occur in equilibrium because it leads to intense price competition between the firms’ standard products.

Comparative static analysis with respect to the key parameters of the model – the fraction of consumers potentially interested in customization, the waiting costs, and the fixed cost of customization – reveal some interesting results. For example, if scenario (2) obtains in equilibrium, then the higher the fraction of consumers potentially interested in customization is, the lower the firms’ equilibrium prices and profits are. Another intriguing result is that scenario (1) can occur in equilibrium only if the waiting costs are sufficiently high.

**Literature Review**

I will briefly summarize the existing theoretical papers on mass customization competition and contrast them with the present study. Next, I will relate my model of customization to the advertising literature.

Consumers in Xia and Rajagopalan (2009), like in this paper, are heterogeneous in preferences for the two firms (brands). The firms decide which type of products, standard or customized, to offer and then a standard product firm chooses the product variety and a custom product firm chooses the lead time. Customization eliminates the loss in utility from getting a standard product that does not meet a consumer’s needs exactly. Unlike the present study, in Xia and Rajagopalan (2009) consumers’ benefits from customization are independent of their valuations of the brand. The
authors develop an index that signifies the relative attractiveness of standardization and customization. They also identify the strategic roles of product variety and lead time.

Other papers that consider duopoly price competition in which the firms choose whether to customize their products, assume consumer heterogeneity in product—not brand—preferences. The firms’ standard products are located at the end points of the unit interval representing the product space. Customization reduces (Mendelson and Parlaktürk, 2008b, Syam and Kumar, 2006) or eliminates (Syam, Ruan, and Hess, 2005, Loginova and Wang, 2011) a consumer’s disutility of misfit—the distance from the consumer’s ideal product to the firm’s standard product. Hence, the closer the consumer is to the firm, the less he/she gains from purchasing a customized product of this firm. It follows that customization by one or both firms reduces product differentiation and intensifies price competition. This is diametrically opposite to the present study that shows that customization softens price competition. The difference in the findings can be traced to the differences in the underlying assumptions on the standard product offerings. The above papers assume that initially (before customization choices are made) each firm produces only one standard product that is maximally differentiated from its rival’s standard product. In the present model each firm produces a number of standard products to target consumers of different tastes, and consumers can find a reasonably well-fitting product among them. That is, a consumer’s disutilities of misfit at the two firms are negatively correlated in the aforementioned papers, but uncorrelated in my model.

Out of the papers cited above only Syam and Kumar (2006) include offering both standard and customized products into the firms’ strategy spaces. The authors show that when a firm offers customized products, it is always beneficial to offer standard products as well. In equilibrium either both firms offer standard and customized products, or one firm offers standard products and the other firm offers standard and customized products. These results are quite different from the present study, due to the differences in the modeling approaches.

The following studies do not allow firms to choose between mass production and customization, focusing instead on technological aspects of flexible manufacturing. Mendelson and Parlaktürk (2008b) consider a traditional firm and a customizing firm. They model replenishment and inventory costs for the traditional firm and assume limited capacity for the customizing firm. In Bernhardt, Liu, and Serfes (2007) two customizing firms acquire information about each individual consumer to match his/her needs as

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4 In Syam, Ruan, and Hess (2005) the product space is two-dimensional.
much as they can. Given investments in information acquisition, the firms then compete in prices. The authors show that in equilibrium the firms make asymmetric investments in order to reduce price competition. In their extension a “brand name” dimension is added. When consumers differ enough on this dimension, then both firms make extensive investments in information acquisition technology. Dewan, Jing, and Seidmann (2003) consider two firms that choose their customization scopes simultaneously, sequentially, and in an incumbent plus entrant situation. They show that an early adopter may be able to keep out potential competitors by choosing its customization scope strategically.

The present study is broadly related to the literature on advertising and product differentiation. Of the two types of advertising, informative and persuasive, customization has much in common with the latter. In the context of the Hotelling model, Von der Fehr and Stevik (1998) distinguish between three types of persuasive advertising. The first type enhances the value of a product in the eyes of consumers, the second type shifts the distribution of consumers in the direction of the firm’s product, and the third type increases perceived product differences. Customization in my model, thus, combines the effects of both the first and the third types of persuasive advertising. The main finding of Von der Fehr and Stevik (1998) is that a positive relationship between the degree of (inherent) product substitutability and equilibrium levels of advertising is consistent only with the advertising that increases perceived product differences.

Despite the similarities between customization and persuasive advertising, my model does not have a close equivalent in the advertising literature. Bloch and Manceau (1999) and Tremblay and Polasky (2002) use the Hotelling line, but consider the second (in Von der Fehr and Stevik’s terms) type of persuasive advertising. Johnson and Myatt (2006) allow for demand shifts (the first type) and rotations (the third type), but analyze the monopoly supply of a single product. They show that when consumers’ valuations are relatively homogenous, the monopolist will choose to serve a large fraction of potential consumers. When consumers are heterogeneous, the monopolist will restrict sales to a relatively small niche of consumers.

The rest of the paper is organized as follows. In the next section I introduce the model. In Section 3 the pricing stage is analyzed. In Section 4 I study the firms’ equilibrium choices of product strategies. Concluding remarks are provided in Section 5. Proofs of all lemmas propositions are relegated to the Appendix.

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2 The Model

Two symmetric firms, A and B, compete for a continuum of heterogeneous consumers with a total mass of one. Firm A produces brand A and firm B produces brand B. Investing $K \geq 0$ into manufacturing flexibility enables a firm to offer customization. In the spirit of mass customization’s postulate of achieving near mass production efficiency, I assume that both standard and customized products are produced at the same constant marginal cost $c$. Without loss of generality, I normalize the marginal cost to zero.

Consumers are in the market to purchase at most one unit of the product. They are heterogeneous in two dimensions. First, each consumer is identified by a point $x$ in the unit interval $[0, 1]$ that represents his/her relative preference for brand A versus brand B. To keep the model tractable, I assume that consumers are uniformly distributed along this dimension. Second, independent of $x$, consumers differ in their levels of readiness for customization. Specifically, I assume that fraction $1 - \alpha$ of consumers never buys customized products for exogenous reasons like privacy, lack of computer literacy, or general resistance to change. The rest of consumers (fraction $\alpha$) are potentially interested in customization. For the ease of exposition I will refer to the former as traditional consumers and to the latter as tech-savvy consumers.

Let $p_A$ and $p_B$ denote the prices charged by firm A and firm B for their standard products. For the consumer at location $x$, the payoff from purchasing firm A’s standard product equals

$$v - tx - p_A.$$  (1)

Here $v - tx$ is his/her valuation of brand A. Similarly, the consumer’s payoff from purchasing firm B’s standard product is

$$v - t(1 - x) - p_B.$$  (2)

The term $v - t(1 - x)$ is his/her valuation of brand B. Parameter $t$ represents the intensity of consumers’ relative preferences for the two brands.

Let $\bar{p}_A$ and $\bar{p}_B$ denote the firms’ prices for their customized products. (I use the overbar symbol to distinguish prices for the customized products from prices for the standard products.) For the consumer at location $x$, the payoff from purchasing firm A’s customized product is

$$(1 + \Delta)(v - tx) - w - \bar{p}_A,$$  (3)

where $\Delta > 0$ and $w$ is the cost of waiting for the product to be assembled and delivered.
Similarly, his/her payoff from purchasing firm B’s customized product is

\[(1 + \Delta)(v - t(1 - x)) - w - \bar{p}_B.\]  

(4)

It follows from (1) through (4) that the consumer’s benefits from customization are

\[\Delta(v - tx)\]

if he/she purchases from firm A,

\[\Delta(v - t(1 - x))\]

if he/she purchases from firm B. I believe that the positive relationship between the consumer’s valuation of a given brand and his/her benefits from customization is the most realistic assumption. In support of this, let me reiterate some parts of the Introduction. Customization benefits for consumers are twofold:

(a) the rewards from a special shopping experience and satisfaction with the fulfillment of a co-design task,

(b) the increment of utility a consumer gains from a product that fits better to his/her needs than the best standard product available.

The rewards from an enjoyable shopping experience (a) are, obviously, higher for consumers who are dedicated to the customizing firm. The same applies to (b). Indeed, consumers who favor a certain brand would, in general, possess more knowledge of this brand. Knowledgeable consumers can more easily transfer their needs into appropriate characteristics of the brand than less knowledgeable consumers, and thus the products they co-design better match their needs.

Since the focus of this paper is on strategic effects of customization rather than customization technology, \(\Delta\) and \(w\) are treated as exogenous parameters. In reality firms have some control over these variables. They can reduce the waiting costs \(w\), for example, by expediting the production process and shipping by air. They can increase \(\Delta\) by acquiring technologies that foster joint creativity during product design or reduce the difficulty of transferring customer needs into a concrete product specification.

The game unfolds in two stages. The first stage is the customization stage, in which each firm simultaneously chooses between offering the standard product (S), the customized product (C), or both standard and customized products (SC). These decisions

\[6\] By “the standard product” I mean “a variety of products to meet heterogeneous needs of consumers”
become observable after they are made. In the second stage the firms simultaneously choose prices. Consumers subsequently decide which products to purchase, and the firms’ profits are realized. The equilibrium concept employed is subgame perfect Nash equilibrium.

3 Analysis of the Pricing Stage

In this section I investigate the firms’ pricing decisions, taking as given their choices in the first stage of the game. There are nine subgames, but only six scenarios to consider: both firms choose S, both firms choose SC, both firms choose C, one firm chooses SC and the other firm S, one firm chooses C and the other firm S, and one firm chooses C and the other firm SC.

In subsequent analysis the following constraints will be placed on the parameters $v$, $t$, $w$, $\Delta$, and $\alpha$. First, I assume that the benefits from customization exceed the waiting costs $w$ at the aggregate level, but not uniformly. Algebraically,

$$
\int_0^1 \Delta(v - tx) \, dx > w
$$

and

$$
\Delta(v - t) < w.
$$

The latter inequality simply means that $\Delta(v - tx) > w$ fails to hold for consumers located further away from the customizing firm. The two inequalities can be combined into one constraint:

$$
\Delta(v - t) < w < \Delta \left( v - \frac{t}{2} \right). \quad (A1)
$$

Second, I assume competitive environment. There is enough interest in customization on the part of consumers, i.e., $\alpha$ is not too low:

$$
\alpha \geq \frac{1}{2}. \quad (A2)
$$

Also, $v$ is sufficiently high so that in equilibrium all consumers would buy a product from one of the two firms (with the exception of $1 - \alpha$ traditional consumers under the

(e.g., athletic shoes for running, basketball, hiking, fitness and training), and “the customized product” is unique for each customer.)
scenario in which both firms choose C):

\[
v \geq \max \left\{ \frac{3t}{2} + \Delta t, 2t + \frac{\Delta t}{2} \right\}.
\]  

(A3)

These parameter constraints seem reasonable; they will keep the analysis of the model focused and the results tractable.

### 3.1 Subgames (S, S) and (C, C)

Subgames (S, S) and (C, C) are straightforward. When both firms offer the standard products, the equilibrium prices and profits are as in the Hotelling linear city model. That is,

\[
p_A^{(S,S)} = p_B^{(S,S)} = c + t = t
\]

and

\[
\Pi_A^{(S,S)} = \Pi_B^{(S,S)} = \frac{t}{2}.
\]

Now suppose both firms offer the customized products. Expressions (3) and (4) can be written as

\[
(1 + \Delta)v - w - (1 + \Delta)tx - \bar{p}_A
\]

and

\[
(1 + \Delta)v - w - (1 + \Delta)t(1 - x) - \bar{p}_B.
\]

It immediately follows that in subgame (C, C) the equilibrium prices and profits are

\[
\bar{p}_A^{(C,C)} = \bar{p}_B^{(C,C)} = (1 + \Delta)t
\]

and

\[
\Pi_A^{(C,C)} = \Pi_B^{(C,C)} = \frac{\alpha(1 + \Delta)t}{2}.
\]

As the firms’ customized products are more differentiated than their standard products, price competition is less intense in subgame (C, C). Note that the profits of the firms in subgame (C, C) may be lower than in subgame (S, S), because fraction 1 − α drops out from the pool of consumers.

### 3.2 Subgame (SC, SC)

Suppose each firm offers both standard and customized products. Consumers’ optimal purchasing decisions are illustrated in Figure 1. Tech-savvy consumers from interval
[0, \hat{x}_A] will purchase firm A’s customized product and those from interval [\hat{x}_B, 1] will purchase firm B’s customized product. The rest of the tech-savvy consumers will purchase firm A’s and firm B’s standard products (intervals [\hat{x}_A, \hat{x}] and [\hat{x}, \hat{x}_B], respectively). Traditional consumers from interval [0, \hat{x}] will purchase firm A’s standard product and those from interval [\hat{x}, 1] will purchase firm B’s standard product.

Marginal type \hat{x}_A is indifferent between firm A’s customized and standard products,

\[(1 + \Delta)(v - t x) - w - \bar{p}_A = v - t x - p_A,\]

hence

\[\hat{x}_A = \frac{\Delta v - w - \bar{p}_A + p_A}{\Delta t}.\]

Similarly, marginal type \hat{x}_B is indifferent between firm B’s customized and standard products,

\[(1 + \Delta)(v - t(1 - x)) - w - \bar{p}_B = v - t(1 - x) - p_B,\]

hence

\[\hat{x}_B = 1 - \frac{\Delta v - w - \bar{p}_B + p_B}{\Delta t}.\]

Finally, marginal type \hat{x} is indifferent between firm A’s and firm B’s standard products,

\[v - t x - p_A = v - t(1 - x) - p_B,\]

so

\[\hat{x} = \frac{t - p_A + p_B}{2t}.\]

The profit functions of the firms in subgame (SC, SC) are

\[\Pi_A = \alpha \hat{x}_A \bar{p}_A + \alpha (\hat{x} - \hat{x}_A)p_A + (1 - \alpha)\hat{x}p_A\]
and
\[
\Pi_B = \alpha(1 - \hat{x}_B)\bar{p}_B + \alpha(\hat{x}_B - \hat{x})p_B + (1 - \alpha)(1 - \hat{x})p_B.
\] (9)

Maximizing \(\Pi_A\) with respect to \(p_A\) and \(\bar{p}_A\), and \(\Pi_B\) with respect to \(p_B\) and \(\bar{p}_B\) yields the equilibrium prices and profits, which are summarized in the following lemma.

**Lemma 1** (Equilibrium prices and profits in subgame (SC, SC)). *Suppose each firm offers both standard and customized products. The equilibrium prices and profits are*

\[
p_A^{(SC,SC)} = p_B^{(SC,SC)} = t,
\]

\[
\bar{p}_A^{(SC,SC)} = \bar{p}_B^{(SC,SC)} = t + \frac{\Delta v - w}{2},
\]

and

\[
\Pi_A^{(SC,SC)} = \Pi_B^{(SC,SC)} = \frac{t}{2} + \frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2.
\]

This lemma deserves a discussion. The two firms compete for marginal type \(\hat{x}\) with their standard products. Hence, \(p_A^{(SC,SC)} = p_B^{(SC,SC)} = t\) as in subgame (S, S). The firms’ customized products are isolated from direct competition.\(^7\) When setting a price for its customized product, each firm only considers the price for its standard product. Take, for example, firm A. The optimal choice of \(\bar{p}_A\) maximizes what the firm makes on top of \(\hat{x}p_A\) (if firm A offered only the standard product). That is,

\[
\max_{\bar{p}_A} \alpha\hat{x}_A(\bar{p}_A - p_A).
\] (10)

The first-order condition implies

\[
\bar{p}_A = p_A + \frac{\Delta v - w}{2},
\]

therefore

\[
\max_{\bar{p}_A} \alpha\hat{x}_A(\bar{p}_A - p_A) = \frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2.
\]

### 3.3 Subgame (SC, S)

Suppose one of the firms (say, firm A) offers both standard and customized products, and firm B only the standard product. Consumers’ optimal purchasing decisions are

\(^7\)This is in contrast to Syam and Kumar (2006) setting, in which the firms compete with their *customized* products while insulating their standard products from head-on price competition. Viewed in this manner, the present model is similar in spirit to Dewan, Jing, and Seidmann (2003). In Dewan, Jing, and Seidmann (2003) the firms’ customization scopes do not overlap by contraction, so the marginal consumer is indifferent between the firms’ standard products.
illustrated in Figure 2. Tech-savvy consumers from interval $[0, \hat{x}_A]$ will purchase firm A’s customized product. The rest of the tech-savvy consumers will purchase firm A’s and firm B’s standard products (intervals $[\hat{x}_A, \hat{x}]$ and $[\hat{x}, 1]$, respectively). Traditional consumers from interval $[0, \hat{x}]$ will purchase firm A’s standard product and those from interval $[\hat{x}, 1]$ will purchase firm B’s standard product.

Marginal types $\hat{x}_A$ and $\hat{x}$ are determined by the same indifference conditions as in subgame (SC, SC) (equations 5 and 7), hence

$$\hat{x}_A = \frac{\Delta v - w - \bar{p}_A + p_A}{\Delta t}$$

and

$$\hat{x} = \frac{t - p_A + p_B}{2t}.$$  

The profit functions of the firms in subgame (SC, S) are

$$\Pi_A = \alpha \hat{x}_A \bar{p}_A + \alpha (\hat{x} - \hat{x}_A)p_A + (1 - \alpha)\hat{x}p_A$$  \hspace{1cm} (11)

and

$$\Pi_B = (1 - \hat{x})p_B.$$  \hspace{1cm} (12)

Maximizing (11) with respect to $p_A$ and $\bar{p}_A$, and (12) with respect to $p_B$ yields the equilibrium prices and profits.

**Lemma 2** (Equilibrium prices and profits in subgame (SC, S)). *Suppose firm A offers both standard and customized products, and firm B offers the standard product. The equilibrium prices and profits are*

$$p_A^{(SC,S)} = p_B^{(SC,S)} = t.$$
Figure 3: Market shares in subgame (C, S)

\[ p_A^{(SC,S)} = t + \frac{\Delta v - w}{2}, \]
\[ \Pi_A^{(SC,S)} = \frac{t}{2} + \frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2, \]

and
\[ \Pi_B^{(SC,S)} = \frac{t}{2}. \]

The equilibrium prices in subgame (SC, C) are the same as in subgame (SC, SC). This is because in both subgames the firms compete with their standard products. As a result, in equilibrium the firms charge \( t \) for them. When setting a price for its customized product, firm A faces optimization problem (10). Hence, \( p_A^{(SC,S)} = t + (\Delta v - w)/2. \)

### 3.4 Subgame (C, S)

Suppose one of the firms (say, firm A) offers the customized product and firm B the standard product. Tech-savvy consumers from interval \([0, \hat{x}]\) will purchase firm A’s customized product, the rest will purchase firm B’s standard product. All traditional consumers will purchase firm B’s standard product. (See Figure 3.)

Marginal type \( \hat{x} \) is indifferent between firm A’s customized product and firm B’s standard product,

\[ (1 + \Delta)(v - tx) - w - \bar{p}_A = v - t(1 - x) - p_B, \]

hence
\[ \hat{x} = \frac{\Delta v - w + t - \bar{p}_A + p_B}{(2 + \Delta)t}. \]
The profit functions of the firms in subgame (C, S) are

\[ \Pi_A = \alpha \hat{x} \bar{p}_A \]  

(14)

and

\[ \Pi_B = \alpha (1 - \hat{x}) p_B + (1 - \alpha) p_B. \]  

(15)

Maximizing (14) with respect to \( p_A \) and (15) with respect to \( p_B \) leads to Lemma 3.

**Lemma 3** (Equilibrium prices and profits in subgame (C, S)). Suppose firm A offers the customized product and firm B offers the standard product. The equilibrium prices and profits are

\[ \bar{p}_A^{(C,S)} = \frac{(2 + \Delta)t}{3\alpha} + \frac{\Delta v - w + t}{3}, \]

\[ p_B^{(C,S)} = \frac{2(2 + \Delta)t}{3\alpha} - \frac{\Delta v - w + t}{3}, \]

\[ \Pi_A^{(C,S)} = \frac{\alpha}{2(2 + \Delta)t} \left( \frac{(2 + \Delta)t}{3\alpha} + \frac{\Delta v - w + t}{3} \right)^2, \]

and

\[ \Pi_B^{(C,S)} = \frac{\alpha}{2(2 + \Delta)t} \left( \frac{2(2 + \Delta)t}{3\alpha} - \frac{\Delta v - w + t}{3} \right)^2. \]

Firm A competes with its customized product and firm B with its standard product. These two products are more differentiated than the standard products in subgames (S, S), (SC, SC), or (SC, S), hence price competition is less intense. Indeed, it can be shown that for any \( \alpha, w, \) and \( v \) satisfying (A1) through (A3), both \( \bar{p}_A^{(C,S)} \) and \( p_B^{(C,S)} \) exceed \( t \).

How does \( \alpha \), the fraction of tech-savvy consumers, affect the firms’ equilibrium prices and profits in subgame (C, S)? For comparison, recall that in subgame (SC, SC) the equilibrium prices do not depend on \( \alpha \) and the equilibrium profits increase in \( \alpha \). Lemma 3 implies that both \( \bar{p}_A^{(C,S)} \) and \( p_B^{(C,S)} \) decrease in \( \alpha \). The intuition is as follows. The firms compete with each other only for tech-savvy consumers of mass \( \alpha \). Traditional consumers of mass \( 1 - \alpha \) all purchase from firm B. The smaller the number of traditional consumers is, the more aggressively firm B competes with firm A for tech-savvy consumers, resulting in lower equilibrium prices.

In equilibrium firm A serves

\[ \alpha \hat{x} = \frac{1}{3} + \frac{\alpha(\Delta v - w + t)}{3(2 + \Delta)t} \]

customers, and firm B serves the rest. It is easy to see that firm A’s market share increases in \( \alpha \), implying that firm B’s market share decreases in \( \alpha \). It follows that the
profit of the non-customizing firm B decreases in the fraction of tech-savvy consumers. This result conforms with economic intuition. It is interesting that the profit of the customizing firm A also decreases in the fraction of tech-savvy consumers. (See the Appendix for the proof of this result.) The reason is that firm A’s market share increases in $\alpha$ at a slower rate than $\bar{p}_{A}^{(C,S)}$ decreases.

### 3.5 Subgame (C, SC)

Suppose one of the firms (say, firm A) offers the customized product, and firm B both standard and customized products. Two different purchasing patterns arise in this subgame, depending on the value of the waiting costs $w$. Figure 4 illustrates consumers’ optimal purchasing decisions when the waiting costs are high. Tech-savvy consumers from interval $[0, \hat{x}]$ will purchase firm A’s customized product. The rest of the tech-savvy consumers will purchase firm B’s standard and customized products (intervals $[\hat{x}, \hat{x}_B]$ and $[\hat{x}_B, 1]$, respectively). All traditional consumers will purchase firm B’s standard product.

Marginal types $\hat{x}_B$ and $\hat{x}$ are determined by the indifference conditions (6) and (13), hence

$$\hat{x}_B = 1 - \frac{\Delta v - w - \bar{p}_B + p_B}{\Delta t}$$

and

$$\hat{x} = \frac{\Delta v - w + t - \bar{p}_A + p_B}{(2 + \Delta)t}.$$  

The profit functions of the firms are

$$\Pi_A = \alpha \hat{x} \bar{p}_A$$  

(16)
and
\[ \Pi_B = \alpha(1 - \hat{x}_B)\bar{p}_B + \alpha(\hat{x}_B - \hat{x})p_B + (1 - \alpha)p_B. \]  
(17)

Maximizing (16) with respect to \( \bar{p}_A \) and (17) with respect to \( p_B \) and \( \bar{p}_B \) yields the equilibrium prices and profits.

**Lemma 4** (Equilibrium prices and profits in subgame \((C, SC)\) when \( w \) is high). Suppose firm A offers the customized product, and firm B offers both standard and customized products. If the waiting costs are high, the equilibrium prices and profits are

\[
\begin{align*}
\bar{p}_A^{(C, SC)} &= \frac{(2 + \Delta)t}{3\alpha} + \frac{\Delta v - w + t}{3}, \\
p_B^{(C, SC)} &= \frac{2(2 + \Delta)t}{3\alpha} - \frac{\Delta v - w + t}{3}, \\
\bar{p}_B^{(C, SC)} &= p_B^{(C, SC)} + \frac{\Delta v - w}{2}, \\
\Pi_A^{(C, SC)} &= \frac{\alpha}{(2 + \Delta)t} \left( \frac{(2 + \Delta)t}{3\alpha} + \frac{\Delta v - w + t}{3} \right)^2, \\
\Pi_B^{(C, SC)} &= \frac{\alpha}{(2 + \Delta)t} \left( \frac{2(2 + \Delta)t}{3\alpha} - \frac{\Delta v - w + t}{3} \right)^2 + \frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2.
\end{align*}
\]

It follows that \( \bar{p}_A^{(C, SC)} \) and \( p_B^{(C, SC)} \) are the same as in subgame \((C, S)\). This is because when \( w \) is high, in subgames \((C, SC)\) and \((C, S)\) firm A competes with its customized product and firm B with its standard product. When setting a price for its customized product, firm B only considers the price for its standard product, hence \( \bar{p}_B^{(C, SC)} = p_B^{(C, SC)} + (\Delta v - w)/2 \) (see the discussion after Lemma 1).

In the previous subsection it was shown that both \( \Pi_A^{(C, S)} \) and \( \Pi_B^{(C, S)} \) are decreasing functions of \( \alpha \). Since \( \Pi_A^{(C, SC)} = \Pi_A^{(C, S)} \) when \( w \) is high, \( \Pi_A^{(C, SC)} \) decreases in \( \alpha \) as well. As to firm B, despite the extra profit

\[ \frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2 \]

that it makes in subgame \((C, SC)\) compared with subgame \((C, S)\), \( \Pi_B^{(C, SC)} \) is still a decreasing function of \( \alpha \). (See the Appendix for the proof.)

Figure 5 illustrates consumers’ optimal purchasing decisions when the waiting costs are low. Tech-savvy consumers from interval \([0, \hat{x}]\) will purchase firm A’s customized product. The rest of the tech-savvy consumers will purchase firm B’s customized prod-
uct. All traditional consumers will purchase firm B’s standard product. Marginal type \( \hat{x} \) is indifferent between firm A’s and firm B’s customized products,

\[
(1 + \Delta)(v - tx) - w - \bar{p}_A = (1 + \Delta)(v - t(1 - x)) - w - \bar{p}_B,
\]

hence

\[
\hat{x} = \frac{(1 + \Delta)t - \bar{p}_A + \bar{p}_B}{2(1 + \Delta)t}.
\]

The profit functions of the firms are

\[
\Pi_A = \alpha \hat{x} \bar{p}_A \tag{18}
\]

and

\[
\Pi_B = \alpha(1 - \hat{x})\bar{p}_B + (1 - \alpha)p_B. \tag{19}
\]

Maximizing (18) and (19) leads to the following lemma.

**Lemma 5** (Equilibrium prices and profits in subgame (C, SC) when \( w \) is low). Suppose firm A offers the customized product, and firm B offers both standard and customized products. If the waiting costs are low, the equilibrium prices and profits are

\[
\bar{p}_A^{(C,SC)} = \bar{p}_B^{(C,SC)} = (1 + \Delta)t,
\]

\[
\bar{p}_B^{(C,SC)} = v - t,
\]

\[
\Pi_A^{(C,SC)} = \frac{\alpha(1 + \Delta)t}{2},
\]

and

\[
\Pi_B^{(C,SC)} = \frac{\alpha(1 + \Delta)t}{2} + (1 - \alpha)(v - t).
\]
The two firms compete with their customized products. As a result, \( \bar{p}_A^{(C,SC)} = \bar{p}_B^{(C,SC)} = (1 + \Delta)t \) as in subgame (C, C). Firm B does not face any competition for its standard product, so it sets \( p_B^{(C,SC)} \) to \( v - t \), extracting full surplus from the consumer located at 0.

Lemma 5 implies that firm A’s profit increases in the fraction of tech-savvy consumers \( \alpha \), whereas firm B’s profit decreases in \( \alpha \). This is different from the results obtained for high \( w \).

Having derived the profit functions for the pricing stage, we move one step back to study the customization stage.

4 Equilibrium Choices of Product Strategies

In the customization stage each firm simultaneously decides whether to offer the standard product, the customized product, or both. The strategic form of this game is given by

<table>
<thead>
<tr>
<th>Firm A</th>
<th>S</th>
<th>SC</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>( \Pi_A^{(S,S)}, \Pi_B^{(S,S)} )</td>
<td>( \Pi_A^{(S,SC)}, \Pi_B^{(S,SC)} - K )</td>
<td>( \Pi_A^{(S,C)}, \Pi_B^{(S,C)} - K )</td>
</tr>
<tr>
<td>SC</td>
<td>( \Pi_A^{(SC,S)} - K, \Pi_B^{(SC,S)} )</td>
<td>( \Pi_A^{(SC,SC)} - K, \Pi_B^{(SC,SC)} - K )</td>
<td>( \Pi_A^{(SC,C)} - K, \Pi_B^{(SC,C)} - K )</td>
</tr>
<tr>
<td>C</td>
<td>( \Pi_A^{(C,S)} - K, \Pi_B^{(C,S)} )</td>
<td>( \Pi_A^{(C,SC)} - K, \Pi_B^{(C,SC)} - K )</td>
<td>( \Pi_A^{(C,C)} - K, \Pi_B^{(C,C)} - K )</td>
</tr>
</tbody>
</table>

where \( K \) is the fixed cost of customization. To focus on competitive effects of customization, I will consider \( K = 0 \). I will relax this assumption in Subsection 4.3.

It is easy to see that (S, S), (S, SC) and (SC, S) cannot occur in equilibrium. In all these subgames the firms compete with their standard products, so \( \bar{p}_A = \bar{p}_B = t \). Whichever firm offers the standard product will benefit from offering the customized product as well. Indeed, a deviation from S to SC will not affect the competition between the firms’ standard products, but will allow the deviating firm to sell the customized product to its most loyal customers at a higher price, resulting in

\[
\frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2
\]

increase in profit. (See the discussion after Lemma 1.)

In the spirit of constraint (A1), I will consider two values for the waiting costs, \( w = \Delta(v - t/2) \) and \( w = \Delta(v - t) \). The smaller the waiting costs, the more time efficient is the production of customized products. Thus, I will refer to \( w = \Delta(v - t/2) \) as the case of marginally efficient customization technology and to \( w = \Delta(v - t) \) as highly
efficient customization technology.

Another reason for considering these two values is that they lead to different purchasing patterns in subgames (C, SC) and (SC, C). Namely, Figure 4 and the results of Lemma 4 correspond to marginally efficient customization technology, whereas Figure 5 and the results of Lemma 5 to highly efficient customization technology.

4.1 Marginally Efficient Customization Technology

In this subsection we derive the firms’ equilibrium choices of product strategies when \( w = \Delta(v - t/2) \).

First note that (C, S) and (S, C) cannot occur in equilibrium, for the reason mentioned earlier: Whichever firm offers the standard product will benefit from offering the customized product as well. Consider, for example, subgame (C, S). Firm B’s profit will increase by

\[
\frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2
\]

if it switches from S to SC, as such deviation will not affect the competition between firm A’s customized product and firm B’s standard product (see Lemmas 3 and 4).

Straightforward calculations show that when \( w = \Delta(v - t/2) \),

\[
\Pi_A^{(C,SC)} = \alpha(2 + \Delta) \left( \frac{1}{3\alpha} + \frac{1}{6} \right)^2 t > \Pi_A^{(SC,SC)} = \frac{t}{2} + \frac{\alpha\Delta t}{16}
\]

holds for any \( \alpha \) satisfying (A2). (See the proof of Proposition 1 in the Appendix.) Hence, (SC, SC) cannot occur in equilibrium. The intuition behind this result is as follows. When firm A switches from SC to C, the competition becomes less intense. For firm A, the positive effect of less intense price competition overwhelms the negative effect of losing traditional consumers as customers.

Finally, let us compare \( \Pi_B^{(C,SC)} \) with \( \Pi_B^{(C,C)} \) when \( w = \Delta(v - t/2) \). The inequality

\[
\Pi_B^{(C,SC)} = \alpha(2 + \Delta) \left( \frac{2}{3\alpha} - \frac{1}{6} \right)^2 t + \frac{\alpha\Delta t}{16} > \Pi_B^{(C,C)} = \frac{\alpha(1 + \Delta)t}{2}.
\]

holds for \( \alpha = 1/2 \), but fails for \( \alpha = 1 \). Let \( \alpha^* \) denote the critical value of \( \alpha \). Hence, we have the following proposition.

**Proposition 1** (Equilibrium choices of product strategies when \( w = \Delta(v - t/2) \)). In the case of marginally efficient customization technology, the pure-strategy Nash equilibrium is (C, SC) or (SC, C) if \( \alpha < \alpha^* \) and (C, C) if \( \alpha > \alpha^* \).
The explicit expression of $\alpha^*$ can be found in the Appendix.

4.2 Highly Efficient Customization Technology

In this subsection we derive the firms’ equilibrium choices of product strategies in the case of highly efficient customization technology, $w = \Delta(v - t)$.

Obviously, (C, C) cannot occur in equilibrium. Consider, for example, firm B. If firm B offers the standard product in addition to its customized products, the competition between the firms’ customized products will not be affected (see the discussion after Lemma 5). Firm B’s profit will increase by $(1 - \alpha)(v - t)$ due to traditional customers.

Straightforward calculations show that when $w = \Delta(v - t)$,

$$\Pi^{(C, SC)}_B = \frac{\alpha(1 + \Delta)t}{2} + (1 - \alpha)(v - t) > \Pi^{(C, S)}_B = \frac{\alpha}{2 + \Delta} \left( \frac{2(2 + \Delta)}{3\alpha} - \frac{1 + \Delta}{3} \right)^2 t$$

holds for any $\alpha$ and $v$ satisfying (A2) and (A3). It follows that (C, S) cannot occur in equilibrium. The same applies to (S, C).

Finally, we compare $\Pi^{(C, SC)}_A$ with $\Pi^{(SC, SC)}_A$ when $w = \Delta(v - t)$. The inequality

$$\Pi^{(C, SC)}_A = \frac{\alpha(1 + \Delta)t}{2} + (1 - \alpha)(v - t) > \Pi^{(SC, SC)}_A = \frac{t}{2} + \frac{\alpha\Delta t}{4}$$

is equivalent to

$$\alpha < \frac{v - \frac{3t}{2}}{v - \frac{3t}{2} - \frac{\Delta t}{4}}$$

which holds for any $\alpha$ and $v$ satisfying (A2) and (A3). Therefore, (SC, SC) cannot occur in equilibrium.

Proposition 2 (Equilibrium choices of product strategies when $w = \Delta(v - t)$). In the case of highly efficient customization technology, the pure-strategy Nash equilibrium is (C, SC) or (SC, C).

4.3 Fixed Cost of Customization

In this subsection I consider $K > 0$. First note that (SC, SC) cannot occur in equilibrium for any value of $K$, since it was shown earlier that $\Pi^{(C, SC)}_A > \Pi^{(SC, SC)}_A$, hence

$$\Pi^{(C, SC)}_A - K > \Pi^{(SC, SC)}_A - K.$$
(SC, S) and (S, SC) cannot occur in equilibrium either: Straightforward calculations (see the Appendix) confirm that \( \Pi_A^{(C,S)} > \Pi_A^{(SC,S)} \), hence

\[
\Pi_A^{(C,S)} - K > \Pi_A^{(SC,S)} - K.
\]

Therefore, in the case of marginally efficient customization technology and \( \alpha < \alpha^* \), or in the case of highly efficient technology we have

\[
\begin{align*}
(S, S) \quad & \text{is a NE if } \begin{cases}
K > \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \\
K \in \left( \Pi_B^{(C,SC)} - \Pi_B^{(C,S)}, \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \right) \\
K < \Pi_B^{(C,SC)} - \Pi_B^{(C,S)}
\end{cases} \\
(C, S) \text{ or } (S, C) \quad & \text{is a NE if } \begin{cases}
K > \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \\
K \in \left( \Pi_B^{(C,C)} - \Pi_B^{(C,S)}, \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \right) \\
K < \Pi_B^{(C,C)} - \Pi_B^{(C,S)}
\end{cases}
\end{align*}
\]

In the case of marginally efficient technology and \( \alpha > \alpha^* \) we have

\[
\begin{align*}
(S, S) \quad & \text{is a NE if } \begin{cases}
K > \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \\
K \in \left( \Pi_B^{(C,C)} - \Pi_B^{(C,S)}, \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \right) \\
K < \Pi_B^{(C,C)} - \Pi_B^{(C,S)}
\end{cases} \\
(C, S) \text{ or } (S, C) \quad & \text{is a NE if } \begin{cases}
K > \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \\
K \in \left( \Pi_B^{(C,SC)} - \Pi_B^{(C,S)}, \Pi_A^{(C,S)} - \Pi_A^{(S,S)} \right) \\
K < \Pi_B^{(C,SC)} - \Pi_B^{(C,S)}
\end{cases}
\end{align*}
\]

### 4.4 Summary of the Results

Let me summarize the main results of the equilibrium analysis.

- When the waiting costs are high, the equilibrium changes from (C, SC) or (SC, C) to (C, C) as the fraction of tech-savvy consumers \( \alpha \) increases. The intuition behind this result is as follows. Consider, for example, subgame (C, SC). The competition is between firm A’s customized product and firm B’s standard product. When considering offering only the customized product, firm B faces the tradeoff between less intense price competition and losing traditional consumers as customers. The former overwhelms the latter when the fraction of tech-savvy consumers is high.

- When the waiting costs are low, the equilibrium is (C, SC) or (SC, C). (C, C) cannot occur in equilibrium. This is because in subgames (C, SC) and (SC, C) the competition is between the firms’ customized products, and hence, is already relaxed. Whichever firm offers both products does not benefit from offering only the customized product, as it will lose traditional customers without affecting price competition.

- The result that (C, C) can occur in equilibrium when customization technology is marginally efficient, but cannot when it is highly efficient, is intriguing. What
drives this result are two different purchasing patterns in subgame (C, SC) (as well as in subgame (SC, C)). When the waiting costs are high, not all tech-savvy consumers purchase customized products in equilibrium (Figure 4). Those who do not favor either of the brands (the middle segment) benefit less from customization; they find $w$ too high, and hence purchase firm B’s standard product. When the waiting costs are low, all tech-savvy consumers purchase customized products (Figure 5). The latter pattern implies less intense price competition than the former.

- Another interesting result is that (SC, SC) – the scenario in which both firms offer standard and customized products – does not arise in equilibrium. This is a consequence of firms avoiding head-on competition with their standard products.

- How does an increase in the fraction of tech-savvy consumers affect the firms’ equilibrium prices and profits? If (C, C) obtains in equilibrium, the prices remain the same and the profits increase. If (C, SC) or (SC, C) obtains in equilibrium, the profit of the firm that offers both standard and customized product decreases, whereas the profit of the firm that offers only the customized product may decrease (in the case of marginally efficient customization technology) or increase (in the case of highly efficient customization technology). As to the equilibrium prices, they decrease in the case of marginally efficient technology and remain the same in the case of highly efficient technology.

- If the fixed cost of customization $K$ is substantial, but not prohibitive, then the equilibrium will be (C, S) or (S, C). In other words, only one firm will offer the customized product. Moreover, the customizing firm will not offer the standard product in addition to the customized product. This is because the competition in subgame (C, S) is less intense than in subgame (SC, S) (and the competition in subgame (S, C) is less intense than in subgame (S, SC)).

5 Concluding Remarks

The present paper is the first one to model consumer interactive involvement in product design. This aspect of mass customization has never been the focus of the theoretical literature. I incorporated benefits and drawbacks of customer co-design activities – enjoyable shopping experience, difficulties in transferring individual needs into appropriate product characteristics, waiting costs – into customization competition.
The paper also views the standard product offerings in a manner different from most of the existing theoretical studies on customization. Each firm initially produces a range of standard products, so every consumer can find a reasonably well-fitting product to suit his/her individual needs. The competing firms may end up offering very similar standard products: The differences between Nike’s and Adidas’ running shoes are far smaller than the differences between running and basketball shoes made by Nike, and the differences between geometries of the 56-cm frames produced by Specialized and Trek bike manufacturers are smaller than the differences between the 56-cm and 48-cm frames made by Trek. At this point, the only distinction in the eye of the consumer is the brand name attached to these products. Therefore, in my model consumer heterogeneity on the Hotelling line is interpreted as variability in preferences for brand, rather than product attributes.

The new modeling ideas were motivated by, and aimed at explaining, the predominant findings in the operations management literature that customization softens price competition because affective bonds are formed between the firm and its customers as a result of consumer interactive involvement in co-design activities. These findings apparently contradict the theoretical literature that maintains that customization reduces product differentiation and intensifies price competition. The importance of the present study is that it provides a theoretical model consistent with the phenomena described in the operations management literature.

Other findings of this paper may also be useful. As mass customization is an emerging business strategy, one might want to know how the level of consumer readiness for customization affects firms’ customization choices and prices. I conducted a comparative statics analysis with respect to the key parameters of the model that revealed a number of interesting results.

Appendix

Proof of Lemma 1:

The first-order conditions for (8) and (9)

\[
\begin{align*}
\frac{\partial \Pi_A}{\partial p_A} &= 0 \\
\frac{\partial \Pi_A}{\partial \bar{p}_A} &= 0 \\
\frac{\partial \Pi_B}{\partial p_B} &= 0 \\
\frac{\partial \Pi_B}{\partial \bar{p}_B} &= 0
\end{align*}
\]
yield the equilibrium prices in Lemma 1. We then substitute the equilibrium prices into
the profit functions of the firms to get the equilibrium profits.

The equilibrium value of \( \hat{\alpha} \) is \( \frac{1}{2} \). We need to check that the equilibrium
value of \( \hat{x}_A \) is between 0 and \( \frac{1}{2} \). In fact, it can be shown that \( \hat{x}_A \) \( (SC,SC) \) \( \in (1/4, 1/2) \). Indeed,

\[
\hat{x}_A^{SC,SC} = \frac{\Delta v - w}{2\Delta t} > \frac{1}{4} \iff w < \Delta (v - \frac{t}{2}),
\]

and

\[
\frac{\Delta v - w}{2\Delta t} < \frac{1}{2} \iff w > \Delta(v - t)
\]

holds by (A1). Finally, we check that the consumer located at \( 1/2 \) receives a positive
payoff:

\[
v - \frac{t}{2} - p_A^{SC,SC} = v - \frac{3t}{2} > 0
\]

holds by (A3).

**Proof of Lemma 2:**

See the proof of Lemma 1 and the discussion following Lemma 2.

**Proof of Lemma 3:**

The first-order conditions for (14) and (15)

\[
\begin{align*}
\frac{\partial \Pi_A}{\partial \bar{p}_A} &= 0 \\
\frac{\partial \Pi_B}{\partial p_B} &= 0
\end{align*}
\]

yield the equilibrium prices and profits in Lemma 3.

We need to check that the equilibrium value of \( \hat{x} \) is between 0 and 1. In fact, it can
be shown that \( \hat{x}^{C,S} \) \( \in (1/2, 1) \). Indeed, by (A1),

\[
\hat{x}^{C,S} = \frac{1}{3\alpha} + \frac{\Delta v - w + t}{3(2 + \Delta)t} > \frac{1}{3\alpha} + \frac{\Delta v - \Delta (v - \frac{t}{2}) + t}{3(2 + \Delta)t} = \frac{1}{3\alpha} + \frac{1}{6} > \frac{1}{2}.
\]

By (A1) and (A2),

\[
\frac{1}{3\alpha} + \frac{\Delta v - w + t}{3(2 + \Delta)t} < \frac{2}{3} + \frac{\Delta v - \Delta(v - t) + t}{3(2 + \Delta)t} = \frac{2}{3} + \frac{1 + \Delta}{2 + \Delta} < \frac{2}{3} + \frac{1}{3} = 1.
\]

Straightforward calculations verify that under assumptions (A1) through (A3) the tra-
ditional consumer located at 0 receives positive payoff in equilibrium.

**Proof of** \( \partial \Pi_A^{(C,S)}/\partial \alpha < 0: \)

Differentiating

\[
\Pi_A^{(C,S)} = \frac{\alpha}{(2 + \Delta)t} \left( \frac{(2 + \Delta)t}{3\alpha} + \frac{\Delta v - w + t}{3} \right)^2
\]

with respect to \( \alpha \) yields

\[
\frac{\partial}{\partial \alpha} \Pi_A^{(C,S)} = \frac{1}{9(2 + \Delta)t} \left( \frac{(2 + \Delta)^2 t^2}{\alpha^2} + (\Delta v - w + t)^2 \right).
\]

This is negative since by (A1)

\[
-\frac{(2 + \Delta)^2 t^2}{\alpha^2} + (\Delta v - w + t)^2 < -(2 + \Delta)^2 t^2 + (\Delta v - (v - t) + t)^2 = -(3 + 2\Delta)t^2 < 0.
\]

**Proof of Lemma 4:**

The first-order conditions for (16) and (17)

\[
\begin{cases}
\frac{\partial \Pi_A}{\partial \bar{p}_A} = 0 \\
\frac{\partial \Pi_A}{\partial p_B} = 0 \\
\frac{\partial \Pi_B}{\partial \bar{p}_B} = 0
\end{cases}
\]

yield the equilibrium prices and profits in Lemma 4.

The equilibrium value of \( \hat{x} \) is the same as in subgame (C, S), hence it is between 1/2 and 1. It is left to check that

\[
\hat{x}^{(C, SC)} = \frac{1}{3\alpha} + \frac{\Delta v - w + t}{3(2 + \Delta)t} < \hat{x}^{(C, SC)} = 1 - \frac{\Delta v - w}{2\Delta t}
\]

holds for high values of \( w \). Indeed, this inequality holds for any \( \alpha \) satisfying (A2) if we set \( w \) to its upper bound \( \Delta(v - t/2): \)

\[
\frac{1}{3\alpha} + \frac{\Delta v - \Delta(v - t/2) + t}{3(2 + \Delta)t} < 1 - \frac{\Delta v - \Delta(v - t/2)}{2\Delta t}.
\]

\[
\frac{1}{3\alpha} + \frac{1}{6} < 1 - \frac{1}{4}, \quad \alpha > \frac{7}{5}.
\]
The inequality is reversed if \( w = \Delta(v - t) \):

\[
\frac{1}{3\alpha} + \frac{\Delta v - \Delta(v - t) + t}{3(2 + \Delta)t} > 1 - \frac{\Delta v - \Delta(v - t)}{2\Delta t},
\]

\[
\frac{1}{3\alpha} + \frac{1 + \Delta}{3(2 + \Delta)} > 1 - \frac{1}{2},
\]

\[\alpha < \frac{6 + 3\Delta}{4 + \Delta}.\]

**Proof of \( \partial \Pi^{C,SC}_B / \partial \alpha < 0 \):**

Differentiating

\[
\Pi^{C,SC}_B = \frac{\alpha}{(2 + \Delta)t} \left( \frac{2(2 + \Delta)t}{3\alpha} - \frac{\Delta v - w + t}{3} \right)^2 + \frac{\alpha}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2
\]

with respect to \( \alpha \) yields

\[
\frac{\partial}{\partial \alpha} \Pi^{C,SC}_B = \frac{1}{9(2 + \Delta)t} \left( -\frac{4(2 + \Delta)^2 t^2}{\alpha^2} + (\Delta v - w + t)^2 \right) + \frac{1}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2.
\]

By (A1),

\[
\frac{\partial}{\partial \alpha} \Pi^{C,SC}_B < \frac{-4(2 + \Delta)^2 t^2 + (\Delta v - \Delta(v - t) + t)^2}{9(2 + \Delta)t} + \frac{1}{\Delta t} \left( \frac{\Delta v - \Delta(v - t)}{2} \right)^2
\]

\[
= \frac{-4(2 + \Delta)^2 t^2 + (1 + \Delta)^2 t}{9(2 + \Delta)} + \frac{\Delta t}{4}
\]

\[= \frac{-\Delta^2 + 6\Delta + 20}{12(2 + \Delta)} t < 0.\]

**Proof of Lemma 5:**

The first-order conditions for (18) and (19) yield the equilibrium prices and profits in Lemma 5.

The equilibrium value of \( \hat{x} \) is \( \hat{x}^{C,SC} = 1/2 \). We need to check that, if the waiting costs are low, the tech-savvy consumer located at 1/2 receives a higher payoff from purchasing firm A’s customized product than firm B’s standard product:

\[
(1 + \Delta) \left( v - \frac{t}{2} \right) - \bar{p}_A^{C,SC} - w > v - \frac{t}{2} - \bar{p}_B^{C,SC}.
\]
Indeed, setting $w$ to its lower bound $\Delta(v - t)$ yields

$$(1 + \Delta)\left(v - \frac{t}{2}\right) - (1 + \Delta)t - \Delta(v - t) > v - \frac{t}{2} - (v - t),$$

$$v > 2t + \frac{\Delta t}{2},$$

which holds by (A3).

**Proof of Proposition 1:**

The discussion preceding Proposition 1 constitutes the proof. It is left to show that

$$\Pi_{A}^{(C,SC)} = \alpha(2 + \Delta)\left(\frac{1}{3\alpha} + \frac{1}{6}\right)^{2} t > \Pi_{A}^{(SC,SC)} = \frac{t}{2} + \frac{\alpha \Delta t}{16}.$$ 

Since the left-hand side of the inequality decreases in $\alpha$ and the right-hand side increases, it is sufficient to show that it holds for $\alpha = 1$:

$$(2 + \Delta)\left(\frac{1}{3} + \frac{1}{6}\right)^{2} t > t + \frac{\Delta t}{16},$$

$$\frac{t}{2} + \frac{\Delta t}{4} > \frac{t}{2} + \frac{\Delta t}{16}.$$ 

Next, the critical value of $\alpha$, $\alpha^*$, is the solution to

$$\alpha(2 + \Delta)\left(\frac{2}{3\alpha} - \frac{1}{6}\right)^{2} t + \frac{\alpha \Delta t}{16} = \frac{\alpha(1 + \Delta)}{2},$$

or

$$\alpha^* = \frac{8}{2 + 3\sqrt{\frac{8 + 7\Delta}{2 + \Delta}}}.$$ 

**Proof of Proposition 2:**

The discussion preceding Proposition 2 constitutes the proof.
Proof of $\Pi_A^{(C,S)} > \Pi_A^{(SC,S)}$:

Since $\Pi_A^{(C,S)}$ decreases in $\alpha$ and $\Pi_A^{(SC,S)}$ increases in $\alpha$, we need to check that $\Pi_A^{(C,S)} > \Pi_A^{(SC,S)}$ for $\alpha = 1$:

$$\frac{1}{(2 + \Delta)t} \left( \frac{(2 + \Delta)t}{3} + \frac{\Delta v - w + t}{3} \right)^2 > \frac{t}{2} + \frac{1}{\Delta t} \left( \frac{\Delta v - w}{2} \right)^2.$$

In the case of $w = \Delta(v - t/2)$ the inequality becomes

$$\frac{1}{(2 + \Delta)t} \left( \frac{(2 + \Delta)t}{3} + \frac{(2 + \Delta)t}{6} \right)^2 > \frac{t}{2} + \frac{1}{\Delta t} \left( \frac{\Delta t}{4} \right)^2,$$

or

$$\frac{t}{2} + \frac{\Delta t}{4} > \frac{t}{2} + \frac{\Delta t}{16}.$$

In the case of $w = \Delta(v - t)$ the inequality becomes

$$\frac{1}{(2 + \Delta)t} \left( \frac{(2 + \Delta)t}{3} + \frac{(1 + \Delta)t}{3} \right)^2 > \frac{t}{2} + \frac{1}{\Delta t} \left( \frac{\Delta t}{2} \right)^2,$$

or

$$\frac{t}{2} + \frac{\Delta t}{3} + \frac{(3\Delta + 2\Delta^2)t}{18(2 + \Delta)} > \frac{t}{2} + \frac{\Delta t}{4}.$$

References


