

CUSTOMER-BASED CUSTOMIZATION AND PRICE COMPETITION

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Among the many consequences on production processes, new technologies, including 3D-printing and web-based co-design, provide end-users with increasingly effective means to locally reshape and co-produce products to fit their needs, decentralizing part of the production process. But do firms have an incentive to design goods that are self-customizable or rather to retain centralized production? Is users' surplus increased when self-customization is an available option? We analyze a duopoly where firms can offer a standard version only, or a menu with two product/price options: a standard and a customizable version. Different from firm-based customization, customizing consumers pay the same price to the firm, who cannot price discriminate among them. We find that both firms introducing a self-customizable product can be an equilibrium, with an increase in profits, consumers surplus, and welfare. However, there also arise situations where one firm only produces standardized goods. The equilibrium configuration depends upon the cost of self-customization and the distribution of consumers.

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I. INTRODUCTION

This paper is about interfirm competition in the wake of the new technologies – massively entering the world of production and consumption – that enable end-users of many products to locally reshape, complete, "self-customize" the purchased items, making production partly decentralized. We cast our analysis in a spatial duopoly framework, where sellers face the advent of these new technologies.

Producer-based product customization, which was typical of pre-modern manufacturing, has long been recognized as a returning prominent phenomenon reshaping contemporary marketing and production (Davis [1989]; Hart [1995]) and it has generated a consistent body of academic literature (see Fogliatto *et al.* [2012], and the references therein). However, most of the literature deals with centralized producer-based customization, while the consequences on pricing and competition of the new wave of self (or customer)-based customization is almost totally unexplored.¹

Thanks to the new technologies, the end-user is often involved in the production process and bears the cost of changing the product characteristics.² An increasing number of decentralized production facilities, like those in the FabLabs network originated at MIT, already exist where end-users find the necessary expertise and technical facilities enabling a complete reshaping of products. Design for self-customization and decentralization needs to be transparent, to adopt modularity, and to involve end-users and users' communities. Also, an object's usefulness to the end-user is enhanced if its components can be repaired, which requires some ability on the part of the

¹ Personal manufacturing or DIY ('Do-It-Yourself') manufacturing are other names for the same phenomenon (see Lipson and Kurman [2010] and Fox [2014] for instance).

² Customization involves both producer and customer at different degrees. In customization, co-design and co-production are involved, as can be found in manufacturing such as textile industry (Duarte *et al.* [2017]), or in services, like logistic services (Mammitzsch and Franczyk [2016]).

user. Further, the value of an investment in repairing is enhanced if the product is self-customized. Self-customization activities, design of products for self-assembly, and repair/reuse are therefore interlinked.³

Firms can seize new opportunities also thanks to the changing attitudes and abilities in the consumers' population. As an excellent example consider assistive technologies and tools used to help overcoming disabilities: recent developments in 3D printing, web-community based collaboration, and user-friendly fabrication tools (Hurst and Tobias [2011]), make self-customization feasible for self-personalization of assistive technologies, like wheelchairs, head pointers for painting, and other devices. Firms can also let customers produce spare parts as in the case of Teenage Technology, a Swedish firm, which sends buyers a link for downloading 3D model of spare parts that they can 3D-print (Walter-Herrmann and Büching [2014]), saving on transportation costs as well as on inventories (see also Khajavi *et al.* [2014] for a comprehensive study). More generally, home fabrication technologies develop at a fast rate, as argued by Fox [2014], 'Third wave DIY draws upon the read/write functionality of the Internet, and digitally-driven design/manufacture, to enable ordinary people to invent, design, make, and/or sell goods that they think of themselves' (Fox [2014, p.18]). Self-customization is also becoming widespread in the production and marketing of medical (Gibson and Srinath [2015]) and surgical applications (Velásquez-García *et al.* [2021]) ranging from bone implants to nerve reconstruction.

One point to note is that the information requirements to allow self-customization are weaker than for producer-based customization. To engage in centralized customization, firms need to know in detail the buyer's tastes and needs to provide a finished good that fits the individual preferences

³ Although one thinks of consumers as the end-users of an object, more generally the end-user transforming the product can be a firm or a local store using an input to adapt it to its own (local) needs.

(Valenzuela *et al.* [2009]). This is also consequential for the pricing strategy: in the case of centralized customization, it is natural to let the firm engage in personalized pricing as in Arora *et al.* [2008] and Bernhardt *et al.* [2007]. When firms do not have enough information on individual tastes, they may still choose to offer self-customizable versions of their products and quote different prices for the standard and the self-customizable product.

Hence, to put together the main features of decentralized customization we build a model where (i) firms can offer a self-customizable version of their product; (ii) consumers bear the cost of customizing and obtain their ideal version of the good; (iii) firms cannot price discriminate between these different customized varieties so determined; (iv) consumers differ in their demand for customization, with two types of consumers. The simultaneous presence of these four features distinguishes our model from the existing literature. In particular, feature (iii) crucially distinguishes the customer-based customization analyzed in this paper from the producer-based customization already discussed in the literature.

Introducing a self-customizable version of the product has three effects: (i) the self-customizable version of a product cannibalizes part of the own demand for the standard version, (ii) it addresses a *different* source of demand; (iii) it diverts customers from the rival.

We analyze self-customization in a Hotelling-type differentiated duopoly framework where consumers are horizontally heterogeneous under a general distribution function that encompasses the uniform distribution as a special case. In the Hotelling model the range of products that a consumer can accept is limited by the ‘transportation cost’, which increases with distance. The classical duopoly analysis simply assumes that this acceptable range covers the whole spectrum of feasible varieties. In our model, instead, this applies only to one

type of customers (type 1), while a second type (type 2) exists that does not accept a specification which is not equal to the preferred one and thus only buys a self-customizable good (if it is offered). Type 1 customers choose between the standard and the self-customizable versions of a firm or of different firms if both versions are offered. When a consumer chooses the self-customizable version, she is able to adapt the product in such a way as to match her ideal point along the Hotelling product characteristic space. We assume that self-customization entails both fixed costs (which do not depend on the extent of self-customization, that is, the distance between the pre-customized product and the post-customization product) and variable costs (which do depend on the extent of self-customization).

Our main results establish that Nash equilibria with self-customizable versions introduced by both firms not only can arise but can also improve the firms' profits. In particular, we show that firms' profits are greater in the case of a self-customization equilibrium when the cost of self-customization is sufficiently *high*. With regard to the variable costs, the reason is that lower variable costs intensify competition among firms, thus being detrimental for profits. With regard to the fixed costs, we prove that they do not affect the consumer choice between one or the other firm self-customizable versions – when both firms are offering it – and hence they do not affect their equilibrium prices; however, they increase the relative attractiveness of the standard products with respect to the self-customizable ones, thus leading to higher equilibrium prices for the standard products, with a positive effect on profits. Therefore, the effects on profits hinge upon the values taken by the two basic parameters (that is, the fixed and the variable costs of self-customization) and by the proportions of types.

We also consider how a firm's profit and strategic responses are affected by the rival's decision to add a customizable version to its product line. We show that, if the proportion of buyers only buying self-customizable products is below a threshold – which depends on the cost of self-customization – then there is no scope for introducing a self-customizable product as a response to such a move by the rival. In this case there exist asymmetric equilibria with only one firm introducing a self-customizable version of the good.

However, this conclusion is reversed when the proportion of buyers only buying self-customizable products exceeds the critical threshold. Then the Nash equilibria entail both firms selling both versions of the product. When the introduction of a self-customizable version by both firms arises endogenously, it is always profit increasing, that is, no firm regrets having introduced a self-customizable product in equilibrium (it is not a Prisoner Dilemma). As the consumer surplus is unambiguously higher under self-customization, welfare is also increased when the self-customizable version is introduced endogenously by both firms.

I(i). *Literature Review*

The implications of producer-based customization have been deeply investigated in the literature. Mostly, the existing models share the properties of the so-called “address models” stemming from Hotelling [1929] and Salop [1979].⁴ For example, Dewan *et al.* [2003] develop a model of product customization by a monopolistic firm and show that the monopolist could increase its profits by producing both the standard and the centrally customized product. When considering a duopoly, however, Dewan *et al.* [2000] and Dewan *et al.* [2003] show that firm-based customization might not benefit firms. Syam *et al.* [2005] consider a situation where the products have two attributes and the

⁴ See Anderson [2008] for a survey.

firms can choose not to customize at all, or to customize either one or both attributes. They introduce an interaction cost of fixed size, which is borne by the consumer when the firm decides to customize. Each firm always produces only one product and, therefore, the interaction cost is attached to a firm's decision: indeed, a consumer cannot buy from the firm offering a customized product a different product that is not customized. Syam *et al.* [2005] find that in equilibrium either no customization or partial customization arises; in the second case both firms customize the same attribute. Differently from our paper, in their model firms offer only one product so that price discrimination never occurs – nor any self-cannibalization effect.

Gu and Tayi [2015] analyze a monopolist choosing whether to offer only a standardized product, only a self-customizable product, or both. In contrast to our model, the standardized product in their model provides the same utility to all consumers while self-customization leads to an increase in the intrinsic value of the product for the customer, leading to vertical differentiation. This makes the two models not directly comparable.⁵ Due to price competition, furthermore, the implications of self-customization are different and more complex than under monopoly.

Ghose and Huang [2009] consider quality customization by firms, and they show that all firms might get higher profits. Loginova and Wang [2011] consider a two-dimensional model where two competing firms can customize the horizontal attribute of the product and find that customization becomes more likely when the two firms differ significantly in their vertical attribute. Mendelson and Parlaktürk [2008] analyze the decision on whether to market only a traditional product or a firm-customized one in a duopoly and show that the incentive to adopt customization is higher if the customizing firm also

⁵ A related recent paper is Sethuraman *et al.* [2018], where the idea of a customization based on customer design is again represented in a vertical differentiation framework.

adopts personalized pricing (perfect price discrimination) instead of uniform pricing, and if it has a cost (or quality) advantage over the rival. Xia and Rajagopalan [2009] analyze a duopoly where customization is represented by an increase in the number of varieties of a product offered by a firm. Consumers differ in the value they assign to firms as well as products attributes, thus leading to a two-dimensional characteristics space. Firms can increase the number of varieties they produce, leading to a finite number of standard products, or engage in customization, leading to a continuum of products. This second strategy requires a waiting time for the customer (akin to a customization cost borne by the customer). They show that the equilibrium strategy in customization is determined by both supply and demand side parameters. In their model an increase in the number of varieties is beneficial to firms.⁶ Similarly to Xia and Rajagopalan [2009], in our model the addition of a self-customizable product to an already existing standard product can increase profits for both firms.⁷

The rest of the paper proceeds as follows. In Section II, we introduce the model, whereas in Section III we provide the benchmark equilibrium without self-customizability. In Section IV, we discuss the introduction of a self-customizable version alongside the standard one by both firms: in Section V we compare the two situations. In Section VI, we discuss the implications for a firm profits and strategic responses of the rival's decision to introduce a self-customizable version, and we derive the customizability policy emerging in equilibrium. Section VII concludes.

⁶ This contrasts with Martinez-Giralt and Neven [1988] where in a one-dimensional space the increase in the number of standard products intensifies competition and it is unprofitable.

⁷ Takagoshi and Matsubayashi [2013] analyze the extent of firm-based customization in a duopoly where products are differentiated in two dimensions, with the first dimension being exogenously set (in a standard way) and the second one being customizable. Alptekinoglu and Corbett [2008] analyze the case where a firm decides whether or not to adopt a customization strategy against a standard rival.

II. THE MODEL

We analyze a Hotelling-type linear city model with two firms, Firm A and Firm B , located at point 0 and 1, respectively. The (constant) production cost of the firms is zero. Consumers are distributed along the unit segment. There are two types of consumers, type 1 and type 2. We denote by $x \in [0,1]$ the location of each consumer in the product space. At each location there is a quota $\alpha \in (0,1)$ of type 1 consumers, and a quota $1-\alpha$ of type 2 consumers. Firms cannot distinguish a consumer type from the other, but they know the value of α .

There are two possible versions of the product, a *standard* version and a *self-customizable* one. Type 1 customers, when buying the standard version, suffer a reduction in utility due to ‘distance’ as in the linear Hotelling model; however, they can also choose to buy the self-customizable version, if it is produced. Type 2 customers, by contrast, are only willing to consider buying the self-customizable version.⁸

The utility of a type 1 consumer when buying the standard version of the good is:

$$(1) \quad u^s = v - p - td,$$

where v is the reservation price, p is the price set by a firm selling the good, t is the standard unit transportation cost, and $d = x$ if the consumer buys from Firm A and $d = 1 - x$ if she buys from Firm B .

⁸ For example, suppose that there is an additional characteristic of the product that would be appreciated by consumers, but no firm has the possibility to add this feature to the product. Type 1 consumers do not value this additional characteristic; at the opposite, type 2 consumers value so much this additional characteristic that they never buy the standard version (where this characteristic is absent) and only buy the self-customizable version (where they include this characteristic by their own). Essentially, a type 2 consumer located at x has a reservation price for variety x_0 given by v if $x_0 = x$ and 0 if $x_0 \neq x$. Alternatively, one can interpret type 2 consumers as consumers having infinite ‘transportation costs’ unless they self-customize the product.

Now, consider the self-customizable version of the product. When the consumer purchases such a version, she is able to adapt the product so that it can match the ideal position on the product characteristic space. Therefore, the ‘transportation costs’ disappear and the good has value v for all x and for both consumer types. However, when self-customizing the product, the consumer sustains a cost. In particular, we assume that customization cost comprises two components, a *fixed* part and a *variable* part. The former refers to the need for each consumer, independently on the extent of customization, to learn how to adjust and to modify the product; the latter refers to the fact that the greater is the modification brought on the original product, the greater is the effort required and so the costs. Therefore, the cost of self-customization for a consumer located at x is:

$$(2) \quad C(x) = c + \tau d ,$$

where $c > 0$ is the fixed cost, and $\tau > 0$ is the unit variable cost of self-customization. We assume that both the fixed and the variable cost of self-customization are sufficiently low, namely $t > \frac{4c}{3} + \tau > 0$.⁹

The utility from a self-customizable version of a good which is sold at price w is therefore:

$$(3) \quad u^c = v - w - c - \tau d .$$

⁹ This condition guarantees that any type 1 customer always prefers complete customization to partial customization. Consider a customer located at x and buying the self-customizable version of Firm A . Under partial customization the cost of customization is $c + \tau x_0 + t(x - x_0)$, where $x_0 < x$ is the customized version that does not fully matches the ideal point of the consumer. It is immediate to observe that when $\tau < t$, the cost of partial customization is always larger than the cost of complete customization, i.e. $c + \tau x$. Furthermore, this condition also guarantees that the conjectured market structure (see later) holds in equilibrium.

Finally, we discuss the distribution of the consumers. As in Esteves *et al.* [2022], we assume the following non-uniform distribution, with $f(x)$ being the density function of the cumulative distribution function $F(x)$ over the support $x \in [0, 1]$:

$$(4) \quad f(x) = \begin{cases} 4\beta x + (1-\beta) & \text{if } x \in [0, 1/2] \\ 4\beta(1-x) + (1-\beta) & \text{if } x \in (1/2, 1] \end{cases}$$

Parameter $\beta \in [-\underline{\beta}, 1]$, with $\underline{\beta} = (3 - \sqrt{5})/2$, is half the difference between the density of the endpoints of the market and the centre, that is $\beta = \frac{f(1/2) - f(0)}{2} = \frac{f(1/2) - f(1)}{2}$. Note that the distribution is symmetric around $x = 1/2$ and it is continuous everywhere. In particular, when $\beta = 0$, consumers are uniformly distributed. When β increases from 0 to 1, there are more consumers at the centre and less at the endpoints. When $\beta = 1$, there is a pure triangular distribution, with no consumers at the endpoints. At the opposite, when β is negative, there are more consumers at the endpoints of the market and less in the centre, so that we have an inverse triangular distribution.¹⁰ Figure 1 illustrates the impact of parameter β :

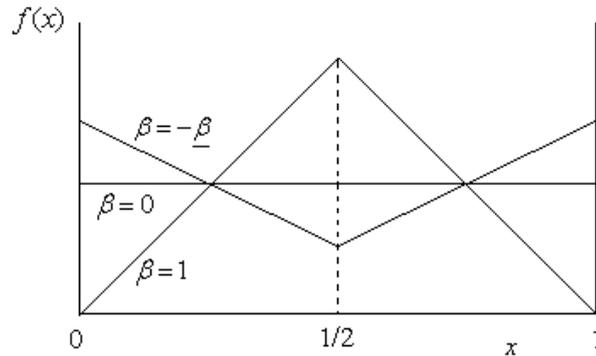


Figure 1

The Consumers' Distribution

¹⁰ $\beta \geq -\underline{\beta}$ is needed to ensure that the second-order conditions of the problem are satisfied (see Esteves *et al.* [2022]).

III. ONLY STANDARD PRODUCTS

In this section, we assume that the two firms offer only standard (non-customizable) versions of the product. Therefore, only type 1 consumers buy.

The indifferent consumer is $h = \frac{p_B - p_A + t}{2t}$. Suppose $h \leq 1/2$. The demand of

Firm A is given by: $D_A = \frac{\alpha h [f(h) + 1 - \beta]}{2}$, so that the profits are: $\pi_A = p_A D_A$.

Then, by taking the first-order derivative and applying symmetry (that is, $p_A = p_B$), we get the equilibrium prices and profits in this situation, that we

label configuration NN, which are $p_J^{NN} = \frac{t}{1 + \beta}$ and $\pi_J^{NN} = \frac{\alpha t}{2(1 + \beta)}$, respectively.¹¹

Not surprisingly, prices and profits are decreasing with β : when more consumers are located in the centre of the market (that is, more consumers are indifferent between the two firms) competition is more intense, with a detrimental effect for prices and profits.¹²

IV. STANDARD AND SELF-CUSTOMIZABLE PRODUCTS

Suppose now that each firm sells both a standard and a self-customizable version of the product. Each firm can quote a price for each version, denoted as p for the standard version and w for the self-customizable one. This constitutes a second-degree discriminatory pricing scheme: indeed, within a menu of price-product pairs each consumer chooses the preferred one.

¹¹ The proof of Proposition 1 in Esteves *et al.* [2022] can be directly applied here and later in Section IV to show that, even if the demand has a kink at $h=1/2$, the first-order condition still works at the symmetric equilibrium and the second-order conditions are also satisfied (see Esteves *et al.* [2022, pp.22-23]). Moreover, in equilibrium it must be $h=1/2$, so our conjecture is confirmed.

¹² It is immediate to observe that if both firms offer only self-customizable goods, the equilibrium prices and profits are $\tau/(1 + \beta)$ and $\tau/2(1 + \beta)$, respectively. However, as discussed later on, offering only self-customizable goods is a strictly dominated strategy for each firm, so we can disregard this case.

With regard to type 1 consumers, we temporarily fix the following market structure (as in Fudenberg and Tirole [2000] we then check that this market structure is indeed confirmed in equilibrium), moving from the left to the right: consumers buying the standard good A , consumers buying the self-customizable good A , consumers buying the self-customizable good B , and consumers buying the standard good B . This market structure is illustrated in Figure 2, below the α -line. Consumers at the left (right) of k buy from Firm A (B), while the price paid by the consumers is indicated within the associated population segments. This market structure reflects the idea that consumers for whom the product offered by the firm is close to their ideal point do not need to choose a self-customizable version. By contrast, those consumers who suffer a greater disutility from buying the standard product are the most interested in the self-customizable version.

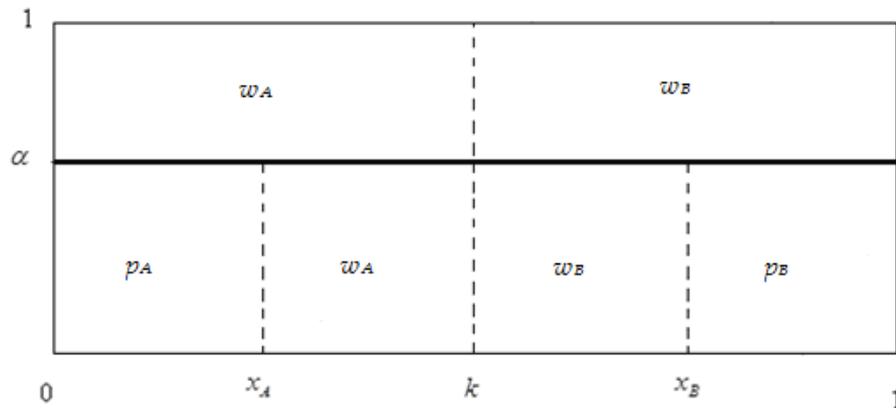


Figure 2
Market Structure

Type 2 consumers only buy the self-customizable version. Therefore, the market structure for type 2 consumers is (from the left to the right): consumers buying the self-customizable good A , and consumers buying the self-customizable good B (see Figure 2, above the α -line).

The threshold consumers are obtained by equating the appropriate utility functions. Solving for $p_A + tx = w_A + \alpha + c$ yields the consumer of type 1

indifferent between the standard and the self-customizable version produced by Firm A . This is $x_A = (c - p_A + w_A)/(t - \tau)$, while the similar indifference condition returns $x_B = (t - \tau - c + p_B - w_B)/(t - \tau)$.

On the other hand, the consumer indifferent between buying the self-customizable version of firm A or B does not depend on the type. Indeed, for both type 1 and type 2 consumers we get $k = 1/2 + (w_B - w_A)/2\tau$.

If the inequalities $1 \geq x_B \geq k \geq x_A \geq 0$ hold, and provided that $k \leq 1/2$, Firm A 's demand for the standard product is $D_A^s = \frac{\alpha x_A [f(x_A) + 1 - \beta]}{2}$ and that for the self-customizable product is $D_A^c = \frac{\alpha(k - x_A)[f(k) + f(x_A)]}{2} + \frac{(1 - \alpha)k[f(k) + 1 - \beta]}{2}$.

Therefore, the profit function of Firm A is $\pi_A = p_A D_A^s + w_A D_A^c$. By taking the first-order derivative and applying symmetry (i.e. $p_A = p_B$ and $w_A = w_B$), the equilibrium prices in this situation, that we label configuration CC, are:

$$(5) \quad w_j^{CC} = \frac{\tau}{1 + \beta},$$

$$(6) \quad p_j^{CC} = w_j^{CC} + \frac{2c}{3} + \frac{(1 - \beta)(t - \tau)}{6\beta} - \sqrt{\frac{4c^2\beta^2 + 2c\beta(1 - \beta)(t - \tau) + (1 - \beta)^2(t - \tau)^2}{6\beta}}.$$

It can be observed that, at the equilibrium prices and given $t > \frac{4c}{3} + \tau > 0$, the conditions $1 \geq x_B \geq k = 1/2 \geq x_A \geq 0$ are satisfied, so the market structure in Figure 2 is realized in equilibrium.

Furthermore, the price of the self-customizable version is lower than that of the standard good, which is commonly observed in real world. Indeed, the consumers buying the self-customizable version are located close to the center of the segment. It follows that if a firm wants to serve these consumers it has to set a low price, because they are rather far from it and rather close to the rival.

Also, in equilibrium CC, type 1 customers buying the self-customizable version pay $\tau/(1 + \beta)$ for a unit while they would pay $t/(1 + \beta)$ in equilibrium NN

for the standard good (this is the cost of self-cannibalization). Therefore, competition for the central segment is fierce and the equilibrium price is low.

Let the equilibrium demand for the self-customizable product to Firm J be denoted by D_J^c* and that for the standard version by D_J^s* . It can be shown that a decrease in τ or c reduces D_J^s* and increases D_J^c* , due to a stronger cannibalization effect of the introduction of the self-customizable version.¹³

In what follows, we consider the impact of the parameters on the equilibrium prices. Consider parameter τ . When the variable cost of the self-customizable version decreases, the distance-cost for the self-customizable product decreases. That is, the two self-customizable goods are less differentiated. This implies that when the variable cost of the self-customizable product decreases, the equilibrium price for the self-customizable product decreases as well; since the self-customizable and the standard products are (imperfect) substitutes, the prices of the standard goods also decrease.

Next, consider parameter c . When the fixed cost of self-customization goes down, all else being equal, consumers are more attracted by the self-customizable version. Therefore, for each firm, the standard product (which is alternative to the self-customizable product) should be charged with a lower price (see the conditions determining the threshold consumers x_A and x_B). However, given face-to-face competition between firms for those consumers that buy the self-customizable products, a decrease in c does not affect the threshold consumer k . Therefore, the price for the self-customizable product is not affected by the fixed cost of self-customization.

¹³ For example, suppose $\beta = 0$ (uniform distribution of consumers). In this case, we have $D_J^s = \alpha c / 2(t - \tau)$ and $D_J^c = \alpha(1 - c/(t - \tau)) / 2 + (1 - \alpha) / 2$, where it can be immediately observed that $\frac{\partial D_J^s}{\partial \tau} \geq 0$, $\frac{\partial D_J^c}{\partial \tau} \leq 0$, $\frac{\partial D_J^s}{\partial c} \geq 0$ and $\frac{\partial D_J^c}{\partial c} \leq 0$. The same holds for a generic value of parameter β .

Finally, the impact of β on the equilibrium prices is negative: when there are more consumers located in the centre of the market, competition is fiercer because the perceived degree of differentiation is low for more consumers.¹⁴

The next proposition summarizes the impact of the parameters on the equilibrium prices.

Proposition 1. The equilibrium price of the standard product strictly increases with τ and c , and strictly decreases with β . The equilibrium price of the self-customizable product strictly increases with τ , strictly decreases with β , and it is not affected by c .

Figure 3 illustrates the impact of τ , c and β on the equilibrium prices.

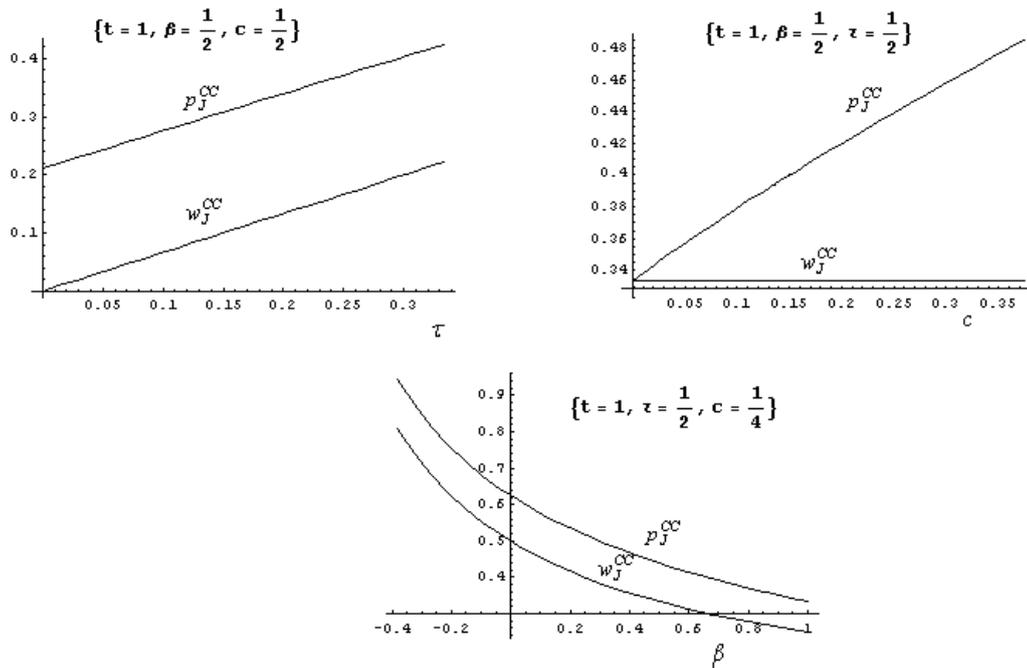


Figure 3

Impact of the Parameters on Equilibrium Prices

¹⁴ The impact of the transportation cost parameter, t , is obvious: it does not affect the price of the self-customizable product, while it increases the price of the standard one. Indeed, a greater distance cost implies greater product differentiation.

Let the equilibrium profits under CC to be indicated by π_J^{CC} . In Table I we report the equilibrium prices and profits for the representative cases of uniform distribution ($\beta = 0$) and pure triangular distribution ($\beta = 1$).¹⁵

Table I
Equilibrium Profits with Uniform and Pure Triangular Distribution

	p_J^{CC}	w_J^{CC}	π_J^{CC}
uniform distribution ($\beta = 0$)	$\frac{c}{2} + \tau$	τ	$\frac{\alpha c^2 + 2\tau(t - \tau)}{4(t - \tau)}$
pure triangular distribution ($\beta = 1$)	$\frac{c}{3} + \frac{\tau}{2}$	$\frac{\tau}{2}$	$\frac{32\alpha c^3 + 27\tau(t - \tau)^2}{108(t - \tau)^2}$

We state the following proposition:

Proposition 2. The equilibrium profits strictly increase with α , τ and c , and strictly decrease with β .

Proposition 2 has the following explanation. As p_J is higher than w_J , when the proportion of type 2 consumers decreases (i.e., α goes up), the profits increase. On the other hand, higher differentiation allows higher prices and lower cannibalization. Therefore, when the variable cost of self-customization increases, the profits increase. Furthermore, we know from the above discussion that c increases the price for the standard good but has no effect on the price for the self-customizable good. Consequently, the profits increase with the fixed cost of self-customization. Finally, the impact of β is negative: as explained above, when consumers are massed around the centre (with a lowering of the variance of tastes), competition is fiercer, pushing down the prices and hence the profits.

¹⁵ The expression of the equilibrium profits for a generic β is in the Appendix.

V. COMPARISON OF THE TWO CASES

In this section we compare the situation CC, where both firms add the self-customizable version to the standard version, and the situation NN, where only the standard (non-customizable) products are offered. Let indicate with $\tilde{\alpha}(t, \tau, c, \beta)$ the level of α that equates π_j^{CC} and π_j^{NN} .¹⁶ We can state the following proposition:

Proposition 3. When α , c , τ , t , and β are such that α is smaller than $\tilde{\alpha}(t, \tau, c, \beta)$, the profits with a self-customizable version in addition to the standard version are higher than the profits with only standard products.

Proof. Compare π_j^{CC} and π_j^{NN} . ■

The dependence of $\tilde{\alpha}(t, \tau, c, \beta)$ in Proposition 3 upon the parameters of the model provides the key insights of the model. Obviously, firms are better off under CC only if α is sufficiently small, as adding a self-customizable version to the standard one leads to higher profits if the proportion of type 2 consumers is higher than a certain threshold.

However, this threshold interestingly depends upon the other parameters of the model. Indeed, $\tilde{\alpha}(t, \tau, c, \beta)$ is strictly increasing in c , τ , t , and β . Hence, an increase in the fixed cost of self-customization, c , tends to enlarge the parameter set where the profits in the CC case are higher than the profits in the NN case. Indeed, as c positively affects the price of the standard good but it does not affect the price of the self-customizable good, an increase in the fixed cost of self-customization increases the profits under CC, while leaving the profits unaffected in the NN case. Consider then parameter τ : while profits in the NN

¹⁶ The complete expression of $\tilde{\alpha}(t, \tau, c, \beta)$ is quite long, and therefore it is reported in the Appendix.

case do not depend on it, profits in the CC case increases with τ because a higher variable cost of self-customization implies greater product differentiation for the self-customizable versions. Consequently, when τ goes up, the parameter space where the profits in CC are larger than the profits in NN enlarges. Next, consider the parameter t , the transportation cost, which also represents the reciprocal of the market competitiveness for the standard good. Since $\tilde{\alpha}(t, \tau, c, \beta)$ increases with t , a decrease in market competitiveness enlarges the region where CC dominates. Finally, the impact of β on $\tilde{\alpha}(t, \tau, c, \beta)$ is strictly increasing. Indeed, when more consumers are located in the centre of the segment, all prices go down, as competition is fiercer for those consumers that are far from the firms. However, the decrease of the price under NN is larger than under CC.¹⁷ Consequently, the more the consumers are massed around the centre relative to the endpoints, the more is likely that profits under CC are greater than under NN.

Corollary. The parameter region in which firms are better off under CC than under NN expands if the (fixed and variable) cost of self-customization increases, the transportation cost increases, and more consumers are located in the centre of the segment.

We conclude with some considerations about the impact of adding a self-customizable version to the standard one on consumer surplus. When considering type 2 consumers, they are obviously better off when a self-customizable version of the product is available, otherwise they do not

¹⁷ Consider $w_J^{CC} = \frac{\tau}{1+\beta}$ and $p_J^{NN} = \frac{t}{1+\beta}$. Since $t > \tau$, the impact of β on p_J^{NN} is greater in absolute value than the impact on w_J^{CC} . Similarly, it can be shown that the impact on p_J^{NN} is greater than the impact on p_J^{CC} (details available).

purchase. Type 1 consumers also benefit from the possibility to purchase a self-customizable version. Indeed, all prices are lower in CC than in NN.¹⁸ Moreover, type 1 consumers buy the self-customizable version rather than the standard product only if the former allows greater utility. It follows that the surplus of type 1 consumers is greater in CC than in NN. Since under some conditions (see Proposition 3) the profits are also higher in CC than in NN, our analysis shows that a symmetric offering of a self-customizable version in addition to the standard one might increase overall welfare, thus resulting in a welfare improvement.

VI. PRODUCT VERSIONING

According to the results, including a self-customizable version in addition to the standard one allows producers to enlarge the market reach. This might lead to higher profits. Producers however may wish to refrain from introducing self-customizable versions of their products if the cost of self-customization is too low (c and/or τ is too low) and there is too little gain from the extensive margin (α is too high). At the same time, producing only a standard product exposes a firm to the risk that the rival will introduce a self-customizable version in addition to the existing one. This then leads to a situation where firms have asymmetric policies, e.g. Firm A produces both versions of its product and Firm B only the standard version, or vice-versa.

In what follows, we focus on such asymmetric policies, and we look for the product policy that is likely to emerge when each firm chooses whether to introduce or not a self-customizable version before setting the prices. We focus on the case where only Firm A introduces a self-customizable version, and we indicate this situation with CN. The other situation, where only Firm B

¹⁸ In Section IV we have shown that $w_J^{CC} < p_J^{CC}$. It is also possible to show that $p_J^{CC} < p_J^{NN}$ for the whole admissible parameter set.

introduces a self-customizable version (NC), is clearly symmetric, so its analysis is omitted.

There are in principle two cases:

Case *i*) none of type 1 consumers buy the self-customizable version;

Case *ii*) some of type 1 consumers buy the self-customizable version.

Case *i*) is extensively discussed in what follows, whereas case *ii*) is briefly discussed at the end of this section. Indeed, CC might be an equilibrium in case *i*), but not in case *ii*).

Lemma 1. A necessary and sufficient condition for case *i*) to occur is that v is sufficiently high.

Proof. See the Appendix.

If no consumer of type 1 buys the self-customizable version offered by Firm A , the equilibrium prices at the type 1 consumers segment are $p_A^{CN} = p_B^{CN} = t/(1 + \beta)$ as in NN, and the profits in that segment are simply π_A^{NN} and π_B^{NN} . On the other hand, the equilibrium price of Firm A for type 2 consumers segment is such that the most distant consumer which is served by Firm A , say \hat{x} , is left with zero surplus. Therefore: $\hat{x} = \frac{v - c - w_A^{CN}}{\tau}$, yielding profits in this

segment equal to $\Gamma \equiv \begin{cases} (1 - \alpha)w_A^{CN} [f(1/2) + 1 - \beta + 2(f(1/2) + f(\hat{x}))(\hat{x} - 1/2)]/4 & \text{if } \hat{x} \in [1/2, 1] \\ (1 - \alpha)w_A^{CN} [f(\hat{x}) + 1 - \beta]\hat{x}/2 & \text{if } \hat{x} \in [0, 1/2] \end{cases}$.

Therefore, the overall equilibrium profits are: $\pi_A^{CN} = \pi_A^{CC} + \Gamma$ and $\pi_B^{CN} = \pi_B^{NN}$. Clearly, Firm A gets larger profits than Firm B . Indeed, the two firms obtain the same profits in type 1 consumers market, but Firm A gains additional profits by serving also type 2 consumers through its self-customizable good. Therefore, if the rival is not offering a self-customizable good, then the focal firm should

offer a self-customizable good as far as $\alpha < 1$, while if $\alpha = 1$ the focal firm is indifferent between the two strategies.

Suppose now that Firm B is offering a self-customizable good. As $\pi_A^{NC} = \pi_A^{NN}$, choosing to offer a self-customizable good when the rival offers a self-customizable good is profitable when the profits in CC are higher than the profits in NN. From Proposition 3 in Section V, we know that this requires that α, τ, c, t and β fall in a region where $\alpha \leq \tilde{\alpha}$. Therefore, if for given values of τ, c, t and β , there are many type 2 consumers, offering a self-customizable good is the dominant strategy for both firms, and CC is the unique equilibrium.

It is interesting to note that the condition that guarantees that CC is the unique equilibrium is the same condition that guarantees that the profits of the firms when both of them offer a self-customizable version are larger than the profits when both of them offer only a standard version (Proposition 3). This implies that CC emerges in equilibrium when there is no other situation where both firms are better off: that is, firms are not trapped in a Prisoner Dilemma.

Moreover, in the light of this result, given that the consumer surplus is always larger under CC than under NN (see the discussion in Section V), we can conclude that, when CC emerges endogenously as a product policy, it is *always* welfare increasing. On the other hand, if CC is not an equilibrium, then the focal firm's best reply is not to offer a self-customizable good when the rival does. In this case, there are two asymmetric equilibria, CN and NC.

We can summarize the above discussion in the following proposition:

Proposition 4. Suppose the firms choose simultaneously the product policy. If v is sufficiently high, then the product policy equilibrium at the first stage is symmetric and equal to CC if $\alpha \leq \tilde{\alpha}$, and asymmetric (namely CN or NC) otherwise - (NN, CN and NC are all Nash equilibria if $\alpha = 1$).

We now consider the case where the product policy is chosen sequentially by the two firms before they set simultaneously the prices. A sequential choice of the product policy might describe those situations where the firms have different capabilities in the adoption of new technologies that allow offering a self-customizable version in addition to the standard one.

It can be shown that the leader always chooses C and that (see the Appendix) Proposition 4 still holds, with the only difference being that there is only one asymmetric equilibrium, where the leader chooses C (and has higher profits) and the follower chooses N.¹⁹

Therefore, the leader has a first-mover advantage stemming from offering a self-customizable good if the equilibrium is asymmetric. Indeed, when an asymmetric equilibrium arises, the firm offering a self-customizable good (the leader) obtains greater profits than the firm offering only the standard product (the follower).

Now we briefly discuss case *ii*) by limiting the analysis to a uniform distribution of consumers ($\beta = 0$).²⁰ In such situation, Firm A indents the market of Firm B in the type 1 segment by selling its self-customizable version. The consumer who is indifferent between the two firms comes from $w_A + \alpha x + c = p_B + t(1-x)$, that is $\tilde{x} = \frac{p_B - w_A + t - c}{t - \tau}$. The equilibrium prices are obtained by maximizing the profit functions $\pi_A = \alpha[p_A x_A + w_A(\tilde{x} - x_A)] + (1-\alpha)w_A$ and $\pi_B = \alpha p_B(1 - \tilde{x})$. By comparing the equilibrium profits under CC and CN

¹⁹ See the Appendix for the formal proof.

²⁰ In the Appendix, we show that the necessary condition for case *ii*) to occur is that v is sufficiently low and α is sufficiently high.

(NC),²¹ we observe that, if the rival is offering a self-customizable good, it is optimal for the focal firm to offer only a standard good, thus focusing on type 1 consumers.²² What happens if the rival is not offering a self-customizable good? In this case, by comparing the equilibrium profits under NN and CN (NC), we observe that if there are few type 2 consumers, offering a self-customizable good is quite costly, as it requires setting a low price for this good. Therefore, offering only a standard good is the dominant strategy and NN is the unique equilibrium. At the opposite, if there are enough type 2 consumers, offering a self-customizable product is profitable. Therefore, in this case there are two asymmetric equilibria, CN and NC, where only one firm offers a self-customizable product. However, CC is never an equilibrium in case *ii*).

VII. CONCLUSIONS

In this paper, we consider the implications of the new technologies allowing self-customization by end-users in a differentiated duopoly with price competition. Self (or customer-based) customization differs from producer-based customization because the former implies that the customization of the product is decentralized to the end-user rather than performed by the producer. Consumers are increasingly attracted by self-customization (Valenzuela *et al.* [2009]), and firms might strategically pursue delegation to consumers as part of the production process.

We develop a spatial model where consumers are horizontally heterogeneous under a general distribution function that encompasses uniform distribution as a special case. The consumers fall into two types: the first buys a standard product if this is the only one offered, and arbitrages between this and

²¹ The complete expressions of the equilibrium prices and profits under CN (NC), case *ii*, are in the Appendix.

²² Indeed, since a high α is a condition for case *ii* to occur (see the Appendix), by selling only the standard product, a firm benefits from the high price of the rival's self-customizable good due to strategic substitutability of prices, without losing a huge margin profits in the type 2 segment.

the self-customizable if both are offered, whereas the second type is only interested in the self-customizable product. In such a context, two firms choose first how many versions to offer (only a standardized version or also a self-customizable one), and then they compete by setting a price for each version.

The firms' choice to introduce a self-customizable version alongside a standard one is without production costs to the firm and yet leads to losses from self-cannibalization and from an increase in competitiveness. The gains arise from (i) tapping a new source of demand, (ii) and indenting the rival's demand (though in equilibrium this may be offset by the rival's strategy choice). Therefore, there is a trade-off such that equilibria with both firms choosing the two-versions strategy are sustained only when the gains outweigh the costs. Differently from most of the literature, this is not a Prisoner's Dilemma and it can also improve welfare.

Our main results are as follows. Introducing self-customizable products alongside standardized ones turns out to be profitable for firms when the cost of self-customization for the consumers is not too low. Furthermore, when the distribution of consumers is more concentrated around the centre of the market, (i.e., when the variance of tastes is reduced) offering a self-customizable version in addition to the standard version is more likely to be profitable for both firms.

When it is an equilibrium strategy, the introduction of a self-customizable version decreases the prices of the standard version, but it is nevertheless profit increasing; in other words, no firm regrets introducing a self-customizable product in equilibrium; in this case, self-customizability also increases consumer surplus and welfare. Furthermore, some situations lead to asymmetric equilibria where a single firm chooses to introduce the two versions and the other only the standard one. In a sequential version of the game, in the asymmetric equilibria, it is the first mover the one who introduces the self-

customizable version, gaining an advantage over the rival. Finally, when the source of demand that can be addressed only by means of self-customizability is sufficiently valuable, both firms introduce a self-customizable product. Our results could help explaining the observed variability in customizability strategies across industries.

Other issues for future research are, for example, consumers' unstable preferences, that is, preferences that might change across periods (Hoeffler and Ariely [1999]). Re-shaping the present one-period model in a two-period model where the preferences of consumers in the second period are related but not identical to the preferences in the first period (Shin and Sudhir [2010]) might allow considering the implications of self-customization in a context of varying preferences. Also, consumers are frequently heterogeneous with regard to their customization capability, depending on their experience, innate skills, and knowledge of their own preferences. The present model could take account of this additional source of heterogeneity by assuming that at each point x there is a continuum of consumers with different customization capabilities. We leave the exploration of these issues for future research.

Finally, in this paper we do not consider explicitly the case where only the self-customizable product is sold by one or both firms. Indeed, it can be shown that this strategy is always dominated by the strategy of offering both the standard and the self-customizable product. Intuitively, the reason is the following. Suppose that Firm A offers only the self-customizable product. Consider a type 1 consumer which is close to point 0. Her disutility is equal to $w_A + c$, plus negligible transportation costs. Therefore, Firm A can get higher profits by offering a standard good at a price $p_A \in (w_A, w_A + c)$ in addition to the

self-customizable product. Therefore, offering only a self-customizable version is always a strictly dominated strategy.²³

APPENDIX

In this Appendix, we set $\delta \equiv t - \tau$ to shorten the equations.

Section IV:

$$\pi_J^{CC} = \frac{\left[8c^3\alpha\beta^3(1+\beta)^2 + 6c^2\alpha\beta^2\delta(1+\beta(1-\beta^2)) + 2c\alpha\beta\delta Z(1+2c\beta-\beta) - 3c\alpha\beta\delta^2(1-\beta^2)^2 \right. \\ \left. + 27t\beta^2\delta^2(1+\beta) + \alpha\delta^2 Z(1-\beta)^2 - 27\beta^2\delta^3(1+\beta) - \alpha\delta^3 + \alpha\beta\delta^3(1+2\beta-2\beta^2-\beta^3+\beta^4) \right]}{54\delta^2(\beta+\beta^2)^2}$$

where $Z \equiv (1+\beta)^2 \sqrt{4c^2\beta^2 + 2c\beta\delta(1-\beta) + \delta^2(1-\beta)^2}$.

Section V:

$$\tilde{\alpha}(t, c, \tau, \beta) = - \frac{-27t\beta^2\delta^2(1+\beta)}{\left[4c^2\beta^2(2c\beta+4c\beta^2+2\beta^3+Z) + 6c^2\beta^2\delta(1+\beta-\beta^2-\beta^3) + 2c\beta\delta Z(1-\beta) + \right. \\ \left. - 3c\beta\delta^2(1+9\beta-2\beta^2+9\beta^3+\beta^4) + \delta^2 Z(1-\beta)^2 - \delta^3(1-\beta-2\beta^2+2\beta^3+\beta^4-\beta^5) \right]}$$

Section VI: *asymmetric product policies (case i)*. Let us consider case CN. The analysis for case NC is symmetric. Since we are assuming that all type 1 consumers buy the standard version of Firm A, two conditions must be satisfied in equilibrium: i) given p_A^{CN} , w_A^{CN} and p_B^{CN} the market structure assumed is confirmed (market structure condition); ii) given p_B^{CN} , Firm A has no incentive to deviate in order to induce another market structure (no deviation condition).

Since h is the type 1 consumer which is indifferent between the two standard products, the market structure condition requires that the type 1 consumer located at h prefers buying the standard good of Firm A rather than the self-customizable good (of Firm A). This occurs if the price of the self-customizable good, w_A^{CN} , is high enough, that is if v is high enough. Turn now to the no deviation condition. It requires that Firm A has no

²³ A formal proof of this statement for the case of uniform distribution of consumers is provided in the Appendix.

incentive to deviate to induce a case where some of type 1 consumers prefer buying the self-customizable version of Firm A . Recall from Section VI that the profits of Firm A when no type 1 consumer buys the self-customizable version increases linearly with v (indeed, as the price for the self-customizable version, w_A^{CN} , is such that the utility of the most distant type 2 consumer is zero, it must be $w_A^{CN} \geq v - c - \tau$).²⁴ Instead, if Firm A wants to serve some type 1 consumers with the self-customizable product, the equilibrium price of the self-customizable version does not depend on v . Indeed, the demand of Firm A (and hence the profits) is now determined by the consumer who is indifferent between the self-customizable good of Firm A and the standard good of Firm B , that is $\hat{h} = \frac{p_B - w_A + t - c}{t + \tau}$, which does not depend on v . Therefore, since the profits of Firm A in equilibrium increases linearly with v , whereas the profits under deviation do not depend on v , also condition *ii*) is satisfied if v is sufficiently high.

Section VI: sequential choice of the product policy. We can state the following proposition:

Proposition A1. Suppose the firms choose sequentially the product policy. If under asymmetric policies no type 1 consumer buys the self-customizable version, the product policy equilibrium is symmetric and equal to CC if $\alpha \leq \tilde{\alpha}$, and asymmetric (namely, the leader chooses C and the follower chooses N) otherwise.

Proof. Suppose Firm $A(B)$ is the leader (follower). If the leader has chosen N, the follower always chooses C (see Proposition 4). If the leader has chosen C, the follower chooses C (N) when $\alpha \leq (\geq) \tilde{\alpha}$. As $\pi_A^{CC} \geq \pi_A^{NC}$, both firms choose C when $\alpha \leq \tilde{\alpha}$. On the other hand, as $\pi_A^{CN} \geq \pi_A^{NC}$, the leader chooses C and the follower chooses N when $\alpha \geq \tilde{\alpha}$.

■

Section VI: asymmetric product policies (case ii). We assume that the consumers are uniformly distributed ($\beta = 0$). Let us consider case CN. The analysis for case NC is symmetric. As for case *i*), even for case *ii*) both the market structure condition and the no deviation condition must be satisfied.

²⁴ Indeed, when all type 2 consumers are served by Firm A (that is, $\hat{x} = 1$), the price is $w_A^{CN} = v - c - \tau$.

The equilibrium prices are:

$$p_{A,ii}^{CN} = \frac{2t(4-\alpha) + c\alpha - 2\delta(2-\alpha)}{6\alpha}$$

$$w_{A,ii}^{CN} = \frac{t(4-\alpha) - c\alpha - \delta(2-\alpha)}{3\alpha}$$

$$p_{B,ii}^{CN} = \frac{t(2+\alpha) + c\alpha - \delta(1+\alpha)}{3\alpha}$$

The market structure condition requires that $1 > \tilde{x} > x_A > 0$ at the prices above, which

is true if $\alpha \geq \underline{\alpha} \equiv \frac{2\delta(t+\tau)}{2\delta(3t+2\tau) - c(5t+\tau)}$. The no deviation condition requires that Firm

A has no incentive to deviate in order to induce case i). Note that the profits in case ii) are equal to:

$$\pi_{A,ii}^{CN} = \pi_{B,ii}^{NC} = \frac{c^2\alpha^2(13t+5\tau) + 4\delta[\delta(2-\alpha) - t(4-\alpha)]\{2c\alpha + [\delta(2-\alpha) - t(4-\alpha)]\}}{36\alpha\delta(t+\tau)}$$

$$\pi_{B,ii}^{CN} = \pi_{A,ii}^{NC} = \frac{[c\alpha + t(2+\alpha) - \delta(1+\alpha)]^2}{9\alpha(t+\tau)}$$

Therefore, the profits of Firm A do not depend on v , whereas the profits under the deviation inducing case i) are positively affected by v (as the deviation price is $v - c - \tau$). Therefore, the no deviation condition for case ii) is satisfied if v is not too high.²⁵

In order to characterize the equilibrium policies, first note that $\pi_{A,ii}^{NC} \geq \pi_A^{CC}$ (and, identically, $\pi_{B,ii}^{CN} \geq \pi_B^{CC}$). Next, by comparing $\pi_{A,ii}^{CN}$ with π_A^{NN} , and, identically, $\pi_{B,ii}^{NC}$ with π_B^{NN} , we observe that $\pi_{A,ii}^{CN} \geq (\leq) \pi_A^{NN}$ and $\pi_{B,ii}^{NC} \geq (\leq) \pi_B^{NN}$ when

$\alpha \leq (\geq) \hat{\alpha} \equiv \frac{4[4t^2\delta - 6t\delta^2 + 2\delta^3 + (t+\tau)(2c\delta - 3\sqrt{\delta(t+\tau)(2t\delta - c^2)})]}{c^2(13t+5\tau) + 8c\tau\delta - 2\delta(11t^2 + 5\tau - 2\delta^2)}$. Hence CN (NC) is an

equilibrium if $\alpha \leq \hat{\alpha}$, whereas NN is the unique equilibrium if $\alpha \geq \hat{\alpha}$.

²⁵ At the same time, v cannot be too low, otherwise the market is not covered. A parameter set satisfying the conditions for case ii) and market coverage is for instance: $t=1$, $\tau=1/5$, $c=1/20$, $\alpha=9/10$ and $v=2$.

Section VII: offering only self-customizable goods. In what follows, we show that offering only self-customizable goods is always a strictly dominated strategy. We consider the uniform distribution case ($\beta=0$). There are three cases:²⁶

- 1) Both Firm A and Firm B offer only self-customizable goods;
- 2) Firm A offers only self-customizable goods, whereas Firm B offers both the self-customizable and the standard good;
- 3) Firm A offers only self-customizable goods, whereas Firm B offers only the standard good.

Next, we show that in each case, Firm A would get greater profits by offering both versions of the good.

1) When both firms offer only the self-customizable goods, the profits are $\pi_A = \pi_B = \frac{\tau}{2}$

(see footnote 12). Now suppose that Firm A offers both versions. The profits functions are: $\pi_A = \alpha[p_A x_A + w_A(k - x_A)] + (1 - \alpha)w_A k$ and $\pi_B = w_B(1 - k)$. By maximizing, the

equilibrium prices are: $p_A = \frac{c}{2} + \tau$, $w_A = w_B = \tau$, yielding the following profits:

$\pi_A = \frac{\alpha c^2}{4\delta} + \frac{\tau}{2}$ and $\pi_B = \frac{\tau}{2}$. Therefore, Firm A prefers offering both versions of the

good.

2) From Case 1, we observe that the profits of Firm A when offering only the self-customizable good are $\pi_A = \frac{\tau}{2}$. Now suppose that Firm A offers both versions. From

Table I, the profits of Firm A are: $\pi_A = \frac{\alpha c^2}{4\delta} + \frac{\tau}{2}$. Therefore, Firm A prefers offering both

versions of the good.

3) Since Firm B offers only the standard good, the type 2 segment is monopolized by Firm A, which sets the price that extracts the surplus from the most distant consumer (we assume that v is sufficiently high). Therefore, $\bar{w}_A = v - c - \tau$. Given \bar{w}_A , the most distant consumer that could be served by Firm B is obtained by

²⁶ There are other two cases, where only Firm B offers only self-customizable goods. However, they are symmetric to case 2 and 3 in the text, so they are disregarded.

$v - p_B - t(1 - x) = v - c - \bar{w}_A - \tau x$, yielding $\bar{x} = 1 - (v - p_B)/\delta$. The profits functions are $\pi_A = \alpha \bar{w}_A \bar{x} + (1 - \alpha) \bar{w}_A$ and $\pi_B = \alpha p_B (1 - \bar{x})$. By maximizing Firm B's profits with respect to p_B , we get $p_B = \frac{v}{2}$, yielding the following profits for Firm A:

$\pi_A = \frac{(v - c - \tau)[2(t + \tau) - v\alpha]}{2(t + \tau)}$. Now suppose that Firm A offers both versions. The

price for the self-customizable good of Firm A is still \bar{w}_A . The profits functions are $\pi_A = \alpha[p_A x_A + \bar{w}_A(\bar{x} - x_A)] + (1 - \alpha)\bar{w}_A$ and $\pi_B = \alpha p_B (1 - \bar{x})$. By maximizing π_A and π_B

with respect to p_A and p_B , respectively, we get $p_A = v - \tau - \frac{c}{2}$ and $p_B = \frac{v}{2}$, yielding

the following profits for Firm A: $\pi_A = \frac{2\delta(v - c - \tau)[2(t + \tau) - v\alpha] + \alpha c^2 \delta}{2\delta(t + \tau)}$. Therefore,

Firm A prefers offering both versions of the good.

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COMPETING INTERESTS DECLARATION

There are no relevant financial or non-financial competing interests to report.