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ACHIEVING FIRST-MOVER ADVANTAGE THROUGH PRODUCT CUSTOMIZATION ON THE INTERNET

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Abstract

The Internet provides an unprecedented capability for sellers to learn about their customers and offer custom products at special prices. Advanced manufacturing technologies have improved sellers' manufacturing flexibility. To examine how these advances affect sellers' products and pricing, we first develop a model of product customization and flexible pricing to incorporate the salient roles of the Internet and flexible manufacturing technologies in reducing the costs of designing and producing tailored consumer goods.

Simultaneous adoption of customization in a duopoly will lead to reduced product differentiation but will not facilitate the price competition between their standard products. Consumer surplus improves after sellers adopt customization but does not always increase as technologies advance. When firms face a fixed entry cost and adopt customization sequentially, the first entrant always achieves a profit advantage and may even deter the entry of the second entrant by choosing his customization scope strategically.

Keywords: Mass customization, price discrimination, product differentiation, Internet economics

1. INTRODUCTION

New information technologies including the Internet are transforming the dynamics of marketing consumer goods. The Internet and consumer tracking technologies such as online registration, cookies, and collaborative filtering allow sellers to better understand each individual customer's taste at very low costs. The ease of collecting consumer preference information makes large-scale custom product design a reality in many product categories. Not surprisingly, mass customization has begun eroding the domain conventionally dominated by mass-produced standard items.

Flexible or discriminatory pricing has also become ubiquitous on the Internet because the considerable costs of implementing multiple prices (the so-called *menu costs*) in brick-and-mortar stores have essentially disappeared in today's electronic market (*Business Week* 1998, 2000). Meanwhile, advances in flexible manufacturing systems (FMS), computer aided design/manufacturing (CAD/CAM), and just-in-time (JIT) have provided a new production choice by trading off the efficiency of assembly lines and the flexibility of non-integrated machines tools in a job shop (Gerwin 1982; Seidmann 1993). This improvement in manufacturing flexibility allows mass customization of consumer products without significantly reducing cost efficiency. Reduced menu costs and customized products allow sellers to price discriminatorily and charge a price premium because personalized product features better comply with buyers' tastes.

Many firms are already customizing and price differentiating their products. Ford offers a Buyer Connection program through which buyers can "design" their own cars. Computer vendors such as Dell and Compaq allow customers to configure their own machines online. Apparel vendor Gap.com takes custom orders besides offering clothes of standard sizes and colors.

There exists abundant empirical or qualitative literature regarding the various substantial impacts of the Internet on a firm's product and marketing strategies (Hagel and Rayport 1997; Pine et al. 1995; Rayport and Sviokla 1994). However, related analytical research is still rare and mostly focuses on the effects of reduced buyer search costs on market-price equilibrium (Bakos 1997; Lal and Sarvary 1999). Extending the classic model of Salop (1979), our current paper incorporates the prominent features of the above-discussed new technologies and investigates their impacts on a firm's product and pricing strategies. In particular, we show how reduced costs of collecting information about customer preferences and flexible manufacturing can enable firms to offer custom products and achieve a first-mover advantage for the early adopters. The following issues relating to product customization are the focus of this paper:

1. What is a seller's optimal mix of customized and standard products, and how do advances in related technologies affect his product mix and pricing?
2. In a duopoly, how does adoption of customization affect price competition? Will consumers, as a group, always benefit from technological progress?
3. In a sequential duopoly, how does the first mover achieve an advantage over the second adopter? Can excess customization capability be used to deter entry?

This research draws upon existing literature in spatial product differentiation, flexible manufacturing, and entry deterrence. Spatial product differentiation dates back to the seminal Hotelling (1929) paper and is generalized by Lancaster (1975) and Salop (1979). In all these models, each brand is represented by one point in the product space and each brand competes only with its immediately neighboring brands ("localized competition"). These models have the desired property of explicitly addressing product attributes, but none can directly capture the increasingly popular practices in electronic markets: customization and price discrimination.

Existing theory on delivered pricing (Beckman 1976; Thisse and Vives 1988) treats customization as redesigning a basic product to satisfy different buyers' tastes, with the marginal cost of redesign increasing in the distance between the basic product and a buyer's ideal taste. *Yet the concept of a "basic product" does not apply in a majority of modern manufacturing settings.* It is very common for a flexible manufacturing facility to produce all of the varieties within its capability equally efficiently. This observation motivates the way we characterize customization and its cost structure in our model.

Flexibility in manufacturing means being able to reconfigure manufacturing resources so as to produce different products efficiently (Sethi and Sethi 1990). *Production flexibility* is the ability quickly and economically to vary the part assortment for any product that an FMS can produce. An obvious measure for production flexibility is the volume of the universe of products the system is capable of producing (Chatterjee et al. 1984). Here volume can be expressed by the number of product models or the range of product specifications (Browne et al. 1984; Gerwin 1987). The concept of customization scope defined later in our model closely resembles the degree of production flexibility.

Strategic entry deterrence is a well-studied topic in economics. Bain (1956) presents three barriers to entry: economies of large scale, brand recognition, and the absolute cost advantages of established firms. Assuming localized competition and substantial repositioning costs, Schmalensee (1978) argues that brand proliferation and overspending on advertising can serve as credible entry-detering threats in the breakfast cereal industry. Spence (1977) presents a simple but elegant model in which existing firms in an industry carry excess capacity to deter entry. Although differing in the deterrence instruments and pre-entry market structure, these models all use irreversible binding commitments by the first mover to make deterrence threats credible. We show that, in a market of customized goods, an incumbent firm can use customization scope to deter potential entry.

We develop a model of product customization and price discrimination in Section 2. Sections 3 and 4 investigate simultaneous and sequential adoption of customization in a duopoly, respectively. In section 5, we show that customization can serve as an effective instrument for entry deterrence. Section 6 points out future research directions and concludes the paper. The Appendix contains all of the proofs.

2. MODEL

We adopt the Salop (1979) model as it allows us to ignore firms' location decisions. Symmetric location among firms is always an equilibrium in the circular model.

2.1 The Product Space and Consumer Preferences

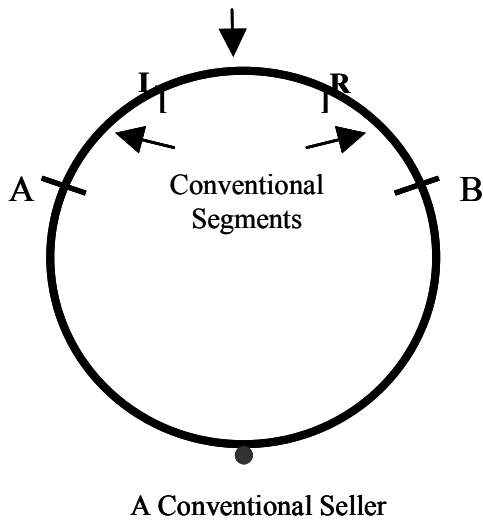
Consumer preferences are uniformly distributed along a circle of unit length. Each consumer is identified by a point that represents her most-favored product. Each consumer has a unitary demand for the products on the market subject to reservation price r . A product at distance y along the circle away from the consumer generates a utility of $r - ty$, where t is called the *fit cost* and measures buyers' sensitivity to product differences. Consumers have perfect information about the available products and prices and do not search. A consumer will buy the product that gives her the maximum net surplus. All these assumptions are commonly seen in the spatial product differentiation literature.

2.2 The Production and Information-Collection Technologies

A firm may choose to produce a standard product or a range of customized products. When the firm produces a single product, the product is still represented as a point on the circle. Actual production demonstrates constant returns to scale, and the marginal cost is normalized to zero. When the firm adopts customization and produces a range of products, they are represented as an arc of the circle. The motivation behind such an extension is that, in electronic markets, sellers observe buyers' preferences by delegating product design to customers (von Hippel 1998) ("customerization"; Wind and Rangaswamy 1999) and can provide a continuous spectrum of customized products fitting each buyer whose ideal taste lies within that spectrum. The firm adopting customization incurs an additional cost of $ax^2 = bx$, where x is called the firm's *customization scope* and is the length of the arc over which the firm produces the customized products. Here the customization scope measures the firm's manufacturing flexibility (a firm providing a standard product has zero manufacturing flexibility).

Flexibility and cost efficiency have in the past been considered as conflicting objectives. The introduction of flexibility into a manufacturing system requires high initial investments (Bobrowski and Mabert 1988; Gupta and Goyal 1989). In the cost function for customization, the quadratic term (ax^2), which we call *diseconomies of scope*, reflects the decreasing returns in manufacturing flexibility investment; the marginal customization expenditure increases as the customization scope increases. This is why build-to-order merchants such as Dell typically provide a limited range of custom product configurations.

A Customizer's Direct Marketing Segment (Customization Scope)



L and R are the two end points of the customization scope and also the customizer's standard products. Buyers in the left and right conventional segments will choose L and R respectively.

Figure 1. A Duopoly of a Customizer and a Conventional Seller

The technologies of information collection and data mining demonstrate constant returns within a very large range of number of buyers. For example, Amazon.com and Yahoo! can gather the purchasing and preference profile information of each member of their huge customer pool at roughly the same marginal cost (*Business Week* 1999). So can Dell in processing each additional custom order. The linear term (bx) of the customization cost function simulates the constant returns to scale in processing information about buyers.

We call buyers in the customization scope the *direct-marketing segment* and call the other adjacently located buyers the *conventional segments*. Figure 1 shows a duopoly of a customizer and a conventional seller. In a duopoly, both sellers have access to identical customization and information-collection technologies.

2.3 The Pricing Scheme

We next construct a second-degree discriminatory pricing scheme. In the conventional market segments, the seller charges a single price p for standard products L and R (see Figure 2). In the direct-marketing segment, the seller provides personalized products and, therefore, can discriminate on price. For a buyer in the direct segment, the seller charges the sum of the conventional market price and the buyer's fit cost of purchasing the closest standard product. In other words, for a

buyer located in the direct segment at distance y ($y < \frac{x}{2}$) away from the closest end point, the price charged is $p + ty$.

Denote the price for buyer y as $p(y)$. If $p(y) > p + ty$, buyer y will switch to purchase the conventional market standard product at price p , leading to a loss of ty for the seller. If $p(y) < p + ty$, the seller is not extracting the maximum rent; he leaves some surplus for the buyer. Under the pricing scheme $p(y) = p + ty$, buyers in conventional segments $[A,L]$ and $[R,B]$ will choose standard products L and R respectively, and buyers in the direct-marketing segment will choose the products tailored specifically for them. The linear pricing scheme $p(y) = p + ty (\forall y < \frac{x}{2})$, therefore, is indeed optimal and prevents arbitrage among buyers.

An observant reader may have noticed that the optimality of the linear price-discrimination scheme critically depends on the assumption of linear fit cost in the conventional market. We call such a strategy of selling both standard and customized products a “mixed” strategy.

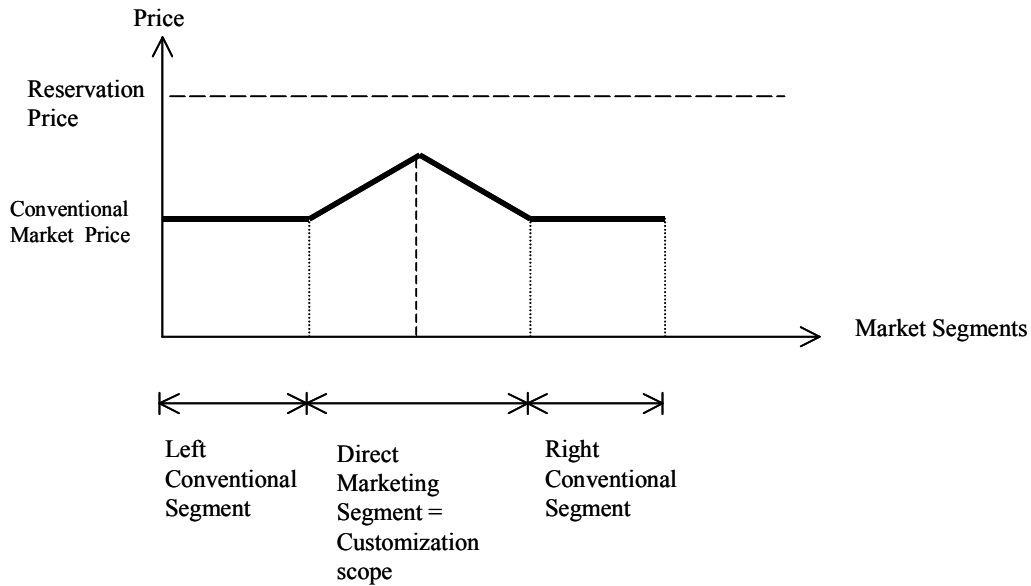


Figure 2. Market Segmentation and Pricing of a Customizer

The seller also has two extreme product strategies to consider. The seller can adopt a *pure standardization* strategy of selling only one standard product or a *pure customization* strategy of selling only customized products by pricing at buyer reservation utility r . However, pure customization is always dominated by the “mixed” strategy.¹ The “mixed” scheme also outperforms pure standardization under very general conditions, as we shall see shortly.

3. A DUOPOLY WITH SIMULTANEOUS CUSTOMIZATION SCOPE CHOICES

We next examine a situation in which both sellers adopt customization simultaneously. To ease comparison, we mention the following facts in a conventional duopoly (Salop 1979): the two sellers set their prices at $t/2$; each seller makes a profit of $t/4$. Total consumer surplus is $r - 5t/8$, and total social surplus is $r - t/8$.

Consider a two-stage game in which seller 1 and seller 2 choose customization scopes x_1 and x_2 respectively in stage 1 and choose conventional market prices p_{d1} and p_{d2} respectively in stage 2. Assume that the two sellers’ customization scopes are located symmetrically along the circle.

Lemma 1. *In any Nash Equilibrium of the two-stage customization-pricing game, the two firms’ customization scopes are not contiguous.*

¹Imagine that the seller adopting pure customization lowers the price of a standard product (L or R) by δ . The seller gains a profit of $(r - \delta)\delta/t$ from the conventional market and loses a profit of $\delta^2/(2t)$ from the direct marketing segment. When δ is not too large, the gain outweighs the loss.

Lemma 1 lets us focus on the case where the two customizers' customization scopes do not overlap. Correspondingly, certain constraints are imposed on the parameters (see restated Lemmas and Propositions in the Appendix) to have a more tractable analysis. The solution to this game is provided by (Dewan et al. 2000), which also shows that adopting customization is the unique equilibrium product strategy. The solution is stated in Lemma 2.

Lemma 2. *The two-stage game in product scopes and conventional market prices has a unique Sub-game Perfect Equilibrium*

$$\langle x_1, x_2, p_{d1}, p_{d2} \rangle = \left\langle \frac{t-6b}{12a-3t}, \frac{t-6b}{12a-3t}, \frac{t}{2}, \frac{t}{2} \right\rangle.$$

At equilibrium the two sellers earn identical profits $\pi_{d1} = \pi_{d2} = \frac{18(b^2 + at) - 5t^2}{18(4a - t)}$.

Proposition 1. *Simultaneous adoption of customization reduces the differentiation between the sellers' standard products but does not aggravate price competition. When $b < \frac{t}{6}$ ($b > \frac{t}{6}$), the seller's profit decreases (increases) as a decreases.*

It is counterintuitive that universal adoption of customization does not facilitate conventional market price competition. Since the prices of customized products explicitly depend on the conventional market price, the conventional market price plays two conflicting roles of directly competing for buyers in the conventional segments and indirectly determining the prices of each seller's custom products. It is the latter role that relieves the otherwise intensified conventional market-price competition. *In this sense, price discrimination on customized products relaxes the price competition between standard products*

As customization and buyer information-collection technologies advance, sellers will expand their customization scopes and hold conventional market prices constant. Each seller can collect higher revenue from his customized products, but customization cost also increases. When $b < \frac{t}{6}$, a is relatively high (see Lemma 2 in Appendix), and the cost of customization increases at a faster

rate than revenue as a decreases, leading to lower profits for the sellers. Exactly the opposite holds when $b > \frac{t}{6}$. Universal adoption of mass customization does not always make the sellers better off when they directly compete with each other. While it is customary to believe that technological advances in a competitive setting must benefit buyers, our next proposition reveals a striking picture.

Proposition 2. *Consumer surplus first increases and then decreases when customization and information collection technologies improve.*

Proposition 2 shows that buyer surplus does not always monotonically increase when information-collection and customization technologies advance. As a or b decreases, buyer surplus first increases and then decreases (see Figure 3). When technologies advance, the prices of custom products increase but the expansion of customization scopes also reduce the fit cost of buyers in the conventional segments. Either effect may dominate the other depending on the technological conditions, leading to an increase or decrease in buyer surplus.

Notice $\pi_{d1} = \pi_{d2} = \frac{18(b^2 + at) - 5t^2}{18(4a - t)} \rightarrow \frac{t}{4}$ as $a \rightarrow \infty$. When the cost of customization is infinitely high, the customizing

duopoly reduces to the conventional duopoly in Salop (1979). Consumer surplus is higher than in the conventional duopoly, but both sellers are worse off. Our results thus shed light on the IT productivity literature. Notice the *number* of products produced remains the same, but *variety* does increase due to customization. Sellers charge higher prices for the customized goods, but customization also reduces total fit costs, leading to higher consumer surplus and supporting the "mismeasurement" hypothesis by Brynjolfsson (1993) for the "IT Productivity Paradox."

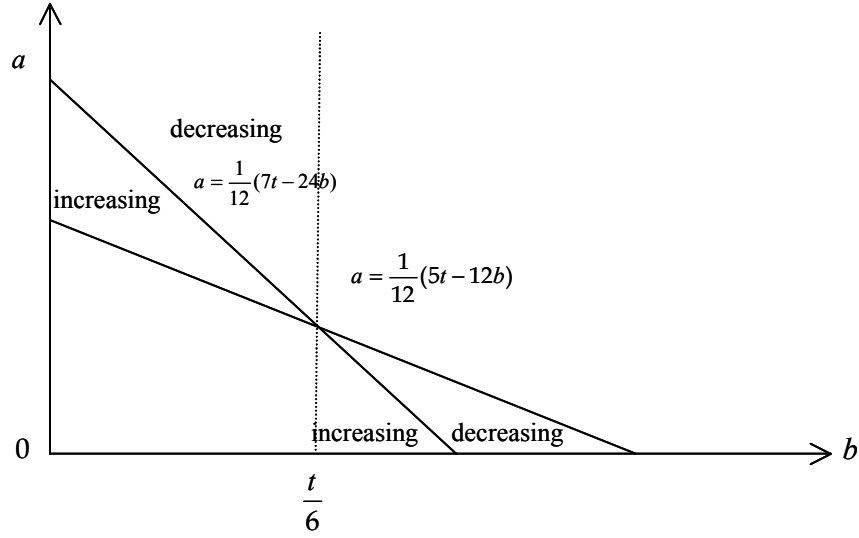


Figure 3. The Monotonicity of Consumer Surplus as a Function of Customization Cost a

4. A DUOPOLY WITH SEQUENTIAL CUSTOMIZATION SCOPE CHOICES

Firms differ in their capabilities of organizational learning and their readiness to adopt new technologies. Even though firms selling only a standard product can not obtain a first-mover advantage, we show that the first entrant can achieve an advantage over the second entrant by adopting customization. Consider a three-stage game in which both sellers adopt customization. Let seller 1 pick customization scope x_{1seq} in stage 1, and let seller 2 pick customization scope x_{2seq} in stage 2 after observing seller 1's choice. Finally, the two sellers choose their conventional market prices p_1 and p_2 simultaneously in stage 3. We start with the third stage of the game.

4.1 Stage 3: The Conventional Market Pricing Game

In stage 3, the sellers can observe their customization scope choices x_{1seq} and x_{2seq} made in the preceding stages. The conventional market pricing subgame is identical to the one analyzed in (Dewan et al. 2000). The equilibrium of the simultaneous price choices is $p_i = \frac{1}{6}t(3 + x_{iseq} - x_{jseq})$. Hence, the seller with a larger customization scope will set a higher conventional market price.

4.2 Stage 2: Seller 2 Chooses his Customization Scope

In stage 2, seller 2 picks his customization scope x_{2seq} to maximize his profit after observing seller 1's choice x_{1seq} and anticipating the third-stage outcome as described above. Seller 2's stage-2 problem can be formulated as:²

$$\text{Max}_{x_{2seq}} \frac{1}{36}t[10x_{2seq}^2 - 2x_{2seq}(x_{1seq} - 3) + (x_{1seq} - 3)^2] - ax_{2seq}^2 - bx_{2seq}. \tag{4.1}$$

Solving (4.1), we obtain seller 2's optimal customization scope response to seller 1's choice

²See our unabridged working paper (Dewan et al. 1999) for the derivation of (4.1) and (4.3).

$$x_{2seq}(x_{1seq}) = \frac{18b + (x_{1seq} - 3)t}{-36a + 10t}. \quad (4.2)$$

4.3 Stage 1: Seller 1 Chooses His Customization Scope

Anticipating the outcomes in the following two stages, seller 1 picks a customization scope x_{1seq} to maximize his profit in stage 1:

$$\text{Max}_{x_{1seq}} \pi_{1seq}(x_{1seq}) \equiv \frac{1}{36} t \left[\left(\frac{18b + t(-3 + x_{1seq})}{-36a + 10t} - 3 \right)^2 + \frac{(108a + 18b + t(-33 + x_{1seq}))x_{1seq}}{18a - 5t} + 10x_{1seq}^2 \right]. \quad (4.3)$$

Solving (4.3) gives seller 1's optimal customization scope:

$$x_{1seq}^* = \frac{2b}{-4a + t} + \frac{3(36a - 11t)t}{1296a^2 - 756at + 109t^2}. \quad (4.4)$$

Substituting x_{1seq}^* into (4.2), we obtain seller 2's optimal customization scope:

$$x_{2seq}^* = \frac{2b}{-4a + t} + \frac{36(3a - t)t}{1296a^2 - 756at + 109t^2}. \quad (4.5)$$

The two sellers' stage 3 prices are

$$p_1^* = \frac{(36a - 11t)(18a - 5t)t}{1296a^2 - 756at + 109t^2} \quad (4.6)$$

and

$$p_2^* = \frac{54(4a - t)(3a - t)t}{1296a^2 - 756at + 109t^2}. \quad (4.7)$$

We summarize the solution to this three-stage game in Lemma 3.

Lemma 3. *The three-stage game of sequential customization scope choices has a unique Sub-game Perfect Equilibrium as described in (4.4) through (4.7).*

At the sequential equilibrium, the two sellers' profits are $\pi_{1seq}^* = \frac{b^2}{4a - t} + \frac{(36a - 11t)^2 t}{5184a^2 - 3024at + 436t^2}$ and

$\pi_{2seq}^* = \frac{b^2}{4a - t} + \frac{648(18a - 5t)(4a - t)(-3a + t)^2 t}{(1296a^2 - 756at + 109t^2)^2}$. The difference between the two sellers' profit is

$\pi_{1seq}^* - \pi_{2seq}^* = \frac{t^3(2592a^2 - 1548at + 229t^2)}{4(1296a^2 - 756at + 109t^2)^2}$. When $a > \frac{4}{9}t$ (see restated Lemma 3 in the Appendix), the numerator

of this difference is positive because $2592a^2 - 1548at + 229t^2 > 0$. The first entrant makes a higher profit than the second entrant. We can also verify that the first entrant covers a larger market.

Proposition 3. *The first entrant will choose a larger customization scope and charge a higher conventional market price than the second entrant. When customization and information technologies advance, the first and second entrants will raise and lower their conventional market prices respectively, and the difference between their customization scopes will increase.*

The first mover will secure its profit advantage by choosing a larger customization scope, charge a higher conventional market price, and serve a larger share of the market. *Such a first-mover advantage is due to the first entrant's freedom to choose a more favorable customization scope and manipulate the follower's customization scope (see (4.2)) and price.* The first entrant can afford to abandon more buyers in the conventional segments because he obtains a higher mark-up from the customized products by charging a higher conventional market price.

5. USING CUSTOMIZATION TO DETER ENTRY

The previous analysis assumes that sellers have already entered the market. When firms face entry costs, the first mover (seller 1) may do even better. As we shall see, entry is *blockaded* when the first-mover's monopoly customization scope automatically eliminates all entry possibilities. When entry is blockaded, we call seller 1 a *natural monopoly*. Entry is *deterred* when seller 1 deliberately chooses a customization scope larger than the monopoly choice to preempt the potential entry of seller 2. When entry is deterred, we call seller 1 a *strategic monopoly*. There also exist situations in which seller 1's best choice is to accommodate entry, and the resulting market structure is a *sequential duopoly*, as shown in section 4.

To find seller 1's best customization scope choice, we need to identify his monopoly profit as a function of his customization scope x_1 . We first find the monopoly price p as a function of x_1 by solving his revenue-maximizing problem for a fixed customization scope x_1 :

$$\text{Max}_p \quad 2p \frac{r-p}{t} + 2 \int_0^{x_1} (p+ty) dy. \quad (5.1)$$

Solving the first-order condition gives $p = \frac{2r+tx_1}{4}$. Plugging this price back into (5.1) and considering the entry and customization set-up costs we get the monopoly profit as a function of his customization scope x_1 :

$$\pi_{1m}(x_1) = \left(\frac{3t}{8} - a\right)x_1^2 + \left(\frac{r}{2} - b\right)x_1 + \frac{r^2}{2t} - c. \quad (5.2)$$

Seller 1's monopoly customization scope is $x_{1m} = \frac{2(r-2b)}{8a-3t}$. We next determine seller 1's entry-detering customization scope choice x_{1d} , the smallest customization scope that makes entry unattractive to seller 2. For whatever customization scope x_1 , seller 2 will respond by choosing a customization scope as given in (4.2) if he decides to enter. Substituting (4.2) into (4.1) and considering the fixed costs of entry, we obtain seller 2's optimal profit as a function of x_1 :

$$\pi_{2seq}(x_1) = \frac{1}{8(18a-5t)} [t(4a-t)(x_1-3)^2 + 4bt(x_1-3) + 36b^2] - c. \quad (5.3)$$

Solving $\pi_{2seq}(x_1) = 0$ gives the entry-detering customization scope for seller 1:

$$x_{1d} = \frac{12a-2b-3t}{4a-t} - \frac{2\sqrt{2t}\sqrt{(18a-5t)[(4a-t)c-b^2]}}{(4a-t)t}. \quad (5.4)$$

As the fixed entry cost c increases, seller 1's entry-detering customization scope will decrease. The larger the entry barrier, the easier entry deterrence is. When $x_{1m} \geq x_{1d}$, seller 1 can act as a natural monopoly by choosing x_{1m} . Equivalently, entry is blockaded when $r \geq r_b$ if we adopt the notation

$$r_b = \frac{8a - 3t}{2} x_{1d} + 2b, \quad (5.5)$$

where x_{1d} is identified in (5.4).

But what if $x_{1m} < x_{1d}$? Recall from Section 4 that π_{1seq}^* is seller 1's optimal profit in the sequential equilibrium, excluding entry cost c . When $\pi_{1m}(x_{1d}) > \pi_{1seq}^* - c$, seller 1's best choice is to pick x_{1d} to deter the entry of seller 2 and act as a strategic monopoly. When $\pi_{1m}(x_{1d}) \leq \pi_{1seq}^* - c$, seller 1 should accommodate seller 2's entry, since deterring seller 2 from entry leads to a lower profit for seller 1. It is prohibitively difficult to identify the technological conditions for $\pi_{1m}(x_{1d}) \leq \pi_{1seq}^* - c$ to hold, but the problem is much simplified by examining the conditions on buyer reservation utility r , given the parameters on customization and information-collection technologies. Solving the equation $\pi_{1m}(x_{1d}) = \pi_{1seq}^* - c$, we obtain the critical value of the reservation utility:

$$r_d = \frac{1}{2(4a - t)^2} \left(\frac{f_1 + (2\sqrt{2}\sqrt{f_2(f_3 + f_4)})}{1296a^2 - 756at + 109t^2} \right), \quad (5.6)$$

where

$$f_1 = \sqrt{t}(-4a + t)((12a - 2b - 3t)\sqrt{t} - 2\sqrt{2(18a - 5t)[c(4a - t) - b^2]}),$$

$$f_2 = (4a - t)^3(1296a^2 - 756at + 109t^2),$$

$$f_3 = -3(4a - t)\sqrt{t}\sqrt{2(18a - 5t)[c(4a - t) - b^2]}(1296a^2 - 756at + 109t^2), \text{ and}$$

$$f_4 = (-18a + 5t)(-2592r^3(4c + t) + 288r^2(9b^2 + t(30c + 7t)) + t^2(218^2 + t(218c + 43)) - 2at(756b^2 + t(1192c + 257t))).$$

Seller 1's contingent customization scope choice is summarized in Proposition 4.

Proposition 4. *For a given set of customization and information-collection costs that satisfy the conditions for a monopoly to adopt customization ($a \geq \frac{3t}{4r}(r - b)$ and $b < \frac{r}{2}$) and also satisfy the conditions in Lemma 3, we have:*

- (1) when $r \geq r_b$, seller 1 chooses the monopoly customization scope x_{1m} ;
- (2) when $r_d < r < r_b$, seller 1 chooses the entry-detering customization scope x_{1d} ;
- (3) when $r < r_d$, seller 1 accommodates entry and chooses customization scope x_{1seq}^* .

The higher the reservation price, the more favorable are the market conditions for the first entrant. An alternative interpretation of Proposition 4 is that, for a given reservation price, the first mover will act as a natural monopoly (a strategic monopoly, and the leader in the sequential duopoly, respectively) when technologies are highly (moderately, and insufficiently, respectively) advanced.

Investments in specialized flexible production systems are sunk costs, and the first entrant has no incentive to produce only part of the product varieties in his customization scope. The more varieties he produces, the higher will be his revenue. *It is the irreversible nature of customization investments that makes customization scope a credible entry-deterrence instrument.* In this

sense, using customization scope to deter entry is a specific incidence of the general proposition that incumbency provides an intrinsic advantage to commit to irreversible investments in durable capacity that restrict the opportunities available to the later entrant (Dixit 1980; Spence 1979).

Using excessive customization to deter entry is a variant of the brand proliferation strategy discussed in Schmalensee (1978), where the incumbent firms can “crowd out” potential entrants by properly spacing new brands in the product attribute space. A first mover in electronic markets can position itself as a versatile vendor of a sufficiently large span of product varieties, leaving no profitable niche for the new entrant.

Bain (1956) points out that economies of large scale can serve as an entry barrier when the incumbent’s optimal output covers a significant fraction of total industry demand. The residual demand is thus too low and the entrant’s *unit cost* will be high and exceed the resulting market price if he enters. *In contrast, the effectiveness of using customization for entry deterrence critically hinges on the fixed entry cost c , the setup cost besides investments in customization.* Absent such an entry cost, seller 2 can always profitably enter as long as the incumbent’s customization scope does not cover the whole product space.

6. CONCLUSION AND FUTURE EXTENSIONS

The Internet and other information processing technologies allow sellers to better understand each customer’s needs and wants, facilitating market provision of customized consumer goods. Devising a spatial model of customization, we have evaluated firms’ product customization strategy in an electronic market and obtained interesting insights on their product mix, pricing, and consumer surplus, as well as technologies’ impacts on these strategic variables. The novelty of our model derives from a distinct cost-structure assumption that customization requires a fixed initial investment with decreasing returns but can produce each planned variety with equal efficiency. The price of a customized product is the full price that the targeted buyer would incur if she purchases the closer standard product.

Customization is not a differentiating strategy when both sellers endorse it; there is excessive product proliferation and diminished differentiation. However, price competition does not worsen due to the relaxation effect of price discrimination on customized products. Buyers are the long-term beneficiaries of customization, but consumer surplus does not monotonically increase. The irreversible nature of customization investment ensures an advantage for the early adopter. Investing excessively in customization may deter entry of potential rivals by leaving a meager market niche uncovered.

Our model is a highly simplified, abstract characterization of customization and has several limitations. First, the circular product space and the cost structure seem reasonable for most products suitable for flexible manufacturing such as clothes, furniture, cars, and computers, but may not apply for certain information goods and services such as customized newspapers and travel packages. Second, our model is a single-period one and does not capture inter-temporal learning by the first mover about customers’ tastes. While learning by the sellers is not critical for customization of such durable goods as cars and computers, it may foster switching costs for customers and form another source of first-mover advantage for repeatedly purchased items such as clothes. Third, we assume product differentiation is conducted along a single horizontal attribute. In reality, customizing firms also differentiate themselves by other dimensions such as brand name, quality, and delivery time, etc. Therefore, the predictions of our model may not be duplicated in all real-world settings.

Two potential extensions to our model can be made. One particularly meaningful direction is to build a multi-period model to incorporate learning about customer tastes and examine its impacts on competition. We hypothesize that this extension will reveal more dynamics about the first mover’s advantage. Second, by relaxing the assumption that firms have access to identical technologies, we may treat customization costs endogenously as functions of firms’ investments.

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Appendix

Proof of Lemma 1: We prove this Lemma in two steps by contradiction. First, we show overlapping customization scopes are not a Nash equilibrium. Suppose there is an equilibrium in which the two sellers' customization scopes overlap. Bertrand competition implies that the prices for the customized products in the overlapped segment are zero. Either firm (firm 1, say) can be strictly better off by retreating to the point where the two firms' customization scopes just touch, maintaining his revenue but reducing customization costs.

Next, we show the state where the two customization scopes are contiguous is not Nash. Suppose firm 1 (2) chooses customization scope x_1 (x_2) respectively and $x_1 + x_2 = 1$. Denote E and F to be the touching points of the two firms' customization scopes. Then the prices of products E and F are zero. Now imagine firm 1 retreats slightly by ξ on both ends and denote his standard products (the new end points of his customization scope) as G and H . The new equilibrium prices of the standard products are found to be $p_G = p_H = \frac{t}{6}(3 + x_1 - 2\xi - x_2) > \frac{t}{3}$ and $p_A = p_B = \frac{t}{6}(3 + x_2 - x_1 + 2\xi) > \frac{t}{3}$ because $-1 < x_2 - (x_1 - 2\xi) < 1$. Retreating makes firm 1 strictly better off; he loses 2ξ in sales but can charge a much higher price on each of his remaining product offerings.

We have completed the proof of Lemma 1. *Q.E.D.*

Lemma 2: When $(a, b) \in \{(a, b) \mid a > \frac{1}{12}(5t - 12b), b < \frac{t}{6}\} \cup \{(a, b) \mid a < \frac{1}{12}(5t - 12b), b > \frac{t}{6}\}$, and

$r > (\frac{1}{2} + \frac{t-6b}{12a-3t})t$, the two-stage game in product scopes and conventional market prices has a unique Sub-game Perfect

Equilibrium $\langle \frac{t-6b}{12a-3t}, \frac{t-6b}{12a-3t}, \frac{t}{2}, \frac{t}{2} \rangle$.

Proof of Lemma 2:

When $(a, b) \in \{(a, b) \mid a > \frac{1}{12}(5t - 12b), b < \frac{t}{6}\} \cup \{(a, b) \mid a < \frac{1}{12}(5t - 12b), b > \frac{t}{6}\}$, sellers have positive customization scopes and conventional segments. When $r > (\frac{1}{2} + \frac{t-6b}{12a-5t})t$, each seller's highest price in the direct marketing segment is less than r . The rest of the proof is self-evident from the above deduction. *Q.E.D.*

Proof of Proposition 1: When sellers adopt customization, there is less differentiation between their standard products because they are located closer to each other due to the presence of the customized product scopes. According to Lemma 2, the conventional market price is still $\frac{t}{2}$, the same as the price in a duopoly of conventional sellers.

We can easily show that $\pi_{d1} = \pi_{d2} = \frac{18(b^2 + at) - 5t^2}{18(4a - t)} < \frac{t}{4}$ is equivalent to

$(a, b) \in \{(a, b) \mid a > \frac{t}{4}, b < \frac{t}{6}\} \cup \{(a, b) \mid a < \frac{t}{4}, b > \frac{t}{6}\}$, which clearly holds under the conditions of Lemma 2. The last

part of the proposition follows from $\frac{\partial \pi_{d1}}{\partial a} = \frac{\partial \pi_{d2}}{\partial a} = \frac{(t+6b)(t-6b)}{9(4a-t)^2}$. *Q.E.D.*

Proposition 2. (Restated) Buyer surplus is increasing in information collection cost b when $b < \frac{1}{24}(7t - 12a)$ and decreasing in b when $b > \frac{1}{24}(7t - 12a)$. If $b < \frac{t}{6}$, buyer surplus is increasing in customization cost a when $\frac{1}{12}(5t - 12b) < a < \frac{1}{12}(7t - 24b)$ and decreasing in a when $a > \frac{1}{12}(7t - 24b)$. If $b > \frac{t}{6}$, buyer surplus is increasing in a when $a < \frac{1}{12}(7t - 24b)$ and decreasing in a when $\frac{1}{12}(7t - 24b) < a < \frac{1}{12}(5t - 12b)$.

Proof of Proposition 2: Buyer surplus when both sellers adopt customization is

$$BS_{cc} = r - \frac{[144(5a^2 + 2ab + 2b^2) - 24(17a + 7b)t + 65t^2]t}{72(4a - t)^2}.$$

The first- and second-order derivatives of buyer surplus w.r.t. b are $\frac{\partial BS_{cc}}{\partial b} = \frac{t(-12(a + 2b) + 7t)}{3(4a - t)^2}$ and

$\frac{\partial^2 BS_{cc}}{\partial b^2} = \frac{-8t}{(4a - t)^2} < 0$. Therefore, buyer surplus is concave in b and its monotonicity in b can be obtained by directly observing the first derivative.

We can also verify that $\frac{\partial BS_{cc}}{\partial a} = \frac{2(12a + 24b - 7t)(6b - t)t}{9(4a - t)^3}$ and $\frac{\partial^2 BS_{cc}}{\partial a^2} = \frac{-16(4a + 12b - 3t)(6b - t)t}{3(4a - t)^4}$. Inspecting the conditions in Lemma 2 and this first derivative leads to the monotonicity of buyer surplus in a . Note that the second-order condition is also satisfied when determining the monotonicity of buyer surplus in a . *Q.E.D.*

Lemma 3. When $a > \frac{4}{9}t$, $b > \frac{4a - t}{t} \left[\frac{(36a - 11t)(36a - 7t)t}{2(1296a^2 - 756at + 109t^2)} - r \right]$ and $b < \min \left\{ r, \frac{18(3a - t)(4a - t)t}{1296a^2 - 756at + 109t^2} \right\}$, the three-stage game of sequential customization scope choices has a unique Sub-game Perfect Equilibrium as described in (4.4) through (4.7).

Proof of Lemma 3: When $a > \frac{4}{9}t$, sellers have positive conventional prices and nontrivial conventional segments. When $b > \frac{4a - t}{t} \left[\frac{(36a - 11t)(36a - 7t)t}{2(1296a^2 - 756at + 109t^2)} - r \right]$, sellers' highest prices in their direct-marketing segments are below r so that no buyer in the direct-marketing segment is priced out of the market. When $b < \min \left\{ r, \frac{18(3a - t)(4a - t)t}{1296a^2 - 756at + 109t^2} \right\}$, sellers have positive customization scopes and they both indeed adopt customization. *Q.E.D.*

Proof of Proposition 3: The difference between the two sellers' customization scopes is

$$x_{1se}^* - x_{2se}^* = \frac{3t^2}{1296a^2 - 756at + 109t^2}. \text{ We can easily check that } 1296a^2 - 756at + 109t^2 > 0 \text{ when } a > \frac{4}{9}t.$$

Therefore we have $x_{1se}^* - x_{2se}^* > 0$. Seller 1's conventional market price is higher than that of seller 2 because

$$p_1^* - p_2^* = \frac{t^2}{1296a^2 - 756at + 109t^2} > 0. \text{ The remaining part of Proposition 4 follows from the facts that}$$

$$\frac{\partial p_1^*}{\partial a} = -\frac{54(24a - 7t)t^3}{(1296a^2 - 756at + 109t^2)^2} < 0, \quad \frac{\partial p_2^*}{\partial a} = -\frac{\partial p_1^*}{\partial a} > 0 \text{ and}$$

$$\frac{\partial(x_{1se}^* - x_{2se}^*)}{\partial a} = \frac{-324(24a - 7t)t^2}{(1296a^2 - 756at + 109t^2)^2} < 0 \text{ under the conditions of Lemma 3. } Q.E.D.$$