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# Adoption of Internet-Based Product Customization and Pricing Strategies

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**ABSTRACT:** The Internet commerce technologies have significantly reduced sellers' costs of collecting buyer preference information and managing multiple prices. Advanced manufacturing technologies have also improved sellers' manufacturing flexibility. These changes allow an online seller to offer custom products at discriminatory prices. We show that these technologies offer significant advantages to an early adopter who gains market share and profits at the expense of the conventional seller. Not only does the customizing seller charge more for customized products, it also provides

standard products but charges more for them than in a conventional market. The benefits of customization disappear when both the competing sellers adopt customization. They now compete not just on prices but also on degree of customization. Consequently, we see that the sellers “over-customize,” to the detriment of their profits. Both the sellers know this when choosing their customization strategies and yet they both end up choosing to customize. A seller that does not customize sees a sharp decrease in profits if its competitor customizes. This is an instance of the “Prisoner’s Dilemma” type of situation in technology adoption. This confirms some key findings in IT productivity and strategic IT investments literature.

KEY WORDS AND PHRASES: adoption of information technology, customization, electronic commerce, flexible manufacturing systems.

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*The Internet has turbocharged our ability to understand our customers.*

—Chris Halligan, Director of Dell Computer’s  
E-Commerce Business

WELL-KNOWN FOR THEIR ECONOMIES OF SCALE, mass production of standard products and mass broadcasting have been the dominant model of production and marketing, respectively, of consumer products. This, however, is changing in the New Economy as the Internet facilitates a continuous learning relationship between sellers and customers, which is critical for sellers to achieve long-term business success [18]. The Internet allows the buyer and the seller to interact on a one-to-one basis and allows the seller to collect information from online user registration, cookies, log pages of the Web server, etc. This, combined with collaborative filtering and data mining, allows the seller to design products for individuals. On-line sellers are using these technologies to target their most valuable prospects effectively with personalized messages and products [12, 17]. Dell Computer and Levi Strauss are two real-world examples of directly marketing custom products on the Internet by successfully leveraging customer information.

Meanwhile, advances in manufacturing technologies have improved sellers’ flexibility in manufacturing consumer products. Conventional manufacturing has mainly relied on two extremes: assembly lines and job shops. Dedicated machinery such as assembly lines allows mass production of a standard product, attaining high efficiency but inhibiting flexibility. On the other hand, nonintegrated machine tools in a job shop render small batch production of different varieties of products, permitting flexibility but sacrificing efficiency. Recently, advanced manufacturing technologies such as flexible manufacturing systems (FMSs), computer-aided design/manufacturing (CAD/CAM), and cellular (modular) manufacturing have provided a new production choice by trading off the efficiency of assembly lines and the flexibility of nonintegrated machines tools in a job shop [23]. This improvement in manufacturing flexibility allows mass customization without a significant loss of efficiency. The

Internet also reduces the *menu cost* for managing multiple prices to near zero, enabling real-time individualized pricing [10]. Reduced menu cost and customized products allow sellers to price discriminatorily and charge a price premium since personalized product features better comply with buyers' tastes.

Our current paper contributes to electronic commerce literature by examining the impacts of reduced costs of collecting buyer information and menu costs on a firm's product and pricing strategies. Adopting a game-theoretic approach, we extend a classic spatial model of product competition [21] to incorporate the prominent new features of the Internet and derive several meaningful results on the product and pricing policy choices for firms operating in the Internet era. In particular, we confirm the widely held premise that mass customization allows the seller to sell more and price higher [25] and further show that this premise only holds for early adopters of customization.

In general, firms do not have an identical capability in assimilating new technologies. We show that an early adopter to Internet technologies for customization gains market share and profits at the expense of the conventional seller. The seller adopting mass customization also provides standard products. Moreover, it will raise the price of the standard products in order to capture the maximum premium from the customized products. The late mover does better by adopting Internet-based customization than continuing to offer a single standard product. The wider adoption of Internet customization technologies reduces differentiation between sellers. The profits are lower when both the early and late movers adopt customization than when both do not. Despite this, the two firms end up choosing to customize. If only one of them customizes then the customizer does far better and the other does far worse. This compels them both to customize. Thus the firms end up in a Prisoner's Dilemma situation. Treating the Internet customization technologies as a particular type of strategic information technology (IT), we can also explain some of the major hypotheses in the recent literature of strategic IT investments and IT productivity.

## Related Literature

Our current work borders several lines of existing research in electronic commerce, spatial product differentiation, and flexible manufacturing.

There exists abundant empirical or qualitative literature regarding the substantial impacts of the Internet on firms' product and marketing strategies [2, 20]. However, related analytical research is just emerging. Bakos [1] studies the impacts of reduced buyer search cost on price and the allocational efficiency of electronic markets. Dewan et al. [8] identify a monopoly seller's optimal product and pricing strategies and analyze their profit and welfare implications.

Spatial product differentiation based on product attributes (or horizontal differentiation) dates back to the seminal Hotelling [13] paper and is generalized by Lancaster [15] and Salop [21]. In all these models, each firm produces only one brand and each brand is represented by one point in the product space, and heterogeneous consumers have diverse preferences among the available brands. Competition is treated as a localized phenomenon: Each brand only directly competes with its immediately

neighboring brands. The spatial models have the desirable property of focusing explicitly on product attributes, but do not capture the increasingly popular practices in electronic markets: customization and price discrimination. As shown in the next section, we make a significant extension to the existing product differentiation models to capture product customization and differentiated pricing. The concept of customization and production flexibility can be conveniently represented as a continuous spectrum in the product space. Unlike in a linear market model, the firms will always locate symmetrically in the circular model due to the principle of maximum differentiation. Adopting the Salop [21] model thus allows us to ignore firms' location decisions and focus on their product and pricing strategies.

Schmalensee [22] postulates a multi-product firm of positioning several discrete brands in the product space. Such a brand proliferation strategy happens to reduce consumers' fit costs but is primarily intended to occupy market niches and deter potential entry from rival firms. Therefore, product proliferation is essentially different from customization.

Flexibility in manufacturing means being able to reconfigure manufacturing resources so as to produce different products efficiently [24]. Among the various aspects of flexibility, production flexibility is the closest to our notion of product customization. According to Gupta and Goyal [11], *production flexibility* is the ability to quickly and economically vary the part variety 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 [6]. Here volume can be expressed by the number of different product types in the set [4, 9] if they can be counted, and if not, by the range of sizes, shapes, etc. [19]. The concept of customization scope defined later in our paper closely resembles the degree of production flexibility.

## Modeling Framework

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WE EMPLOY THE PRODUCT ATTRIBUTE APPROACH TO product differentiation and characterize customization by extending the model of Salop [21]. As we shall see, the spatial product attribute approach can easily capture the virtue of customization in removing consumers' fit costs. When adopting customization, the firm's degree of production flexibility can also be conveniently represented as a continuous spectrum in the product space. For expositional purposes, we first briefly review the Salop model.

The Salop model is a model of product differentiation under complete information, i.e., consumers know the locations and prices of available brands. In the Salop model, each firm provides only one brand, and a number of firms locate their products symmetrically along the circle at equilibrium, abiding by the principle of maximum differentiation. Consumers have heterogeneous preference and are uniformly distributed along a circle of unit length. Each consumer's most preferred product is identified by a point on the circle. 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 dollar value of  $r - ty$ , where  $t$  is called the fit cost and measures buyers' sensitivity to differences between products. A consumer will buy if

she obtains a positive net surplus and she will buy the product that gives her the maximum net surplus. These assumptions are not unique to the Salop model; they are commonly seen in the spatial product differentiation literature.

We make the following extensions to the Salop model. 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 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 firm adopting customization incurs an additional fixed 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 customization scope measures the firm's manufacturing flexibility. (A firm providing a standard product has zero manufacturing flexibility.) This extension effectively captures customization as an alternative product strategy to the conventional standardization.

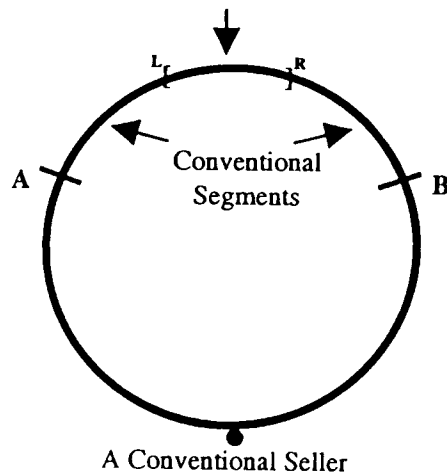
Flexibility and cost efficiency have been considered as conflicting objectives. The introduction of flexibility to a manufacturing system requires high initial investments [11]. For example, a numerically controlled turning center costs \$300,000 to \$400,000, while an FMS installation can balloon to \$25 million [3]. 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: Marginal customization expenditure increases as customization scope increases. This is why build-to-order merchants such as Dell and Levi's typically provide a limited range of custom product configurations.

The technologies of information collection and data mining have 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 [25]. The cost for Dell to process each additional custom order should not vary much. The linear term ( $bx$ ) of the customization cost function simulates the constant returns to scale in buyer information processing.

Since the firm adopting customization attracts customers for whom the customized products are produced and other adjacently located customers, it is also called a *quasi-direct marketer*. We call the seller providing a standard product a *conventional seller*. Figure 1 shows a duopoly of a quasi-direct marketer and a conventional seller. Besides offering tailored products to consumers within its customization scope, the quasi-direct marketer also sells two standard products L and R to the two adjacent conventional segments. We assume that the sellers can only price discriminate to the second degree, i.e., the sellers decide on the offerings and prices and each customer picks his surplus maximizing product. Consequently, the conventional seller charges a single price. The quasi-direct marketer picks a price for each product variety it produces.

We examine the product and price competition between two firms using a game-theoretic approach. Firms enter multistage games in such decision variables as product strategy (custom versus standard), customization scope, and price. A unique Subgame Perfect Equilibrium is derived for each multistage game.

A Quasi-Direct Marketer's Direct Marketing Segment  
(Customized Product Spectrum)



L and R are the two end points of the customized product spectrum. Buyers in the left and right conventional segments will choose L and R, respectively.

Figure 1. A Duopoly of a Quasi-Direct Marketer and a Conventional Seller

### Spatial Duopoly with Customization

TO BETTER EVALUATE THE STRATEGIC IMPLICATIONS OF Internet-based mass customization, we consider three cases in which two sellers compete with different combinations of product strategies. We restrict our attention to the situation when the sellers are actively competing. This amounts to the following assumption:

**Assumption 1:** *The reservation price  $r$  is high enough so that buyers of all preference are served at equilibrium and the sellers actively compete for the marginal customer.*

Assumption 1 is stated mathematically in the proofs of the Lemmas in the appendix to this chapter. This assumption helps avoid two vacuous situations. When reservation price  $r$  is sufficiently low relative to fit cost  $t$ , some buyers between the two sellers may not purchase from either seller to prevent a negative net surplus. When  $r$  is sufficiently low relative to customization cost  $a$  and information cost  $b$ , the highest price in the customization scope (see Figure 2) will exceed  $r$  and some buyers will be priced out of the market.

### No Customization

The first case, when both sellers produce a single product, has been analyzed in the literature [21]. To provide a benchmark for the other cases, we mention the following facts:

- The two sellers produce goods at diametrically opposite positions and price them at  $t/2$ .
- Each seller makes a profit of  $t/4$ .

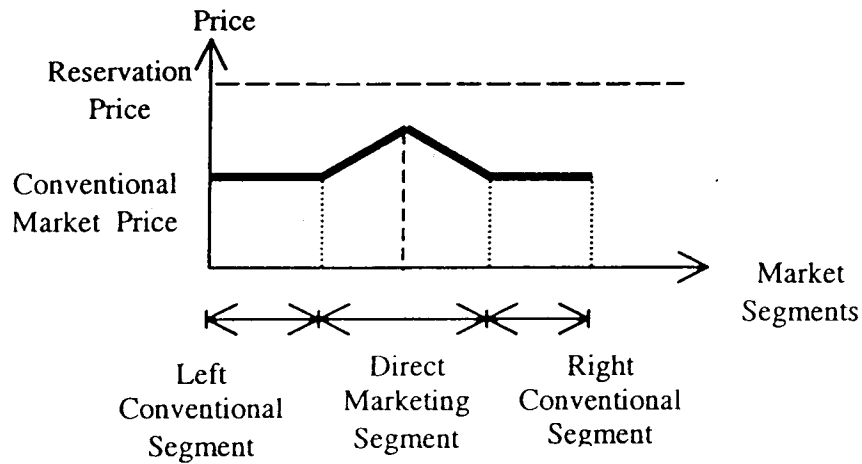


Figure 2. Market Segmentation and Pricing of a Quasi-Direct Marketer

- The total consumer surplus is  $r - 5t/8$ .
- The total social surplus is  $r - t/8$ .

### One Seller Customizes

The game between a conventional seller and a quasi-direct marketer proceeds in two stages. During the first stage, the quasi-direct marketer chooses its customization scope  $x$  and the conventional seller is idle. The principle of maximum differentiation equally applies here, implying that the two sellers are located symmetrically. During the second stage, the conventional seller observes the value of  $x$  and both sellers choose prices simultaneously to maximize their own profits. Indicate the quasi-direct marketer and the conventional seller's conventional market prices as  $p_d$  and  $p_c$ , respectively. Notice that the price choice of the quasi-direct marketer is the price for its standard products. The quasi-direct marketer's two standard products not only directly compete with the conventional seller's standard product, but also limit the prices charged for its own custom offerings, as we shall see shortly. The quasi-direct marketer's customized products do not directly compete with the conventional seller's standard offering. However, the customized products do help expand the quasi-direct marketer's range of offerings and allow it to charge higher prices for the two standard products when competing with the conventional seller. To characterize the Subgame Perfect Equilibrium (SPE) for this game, we invoke backward induction and start with Stage 2.

#### Stage 2: The Conventional Market Pricing Game

We make one more assumption about the customization cost parameters.

**Assumption 2:** *The parameters of customization cost are such that the market segments for both customized and standard products exist.*

Assumption 2 maintains the identity of the quasi-direct marketer and ensures that the quasi-direct marketers have nonoverlapping customization scopes.

A buyer located at distance  $y$  away from the quasi-direct marketer's standard product will be indifferent between purchasing the standard product of the quasi-direct marketer and purchasing from the conventional seller if

$$p_d + ty = p_c + t\left(\frac{1-x}{2} - y\right).$$

The quasi-direct marketer's Stage 2 problem can be formulated as

$$\text{Max}_{p_d} 2p_d \left( \frac{p_c - p_d}{2t} + \frac{1-x}{4} \right) + 2 \int_0^{\frac{x}{2}} (p_d + ty) dy. \quad (1)$$

The first term in this formulation is the quasi-direct marketer's profit from his two conventional segments, and the second term is the profit from his direct marketing segment. In the direct marketing segment of the electronic market, the seller can observe each buyer's location and therefore can price discriminate. To extract maximum surplus from buyers in the direct marketing segment, the seller applies such a pricing scheme: charging the sum of the conventional market price and the buyer fit cost of purchasing the closest conventional market standard product. In other words, for a buyer located in the direct marketing segment at distance  $y$  ( $y < x/2$ ) away from the closest end point, the price charged is  $p_d + ty$ . Denote the price for buyer  $y$  as  $p(y)$ . If  $p(y) > p_d + ty$ , buyer  $y$  will switch to purchase the conventional market standard product at price  $p_c$ , leading to a loss for the seller. If  $p(y) < p_d + ty$ , the seller is not extracting the maximum rent by leaving some extra surplus to buyer  $y$ . Therefore the linear pricing scheme  $p(y) = p_d + ty$  ( $\forall y < x/2$ ) is indeed optimal. Under this pricing scheme, buyers in the conventional segments will choose the standard products at the edges of the customized spectrum and buyers in the direct marketing segment will choose the products tailored specifically for them. There will be no arbitrage among buyers under this pricing method. Figure 2 shows the quasi-direct marketer's market segmentation and pricing scheme.

The conventional seller's Stage 2 problem is:

$$\text{Max}_{p_c} 2p_c \left( \frac{p_d - p_c}{2t} + \frac{1-x}{4} \right). \quad (2)$$

Solving Equations 1 and 2 simultaneously, we obtain the quasi-direct marketer's optimal conventional market price

$$p_d = \frac{t}{2} + \frac{tx}{6}$$

and the conventional seller's price

$$p_c = \frac{t}{2} - \frac{tx}{6}.$$

### Stage 1: The Quasi-Direct Marketer Chooses Customization Scope

In Stage 1, the quasi-direct marketer will choose customization scope  $x$  to maximize his profit, anticipating the outcome of the Stage 2 pricing game. Substituting the prices obtained for Stage 2 into Equation 1 and taking into account the customization costs, we get the quasi-direct marketer's Stage 1 problem:

$$\text{Max}_x \frac{1}{36} t [2x(5x+3)+9] - ax^2 - bx. \quad (3)$$

Solving the first-order condition gives the optimal customization scope, and we can then get the sellers' equilibrium prices. We summarize the outcome of this 2-stage game in the following Lemma.

**Lemma 1.** *Under Assumptions 1 and 2, the two-stage game has a unique Subgame Perfect Equilibrium,*

$$\langle x, p_d, p_c \rangle = \left\langle \frac{3(t-6b)}{2(18a-5t)}, \frac{3(12a-2b-3t)t}{4(18a-5t)}, \frac{(36a+6b+11)t}{4(18a-5t)} \right\rangle.$$

Proof: See Appendix.

At equilibrium, the quasi-direct marketer's profit is

$$\pi_d = \frac{3[12b^2 - 4bt + 3(4a-t)t]}{144a - 40t}$$

and the conventional seller's profit is

$$\pi_c = \frac{(36a+6b-11t)^2 t}{16(18a-5t)^2}.$$

The following proposition shows that, when competing with a conventional seller, the quasi-direct marketer has an advantage.

**Proposition 1.** *Compared with the duopoly of two conventional sellers under the section titled "No Customization" earlier:*

- *The quasi-direct marketer's equilibrium profit is higher, while the conventional seller's profit is lower.*
- *The prices straddle the conventional market price of the duopoly of conventional sellers, with the prices of the quasi-direct marketer being higher.*
- *The quasi-direct marketer's market share increases while that of the conventional seller decreases.*

Proof: See Appendix.

The quasi-direct marketer can charge a higher conventional market price than the conventional seller and can charge a premium of different magnitudes for his custom products. The quasi-direct marketer has larger sales, since it can capture all the buyers in its direct marketing segment as well as those in the adjacent conventional segments. *Proposition 1 thus formalizes the popular belief that vendors of customized products can sell more and charge more.* Two opposing forces determine the quasi-direct marketer's conventional market price. A low conventional market price helps expand its conventional segments, driving up the sales from its standard products but also restricting the prices in the direct marketing segment, impairing the profit from the custom products. *To extract maximum benefit from customization, the quasi-direct marketer will intentionally abandon some buyers in the conventional segments by setting a higher price.*

When customization and information collection technologies advance, marginal customization cost ( $a$ ) and marginal information cost ( $b$ ) will decrease. As  $a$  or  $b$  decreases, the quasi-direct marketer will expand his customization scope and raise his conventional market price (and thus the prices of all custom products), while the conventional seller will lower his price. This is due to the fact that

$$\frac{\partial p_d}{\partial a} = -\frac{9t(t-6b)}{2(18a-5t)^2} < 0$$

and that

$$\frac{\partial p_c}{\partial a} = -\frac{\partial p_d}{\partial a} > 0.$$

The quasi-direct marketer can afford to give up more buyers of standard products and rely more heavily on customized products as a profit source when technologies advance. Even though its conventional market segments shrink as technologies advance, the quasi-direct marketer will enjoy a growing market share because the expansion of its direct marketing segment more than compensates for the contraction of its conventional segments. Correspondingly, the conventional seller will lose market share as customization and information collection technologies advance.

We can also check that

$$\frac{\partial \pi_d}{\partial a} = \frac{-9(t-6b)^2}{4(18a-5t)^2} < 0, \quad \frac{\partial \pi_d}{\partial b} = \frac{-12(t-6b)}{8(18a-5t)} < 0,$$

$$\frac{\partial \pi_c}{\partial a} = \frac{9t(36a+6b-11t)(t-6b)}{4(18a-5t)^3} > 0,$$

and

$$\frac{\partial \pi_c}{\partial b} = \frac{3t(36a+6b-11t)}{4(18a-5t)^2} > 0.$$

Therefore advances in customization and information technologies benefit the quasi-direct marketer (see Figure 3) but reduce the conventional seller's profit.

## Both Firms Customize

Consider a two-stage game in which sellers choose their customization scopes and conventional market prices simultaneously in Stage 1 and Stage 2, respectively. Suppose 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. We start with the second stage of the game.

### Stage 2: The Conventional Market Pricing Game

At Stage 2, sellers can observe their Stage 1 customization scope choices  $x_1$  and  $x_2$ . A buyer located at distance  $y$  away from Seller 1's standard product will be indifferent between purchasing from Seller 1 and Seller 2 if

$$p_{d1} + ty = p_{d2} + t \left( \frac{1 - x_1 - x_2}{2} - y \right).$$

The length of Seller 1's conventional segment is

$$d_{d1} = \frac{p_{d2} - p_{d1}}{2t} + \frac{1 - x_1 - x_2}{4}$$

and Seller 2's conventional segment length is

$$d_{d2} = \frac{p_{d1} - p_{d2}}{2t} + \frac{1 - x_1 - x_2}{4}.$$

Seller  $i$ 's Stage 2 problem can be formulated as

$$\text{Max}_{p_{di}} 2p_{di} \left( \frac{p_{dj} - p_{di}}{2t} + \frac{1 - x_1 - x_2}{4} \right) + 2 \int_0^{\frac{x_i}{2}} (p_{di} + ty) dy. \quad (4)$$

Solving Equation 4 for the two sellers simultaneously leads to the optimal conventional market prices

$$p_{di} = \frac{1}{6} t (3 + x_i - x_j).$$

Hence the seller choosing a larger customization scope in Stage 1 will set a higher conventional market price in Stage 2.

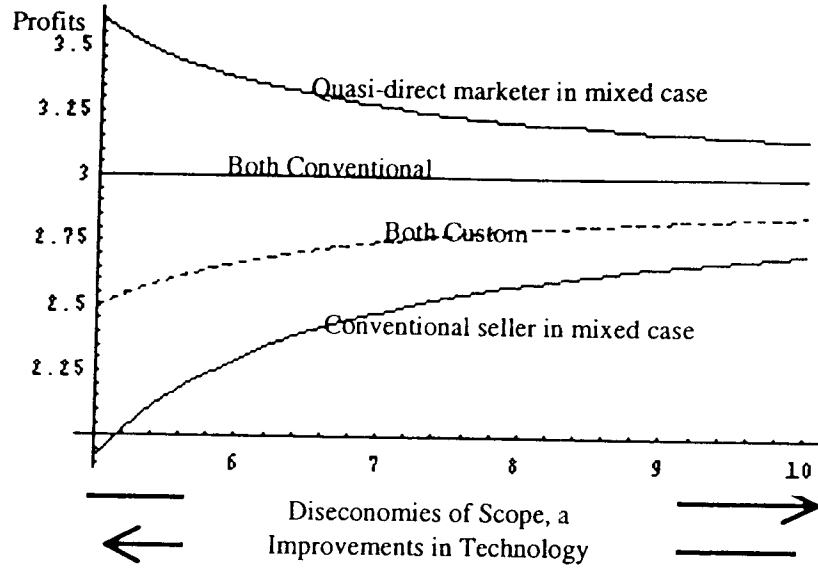


Figure 3. Seller Profits as Customization Technology Improves

### Stage 1: The Customization Scope Investment Game

In Stage 1, the two sellers play a simultaneous game of investing in customization scopes. Substituting the prices obtained above into the profit function, and considering the cost of investing in customization scope, we obtain the two sellers' Stage-1 problems:

$$\text{Max}_{x_i} \frac{1}{36} t \left[ 10x_i^2 - 2x_i(x_j - 3) + (x_j - 3)^2 \right] - ax_i^2 - bx_i. \quad (5)$$

Solving Equation 5 for the two sellers simultaneously, we get their optimal product scopes and conventional market prices, which we summarize into the following lemma.

**Lemma 2.** *Under Assumptions 1 and 2, the two-stage game in product scopes and conventional market prices has a unique Subgame Perfect Equilibrium*

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

Proof: See Appendix.

At equilibrium the two sellers earn the same profit:

$$\pi_{d1} = \pi_{d2} = \frac{18(b^2 + at) - 5t^2}{18(4a - t)}$$

**Proposition 2.** *When both adopt customization and choose their customization scopes simultaneously, both sellers' profits are less than  $t/4$ , the profit in the pure conventional case.*

Proof: See Appendix.

Both sellers are worse off after adopting mass customization because competition forces sellers to overspend in customization. After adopting customization, there is less differentiation between the standard products of the two sellers. However, it is counterintuitive that universal adoption of customization does not increase conventional market price competition, as both sellers still price their standard products at  $t/2$ . We know that the prices of customized products explicitly depend on the conventional market price. The conventional market price thus plays two conflicting roles of directly competing with the other seller for buyers in the conventional segments and of indirectly extracting as much surplus as possible from the buyers in the direct marketing segment. *It is the latter role that relieves the otherwise intensified conventional market price competition.*

When buyer reservation price  $r$  is sufficiently high, we have  $\pi_{d1} = \pi_{d2} \rightarrow t/4$  as  $a \rightarrow \infty$ . *Therefore the duopoly of conventional sellers as discussed in Salop [21] and Tirole [26] is a limiting case of the duopoly of quasi-direct marketers when the marginal cost of customization scope is infinitely high.*

As customization and buyer information collection technologies advance, sellers will expand their customization scopes but will hold conventional market price constant. Each seller can collect higher revenue from its customized products, but customization cost increases at an even faster rate. As shown in Figure 3, seller profit will decrease when  $a$  or  $b$  decreases:

$$\left[ \frac{\partial \pi_{d1}}{\partial a} = \frac{(t + 6b)(t - 6b)}{9(4a - t)^2} > 0 \right].$$

Technological advances have different impacts on the quasi-direct marketers than in the previous section. Universal adoption of mass customization and direct marketing does not make the sellers better off when they directly compete with each other.

## Equilibrium Product Strategies with Simultaneous Choices

WE NEXT IDENTIFY THE EQUILIBRIUM PRODUCT STRATEGY PAIR, if it exists, by allowing sellers to choose product strategies (custom versus standard) simultaneously in the first stage. Sellers are involved in a three-stage game of choosing product strategy, customization scope, and price in each successive stage.

We have previously studied all the subgames of this game and identified a unique Subgame Perfect Equilibrium for each subgame. We can show that the conventional seller does have the incentive to switch to customization if the other seller adopts customization, and therefore <custom, custom> is the first-stage outcome of the unique Subgame Perfect Equilibrium of the three-stage game.

The previous findings are illustrated in Figure 3, where the profits for the two firms are plotted in each of the three cases with  $t = 12$  and  $r = 15$ . Any parameter values satisfying Assumptions 1 and 2 will be able to show the same profit patterns.

Table 1. The Payoff Matrix of the Product-Strategy Game

Payoff (Firm 1, 2)	Firm 2: Standard	Firm 2: Custom
		$\frac{(36a + 6b - 11t)^2}{16(18a - 5t)^2}$
Firm 1: Standard	$\frac{t}{4}, \frac{t}{4}$	$\frac{3[12b^2 - 4bt + 3(4a - t)t]}{144a - 40t}$
	$\frac{3[12b^2 - 4bt + 3(4a - t)t]}{8(18a - 5t)}$	$\frac{18(b^2 + at) - 5t^2}{18(4a - t)}$
Firm 1: Custom	$\frac{(36a + 6b - 11t)^2 t}{16(18a - 5t)^2}$	$\frac{18(b^2 + at) - 5t^2}{18(4a - t)}$

We summarize the profit outcomes when the sellers adopt different product strategies in Table 1, where the first (second) number in each cell is the payoff for Seller 1 (2).

**Proposition 3.** *When Assumptions 1 and 2 hold, there exists a unique pair of product strategies in which both sellers will adopt customization. Further, comparing the equilibrium with the case when neither seller customizes:*

- *The profits for each of the two sellers is lower with customization.*
- *The buyers' surplus is greater with customization.*

Proof: See Appendix.

After both adopt customization, sellers bear higher customization costs but earn less profit than when both provide standard products (see Figure 4). Consistent with Clemons [7], information technologies and mass customization serve as strategic necessities rather than creating competitive advantages for either seller. Interestingly, our results also cast light on the IT productivity literature. Notice the *number* of products produced remains the same, but *variety* and buyer welfare do increase due to customization, supporting the “mismeasurement” hypothesis by Brynjolfsson [5]. Recall that Proposition 1 says that the quasi-direct marketer makes higher profits at the price of the conventional seller, consistent with Brynjolfsson’s “redistribution” hypothesis. So claims *The Economist* [14], “radical change in a competitive economy—even though it may be a matter of life or death for the companies involved—need not yield commensurate improvements in economy-wide productivity.”

It is insightful to compare competition between quasi-direct marketers and that between conventional sellers, as discussed in Salop [21]. Providing a spectrum of customized products allows sellers more pricing flexibility. Meanwhile, the adjacent

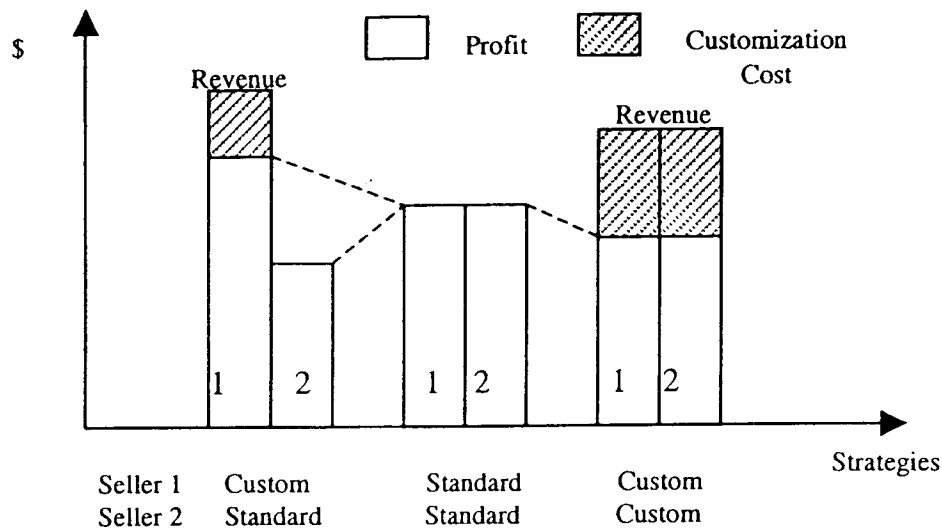


Figure 4. Sellers' Profits and Costs in Different Cases

sellers are located closer to each other due to the presence of direct marketing segments. Product competition between quasi-direct marketers is thus more rigorous than that between conventional sellers. Mass customization also entails extra costs. Therefore sellers are worse off after adopting mass customization and direct marketing. *In this sense, the competitive product strategy equilibrium with simultaneous choices in electronic markets is the well-known Prisoner's Dilemma.*

## Conclusion and Future Extension

OUR CONTRIBUTION IS MULTIFOLD. First, our model is an important extension to the existing models of monopolistic competition by incorporating the notion of production flexibility. Therefore, our paper contributes to the literature of monopolistic competition by allowing firms to consider customization as an alternative choice to standardization. Second, our model captures the role of the Internet in reducing the costs of collecting consumer preference information and enabling cost-efficient custom product design, adding to the emerging literature in Internet economics. Third, several meaningful and interesting insights are derived regarding customization as a product strategy in a competitive setting.

The incredible communications and computing power of the Internet and other information processing technologies such as cookies and collaborative filtering is handing companies an unprecedented opportunity to collect and analyze customer information. The Internet allows sellers to understand their customers' needs and wants on an individual basis. As we have shown, an early adopter of Internet technologies for product customization can sell more and charge more for tailored products, achieving an advantage over its peer conventional sellers. Furthermore, advances in flexible manufacturing and information technologies can reinforce such an advantage. The seller adopting customization will raise the price for its standard goods to obtain a higher margin for its customized goods. Nevertheless, mass customization is no longer a differentiating strategy when all sellers endorse it; there will be excessive

product proliferation and less differentiation. Sellers will tend to overinvest in customization for competitive reasons. Customization serves as a strategic necessity and is the ultimate equilibrium product strategy. Buyers, as a group, will be the long-term beneficiaries of mass customization.

The following observations are worth mentioning. First, our economic model captures the essential tradeoff between the benefits of customization, such as improved product fit for consumers and the extra fixed costs of acquiring production flexibility, but it ignores the operational cost aspects, such as delayed gratification of customized products and the inventory holding costs for carrying standard goods. It will be an important extension to model segmenting consumers based on removal of fit costs and delayed consumption in customization. Second, although our model is primarily motivated for such physical goods as apparel, cars, bikes, computers, and other consumer electronics, it equally characterizes the key features in the process of customizing information goods. It is true that the reproduction and distribution costs for digital goods are negligible on the Internet. The customization costs, however, are not trivial for digital goods. For example, the costs of building a Web site configurable by end users are substantially higher than those of creating a regular site. There are still decreasing returns in *customizing* information goods, and our model therefore applies for information goods as well, including Web pages, software, newspapers, and magazines. Lastly, the results obtained are not unique for the circular model. If a linear market is adopted, the major results will still hold but the analysis will be more complex since firms' location decisions have to be treated explicitly.

Our current model has its limitations, and two major extensions can be made. First, we assume that identical production and information technologies are available to both firms and we ignore the heterogeneity among firms in adopting new technologies. In reality, the costs of acquiring flexible production and Internet-based customization technologies are firm-specific. By adopting two distinct cost functions, we can study the product and price competition between two firms with different productivity in customization. We can also treat the marginal customization and information costs as functions of investments. Second, a more common scenario in the real world is that firms adopt customization sequentially, rather than simultaneously. By studying sequential entry, we can then evaluate the effectiveness of using customization scope to deter entry when each firm faces a fixed entry fee in addition to the initial investment in customization. From the leader's perspective, the unpleasant Prisoner's Dilemma situation may be avoided.

## REFERENCES

1. Bakos, Y. Reducing buyer search costs: implications for electronic marketplaces. *Management Science*, 43, 12 (December 1997), 1676–1692.
2. Bessen, J. Riding the marketing information wave. *Harvard Business Review*, 71, 5 (September–October 1993), 150–160.
3. Bobrowski, P.M., and Mabert, V.A. Alternative routing strategies in batch manufacturing: an evaluation. *Decision Sciences*, 19, 4 (Fall 1988), 713–733.
4. Browne, J.; Dubois, D.; Rathmill, K.; Sethi, S.P.; and Stecke, K.E. Classification of flexible manufacturing systems. *The FMS Magazine*, April 1984, 114–117.

5. Brynjofsson, E. The productivity paradox of information technology. *Communications of the ACM*, 36, 12 (December 1993), 67–77.
6. Chatterjee A.; Cohen, M.A.; Maxwell, W.L.; and Miller, L.W. Manufacturing flexibility: models and measurements. In K.E. Stecke and R. Suri (eds.), *Proceedings of the First ORSA/TIMS Special Interest Conference on FMS* (Ann Arbor, MI). Amsterdam: Elsevier, 1984, pp. 49–64.
7. Clemons, E. Strategic investments in information technology. *Communications of the ACM*, 34, 1 (January 1991), 22–36.
8. Dewan, R.M.; Jing, B.; and Seidmann A. Market segmentation, customization, and pricing strategies in electronic markets. *Working Paper*, Simon School of Business, University of Rochester, Rochester, NY, 1999.
9. Gerwin, D. An agenda for research on the flexibility of manufacturing processes. *International Journal of Operations and Production Management*, 7, 1 (1987), 38–49.
10. Goodbye to fixed pricing? *Business Week*, May 4, 1998.
11. Gupta, Y.P, and Goyal, S. Flexibility of manufacturing systems: concepts and measurements. *European Journal of Operational Research*, 43, 2 (November 1989), 119–135.
12. Hagel, J., and Rayport, J. The coming battle for customer information. *Harvard Business Review*, 75, 1 (January–February 1997), 53–65.
13. Hotelling, H. Stability in competition. *Economic Journal*, 65, 4 (March 1929), 41–57.
14. How real is the New Economy? *Economist*, July 24, 1999.
15. Lancaster, K. Socially optimal product differentiation. *American Economic Review*, 65, 4 (September 1975), 567–585.
16. McFarlan, F.W. Information technology changes the way you compete. *Harvard Business Review*, 62, 3 (May–June 1984), 98–103.
17. McKenna, R. Real-time marketing. *Harvard Business Review*, 73, 2 (July–August 1995), 103–114.
18. Pine, J., II; Peppers, D.; and Rogers, M. Do you want to keep your customers forever? *Harvard Business Review*, 73, 2 (March–April 1995), 103–114.
19. Proth, J.-M. La flexibilité des systèmes de production: les évolutions possibles. *Revue Française de Gestion*, 35, 2 (March–May 1982), 12–20.
20. Rayport, J., and Sviokla, J. Managing in the marketspace. *Harvard Business Review*, 72, 6 (November–December 1994), 141–150.
21. Salop, S. Monopolistic competition with outside goods. *The Bell Journal of Economics*, 10, 1 (Spring 1979), 141–156.
22. Schmalensee, R. Entry deterrence in the ready-to-eat breakfast cereal industry. *The Bell Journal of Economics*, 9, 2 (1978), 305–327.
23. Seidmann, A. Performance management issues in flexible manufacturing systems: an analytical perspective. In R.K. Sarin (ed.), *Perspectives in Operations Management*. New York: Kluwer, 1993, pp. 301–320.
24. Sethi, A.K., and Sethi, S.P. Flexibility in Manufacturing. *International Journal of Flexible Manufacturing Systems*, 2, 4 (July 1990), 289–328.
25. There's gold to be mined in those mountains of data. *Business Week*, July 26, 1999.
26. Tirole, J. *Theory of Industrial Organization*. Cambridge, MA: MIT Press, 1988, pp. 282–283.

## Appendix

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**Lemma 1.** (Restated with parameter space restrictions).

With

$$(a, b) \in \left\{ (a, b) \mid a > \frac{1}{12}(5t - 10b), 0 < b < \frac{t}{6} \right\} \\ \cup \left\{ (a, b) \mid 0 < a < \frac{1}{12}(5t - 10b), b > \frac{t}{6} \right\}$$

and

$$r > \left( \frac{1}{2} + \frac{t - 6b}{18a - 5t} \right) t$$

the two-stage game has a unique Subgame Perfect Equilibrium:

$$\langle x, p_d, p_c \rangle = \left\langle \frac{3(t - 6b)}{2(18a - 5t)}, \frac{3(12a - 2b - 3t)t}{4(18a - 5t)}, \frac{(36a + 6b - 11)t}{4(18a - 5t)} \right\rangle.$$

**Proof of Lemma 1.** The conditions on  $a$ ,  $b$ , and  $r$  are sufficient and necessary for the S.P.E. to exist.

When

$$(a, b) \in \left\{ (a, b) \mid a > \frac{1}{12}(5t - 10b), 0 < b < \frac{t}{6} \right\} \\ \cup \left\{ (a, b) \mid 0 < a < \frac{1}{12}(5t - 10b), b > \frac{t}{6} \right\}$$

the quasi-direct marketer has a nonzero customization scope and a nonnegative conventional segment length. When

$$r > \left( \frac{1}{2} + \frac{t - 6b}{18a - 5t} \right) t,$$

the highest price in the direct marketing segment,  $p_d + tx/2$ , is less than  $r$  (see Figure 2). The remaining part of the proof follows from the solution process above. *Q.E.D.*

**Proof of Proposition 1.** Some basic algebra can show that  $\pi_d > t/4$  is equivalent to  $(6b - t)^2 > 0$ , which holds always. Similarly,  $\pi_c < t/4$  can be shown to be equivalent to

$$(a, b) \in \left\{ (a, b) \mid a > \frac{5t}{18}, b < \frac{t}{6} \right\} \cup \left\{ (a, b) \mid 0 < a < \frac{1}{24}(7t - 2b) \right\},$$

which always holds under the conditions of Lemma 1.

The quasi-direct marketer has a shorter conventional segment than the conventional seller ( $d_d < d_c$ ), because the former sets a higher conventional market price than the latter. However, the market share ( $x + 2d_d$ ) of the quasi-direct marketer,

$$\frac{3(12a - 2b - 3t)}{4(18a - 5t)}$$

is larger than the market share ( $2d_c$ ) of the conventional seller,

$$\frac{36a + 6b - 11t}{4(18a - 5t)}$$

*Q.E.D.*

**Lemma 2.** When

$$(a, b) \in \left\{ (a, b) \mid a > \frac{1}{12}(5t - 12b), 0 < b < \frac{t}{6} \right\} \\ \cup \left\{ (a, b) \mid 0 < a < \frac{1}{12}(5t - 12b), b > \frac{t}{6} \right\},$$

and

$$r > \left( \frac{1}{2} + \frac{t - 6b}{12a - 3t} \right) t,$$

the two-stage game in product scopes and conventional market prices has a unique Subgame Perfect Equilibrium:

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

*Proof of Lemma 2.* When

$$(a, b) \in \left\{ (a, b) \mid a > \frac{1}{12}(5t - 12b), 0 < b < \frac{t}{6} \right\} \\ \cup \left\{ (a, b) \mid 0 < a < \frac{1}{12}(5t - 12b), b > \frac{t}{6} \right\},$$

sellers have positive customization scopes and conventional segments. When

$$r > \left( \frac{1}{2} + \frac{t - 6b}{12a - 5t} \right) t,$$

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 2.** 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

$$(a, b) \in \left\{ (a, b) \mid a > \frac{t}{4}, 0 < b < \frac{t}{6} \right\} \cup \left\{ (a, b) \mid 0 < a < \frac{t}{4}, b > \frac{t}{6} \right\},$$

which clearly holds under the conditions of Lemma 2. *Q.E.D.*

**Proof of Proposition 3.** We just have to show that the conventional seller will also choose customization if the other seller chooses customization, i.e.,

$$\frac{18(b^2 + at) - 5t^2}{18(4a - t)} > \frac{(36a + 6b - 11t)^2 t}{16(18a - 5t)^2}.$$

After some transformation, the desired inequality is equivalent to  $2(6b - t)^2 (1296a^2 - 756at + 119t^2) > 0$ , or just  $1296a^2 - 756at + 119t^2 > 0$  which always holds under the conditions of the proposition.

Recall that Proposition 2 suggests that sellers are worse off when both adopt customization than when both offer standard products. It is worthwhile to compare the social welfare and buyer surplus under these two product strategy schemes. When both sellers adopt customization, total social surplus is less than when both adopt standardization due to extra costs entailed by customization. However, the comparison of buyer surplus is not obvious. The total buyer surplus when both sellers produce standard products is:

$$BS_{ss} = r - 4 \int_0^{\frac{1}{4}} \left( \frac{t}{2} + ty \right) dy = r - \frac{5t}{8}. \quad (6)$$

Buyer surplus when both sellers adopt customization is

$$\begin{aligned} BS_{cc} &= r - 4 \int_0^{\frac{x}{2}} \left( \frac{t}{2} + ty \right) dy - 4 \int_0^{\frac{1}{4} - \frac{x}{2}} \left( \frac{1}{2} + ty \right) dy \\ &= r - \frac{[144(5a^2 + 2ab + 2b^2) - 24(17a + 7b)t + 65t^2]t}{72(4a - t)^2}. \end{aligned} \quad (7)$$

After some tedious algebra, we can show that  $BS_{ss} < BS_{cc}$  is equivalent to  $(6b - t)(12a + 12b - 5t) < 0$ , which always holds under the conditions of Proposition 3. *Therefore total buyer surplus will improve after both sellers switch from standardization to customization. Q.E.D.*