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**Article — Published Version**

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Marketing Letters

**Provided in Cooperation with:**

Springer Nature

*Suggested Citation:* Jost, Peter-J. (2023) : Market expansion and the scope of mass customization, Marketing Letters, ISSN 1573-059X, Springer US, New York, NY, Vol. 35, Iss. 1, pp. 73-94, <https://doi.org/10.1007/s11002-023-09675-6>

This Version is available at:

<https://hdl.handle.net/10419/317856>

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# Market expansion and the scope of mass customization

Peter-J. Jost<sup>1</sup> 

Accepted: 4 April 2023 / Published online: 10 June 2023  
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## Abstract

We consider a market in which two firms with their own customer base have the possibility to expand their business by customization to serve new customer segments. In a two-dimensional model, we examine the optimal scope of customization - that is, whether not to customize, to customize only one dimension, or to customize both dimensions - by analyzing the trade-off between market expansion and expected competition. Depending on the size of their own home markets, we show that in most market constellations one firm fully customizes its standard product whereas the other firm customizes maximally only one dimension. If price discrimination for customized products is possible, firms' incentives to customize increase. However, whereas customization under uniform pricing is always Pareto improving for both firms, it might be Pareto inferior under price discrimination. From a consumer perspective, the situation is reversed. Although full customization implies that customers' preferences are perfectly matched, they do not necessarily benefit from customization under uniform pricing, whereas price discrimination is always a Pareto improvement for customers.

**Keywords** Market expansion · Scope of customization · Limit pricing · Price discrimination

## 1 Introduction

When mymuesli.com was founded in 2007 by three students in Passau, Germany, it was the first company that used mass customization to allow customers to create their own breakfast cereals. Mass customization, the possibility to customize products such that their attributes can be tailored to the individual customer's preferences, was realized with an online configurator on their website. They started their venture in April 2007, first in the German market, extended their business to the Austrian market

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I thank Anna Ressi and Christof Schlindwein for helpful comments.

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in autumn 2007, expanded 2008 to Switzerland and Great Britain, followed by The Netherlands one year later. In this way, *mymuesli.com* is a typical example of a firm entering a new market with its own territory and, as the market evolves, expanding its business to other customer groups.<sup>1</sup> The optimal scope of customization, that is, how many attributes to customize, then is easy to determine for such a firm that is a monopolist in its market, at least if customization costs are negligible: customize as many attributes as possible to meet customers' preferences as best as possible. In the case of *mymuesli.com*, customers could create their own custom-mixed cereal from more than 75 ingredients, thus offering a variety of 566 trillion different products.

However, the optimal scope of customization is less obvious if a firm is not the first entrant into a new market but has to decide on customizing its products in a competitive situation. Consider, for example, the footwear market characterized by the safety and waterproofness of shoes as two attributes of footwear products. Safety ranges from different standards of safety shoes to shoes without safety protection; the waterproofness ranges from waterproofed to water-repellent shoes to shoes without water protection. Consider the two shoe companies, Converse and Rock Fall, in this market to foreshadow our argumentation. Then Converse, with its sneakers and other lifestyle products, produces shoes with low safety and waterproofness, whereas Rock Fall, with its working boots, offers waterproofed safety shoes. They both have their own territories and serve different groups of customers. Now suppose that advances in flexible manufacturing allow the customization of tailor-made shoes along both attributes. This progress enables both companies to expand their business and reach customers in the previously unserved footwear market.<sup>2</sup> But then complete customization, as in the case of the cereal market, is not a successful strategy for both firms: All customers could then buy their ideal product from either firm, and the only way a firm can attract customers is with price discounts. However, this implies severe price competition where prices are driven to marginal production cost.

This paper aims to analyze the optimal scope of customization in such a case of market expansion. We consider a market in which two firms with their own customer base can expand their business by mass customization to serve new customer segments. By examining a two-dimensional product space, each firm can choose its scope of customization - not to customize, partially customize only one attribute, or fully customize both attributes. Customizing an attribute allows all customers to match their ideal preference for that attribute which, as co-creators of their custom products, then bear some cost of interaction.

Our analysis then answers the following questions. First, how does the size of firms' home markets influence their scope of customization? Second, given that both firms customize their products, although this leads to competition, what is the optimal scope

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<sup>1</sup> The new market, in case of *mymuesli.com*, is the market for buying cereal online. Of course, when *mymuesli.com* started its business, numerous cereal manufacturers already offered their products in supermarkets. For information about *mymuesli.com*, see <https://uk.mymuesli.com/about-us>.

<sup>2</sup> Of course, many firms in the footwear market already use mass customization, for example, Adidas and Nike, both in the sports shoe market. However, mass customization, in this case, does not open a new market with customers who were previously not served. See also Section 2.3 for a theoretical discussion and the article by Marconi et al. (2019) and Oliveira et al. (2019) for the complexity of managing the customization of tailor-made shoes.

of such a market expansion? Third, is customization beneficial for both firms even if it leads to competition, or do firms strive for higher market penetration although their profits decrease? Fourth, how does the scope of market expansion change if firms can price discriminate? Finally, is customization and the possibility to buy an ideal product good news for consumers, and what are the consequences of price discrimination on consumer rents?

The answers to these questions are as follows. First, given that customers are willing to bear interaction costs when buying a customized product, the greater the size of its home market, the higher the firm's incentives to customize its product attributes. The firm customizes only one attribute for an intermediate size of its home market; for a more significant size, possibly both attributes. At first sight, this result is surprising. Of course, if the home market is small, customizing one attribute leads to higher market penetration and higher profits if the other firm customizes the same attribute. If, however, the firm's home market is large, demand only slightly increases by market expansion, and one would expect that its incentives to customize are reduced. This reasoning, however, ignores the fact that full customization allows a firm to increase its profit margins. By selling a standard or partially customized product, the firm has to recognize that some customers cannot buy their ideal product but can do it under full customization. In the latter case, the customized product perfectly matches each customer's preferences, and the firm can extract all customers' rent.

This argumentation directly answers also the second and third question above: Given that firms' customization strategies lead to competition, the optimal scope of market expansion for one of these firms is to customize its product in both dimensions. The reason for this result is twofold: On the one hand, the effect of competition on firms' demand is independent of whether one of the firms partially or fully customizes. In both cases, the combat zone of competition, defined as the segment of customers which are indifferent from which firm to buy, is characterized by competition in limit pricing, that is, the customers in the combat zone are also indifferent about whether or not to participate in the market.<sup>3</sup> On the other hand, however, full customization implies higher profit margins than partial customization. Since the profits of the other firm, which customizes only one attribute are unaffected by the customization of its opponent, customization is a Pareto improvement for both firms.

In the case of price discrimination, this finding is no longer valid. Whenever one of the firms fully customizes its product, it can perfectly discriminate between its customers. In particular, it is now possible for this firm to attract additional customers by offering price discounts up to its marginal production costs. The other firm then loses profits because this price competition reduces its profit margins and demand. Whether the firm that fully customizes its product benefits from price discrimination then depends crucially on the opponent's customization strategy. On the one hand, its

<sup>3</sup> The term "combat zone" is borrowed from Syam et al. (2005), the term "limit pricing" is borrowed from the literature on industrial organization and characterizes a price-setting behavior in a market structure which lies between monopoly and competition, see Matutes & Regibeau (1988): In monopoly, a firm's price-setting behavior is independent of any competitor. In competition, firms are competing for customers in the combat zone, and all customers strictly prefer to buy. Because a firm's demand curves in the monopoly and competition regions have different slopes, there exists an intermediate market structure called "weak duopoly" where each firm sets its price at the "kink" of her demand function, see Sect. 4.

price discounts lead to a more significant market expansion with additional profits. On the other hand, however, the resulting price competition also reduces profits from those customers who were charged their maximal willingness to pay under uniform pricing. The first effect is greater than the second one when its opponent decides not to customize, whereas both effects are balanced under partial customization. Although price discrimination increases firms' incentives to customize, it might be Pareto inferior for both.

From a consumer perspective, however, the possibility of price discrimination is good news. Whereas under uniform pricing, some customers might be driven out of the market when firms only offer partially customized products because they are unwilling to bear the necessary interaction costs, discriminatory pricing leads to a Pareto improvement. This results because a firm that only partially customizes its product cannot perfectly price discriminate, so lower pricing uniformly affects all its potential customers.

The paper is organized as follows: Sect. 2 discusses the relevant literature and the contribution of this paper. The basic model is presented in Sect. 3 and analyzed in the following two sections for uniform pricing, respectively discriminatory pricing. Section 6 considers several extensions of the basic model and their influence on the scope of market expansion. We conclude with some final remarks in Sect. 7. All formal proofs are relegated to the Appendix.

## 2 Literature review

The present paper contributes to the literature on mass customization from different perspectives. First, the underlying market structure in most articles is either a monopoly setting or a competitive environment in which two firms simultaneously choose their customization strategy.<sup>4</sup> Studies that consider the customization decision of a single firm usually focus more on operational issues in customization (Jiang et al., 2006; Alptekinoglu & Corbett, 2010; Wong & Lesmono, 2013). Studies that consider customization in a competitive setting focus more on marketing issues (Dewan et al., 2003; Syam & Kumar, 2006). The contribution of the present study, then, is the integration of both a monopoly and competitive market structure into one model. By starting with a market in which two firms act as local monopolists, customization allows both firms to expand their business, which might lead to competition. The present study then focuses on transitioning a monopolistic market into a competitive market structure. It shows that firms' customization strategies are generally asymmetric, and full customization by one firm is possible, even if firms are identical in their initial positioning.

Second, most articles on competitive mass customization consider a market where products are differentiated along a single characteristic or attribute. In such one-dimensional models, complete customization, in the sense that a customized product meets the ideal preferences of every customer in the market, is not considered simply

<sup>4</sup> Some studies consider market structures where firms either decide on their customization strategy sequentially or where an incumbent firm uses customization to deter entry (Dewan et al., 2003; Mendelson & Parlaktürk, 2008; Loginova & Wang, 2013).

because product differentiation then dissolves and products are offered for marginal costs. Some articles consider a two-dimensional product space but assume that the second dimension is either horizontal and non-customizable (Bernhardt et al., 2007; Xia & Rajagopalan, 2009; Takagoshi & Matsubayashi, 2013) or vertical (Loginova & Wang, 2011). The only study where both dimensions are horizontal and customizable is Syam et al. (2005). The crucial difference to our study is the initial market constellation. Whereas Syam et al. 2005 consider a market already covered by firms' standard products, the present study considers two firms serving a local home market. Customization, therefore, serves in our model as a market-expanding measure. This difference then leads to completely different customization strategies for firms. For example, full customization by one firm is never optimal if the market is already covered without customization.

Third, some studies on customization either restrict firms to uniform prices (Syam et al., 2005; Alptekinoglu & Corbett, 2008; Xia & Rajagopalan, 2009), whereas other studies assume that firms use discriminatory pricing for their customized products (Wind & Rangaswamy, 2001; Dewan et al., 2003; Jiang et al., 2006; Alptekinoglu & Corbett, 2010). Two studies compare the effects of uniform and discriminatory pricing on firms' profits and consumer surplus. In Syam and Kumar (2006), firms' incentives to offer higher levels of customization to increase the price premium for the customized product is outweighed by an intensified price competition due to the reduction in product differentiation so that their results are not sensitive to the underlying pricing scheme. In contrast, Mendelson and Parlaktürk (2008) show that price discrimination leads to a broader adoption of customization compared to a situation in which firms are restricted to uniform prices. On the other hand, the degree of customization level can be higher with uniform prices. Our findings support the first but contradict the second of these results by Mendelson and Parlaktürk (2008): We also show that price discrimination increases firms' incentives to customize but that the scope of customization is lower than with uniform pricing. Moreover, different from Syam and Kumar (2006), price discrimination leads to a Pareto improvement for customers. Concerning the economic literature on price discrimination in horizontally differentiated markets, our results confirm the results by Thisse and Vives (1988) and Fudenberg and Tirole (2000). These studies examine the effect of customized prices on price competition and find that firms may not benefit from price discrimination. Our results parallel these studies by showing that price discrimination might be Pareto inferior for both firms compared to uniform pricing.

Our paper also contributes to the small literature on market expansion in a horizontally differentiated market.<sup>5</sup> In Jing (2016), firms can invest in reducing products' evaluation costs which induce additional customers to purchase their products. In Arnaud-Joufray (2020), firms can increase product differentiation, reducing the costs between product characteristics and customers' preferences. As in our paper, both studies assume that the market is initially uncovered, and firms' investments can create a market-expansion effect. Unlike the present paper, however, both studies consider only a one-dimensional horizontal differentiated market. By examining a two-dimensional

<sup>5</sup> Most articles on market expansion study a dynamic market setting where demand is growing in a stochastic way and influenced by advertising, capacity investments, or product development (see, e.g., Terrazas-Santamaria 2021).

product space, our study shows that although firms are identical in their initial competitive positioning, their market expansion might be asymmetric.

To sum up, the following table features the most central papers in the literature on customization and shows the contribution of our paper to extant research (Table 1).

### 3 The basic model

We consider a market in which products are horizontally differentiated along two attributes labeled  $X$  and  $Y$ . Customers have heterogeneous but independent preferences for the two attributes, and their ideal values of the attributes  $(x, y)$  are distributed uniformly over the unit square  $[0, 1] \times [0, 1]$ .  $V$  denotes their reservation value for buying an ideal product that matches their preferences.

Two firms,  $i = A, B$ , offer a standard product in this market. They are maximally differentiated regarding the attributes  $X$  and  $Y$  such that their standard products have locations  $(0, 0)$  and  $(1, 1)$  for  $A$  and  $B$ , respectively. Marginal costs of manufacturing each attribute are assumed to be zero. If a customer with ideal preferences  $(x, y)$  buys one of these standard products, she incurs a misfit cost if the product attributes do not match her preferences. More precisely, the overall disutility of a customer is additive in the two attributes and follows the “city block metric”; that is, her gross utility is given by her reservation value  $V$  minus her disutility in each attribute from not buying her ideal product. Hence, if she buys a standard product from Firm  $A$ , her gross utility is  $U_A(x, y) = V - x - y$ , and similarly  $U_B(x, y) = V - (1 - x) - (1 - y)$  when buying Firm  $B$ ’s standard product.

To analyze the scope of market expansion, we assume that both firms initially start with their own territories. Since a customer’s gross utility is decreasing in her reservation value  $V$ , she is not necessarily inclined to buy a product too far from her ideal product. To ensure that each firm has its own home market, we assume that  $V < 3/2$ .<sup>6</sup> This assumption guarantees that the two firms initially act as local monopolists who do not compete with each other. Since each firm’s demand for its standard product is increasing in  $V$ , the reservation value determines the size of their home markets.<sup>7</sup>

To expand their business, both firms can customize their standard products.<sup>8</sup> The scope of market expansion is defined as firms’ customization strategies. In our two-dimensional model, four strategies are possible for each firm: not to customize, where a firm offers its standard product; partially customize, where a firm decides to customize only one of the two attributes; and fully customize, where a firm decides to customize

<sup>6</sup> For this assumption, see the proof of Proposition 1 for the scenario (No,No).

<sup>7</sup> For the interpretation of  $V$  as a measure of monopoly power in a model of differentiation, see Huang (2009). See also Somogyi (2020), who identifies  $V$  with the degree of product differentiation in a model of horizontal differentiation.

<sup>8</sup> In the basic model, we assume a firm does not offer its standard product when customizing. This extension is discussed in Remark 1 in Sect. 4.

Table 1 Summary of related papers

	Market Structure	Product Attributes	Market Coverage	Customization Strategy	Pricing Strategy
Dewan et al. (2003)	mono & com	$X$	covered or uncovered	$c_X \in [0, 1]$	$p(x)$
Syam et al. (2005)	com	$(X, Y)$	covered	$c_X, c_Y \in \{0, 1\}$	$p$
Jiang et al. (2006)	mono	$X$	covered	$c_X \subset [0, 1]$	$p(x)$
Syam & Kumar (2006)	com	$X$	covered and uncovered	$d_X \in [0, 1]$	$p, p(x)$
Bernhardt et al. (2007)	com	$(X, Y)$	covered	$c_X \in [0, 1], c_Y = 0$	$p$
Alptekinoglu & Corbett (2008)	mono	$X$	uncovered	$c_X \in [0, 1]$	$p$
Mendelson, H. & Parlaktürk (2008)	com	$X$	covered	$c_X \in [0, 1]$	$p, p(x)$
Xia & Rajagopalan (2009)	com	$(X, Y)$	covered	$c_X \in [0, 1], c_Y = 0$	$p$
Alptekinoglu & Corbett (2010)	mono	$X$	uncovered	$c_X \subset [0, 1]$	$p(x)$
Loginova & Wang (2011)	com	$(X, Q)$	covered	$c_X \in [0, 1]$	$p$
Wong & Lesmono (2013)	mono	$X$	uncovered	$d_X \in [0, 1]$	$p$
Takagoshi & Matsubayashi (2013)	com	$(X, Y)$	covered	$d_X \subset [0, 1]$	$p$
<b>This paper</b>	<b>mono</b>	$(X, Y)$	<b>uncovered</b>	$c_X, c_Y \in \{0, 1\}$	$p, p(x, y)$

Where market structure - mono (-polistic) or com (-petitive) - and market coverage refers to market characteristics before customization, and  $X$  denotes product differentiation in one attribute,  $(X, Y)$  in two attributes and  $(X, Q)$  in one attribute and in quality. Firms' endogenous strategic variables are either the customization scope  $c_X, c_Y$  in attribute  $X$  and  $Y$ , or the degree  $d_X$  of customization as a reduction in customers' misfit costs, Syam & Kumar (2006), or as an increase in customers' reservation value, Wong & Lesmono (2013). Firms' pricing strategies are either uniform with  $p$  or discriminatory with  $p(x)$  or  $p(x, y)$  as a function of customers' ideal preferences

both product attributes. A customization strategy  $c_i$  for firm  $i$  is then given by  $c_i \in \{\text{No}, X, Y, \text{Both}\}$  with the following notation: “No” means no customization, “X” or “Y” means customizing attribute  $X$  or  $Y$ , and “Both” means both attributes  $X$  and  $Y$  are customized. We denote with  $p_i \geq 0$  the uniform price charged by firm  $i$  for its product.

For customers, buying a product that customizes one of the attributes implies no disutility for this attribute. That is, if a firm customizes an attribute, this attribute exactly matches a customer’s ideal level of that attribute. Buying a customized product, however, implies some interaction cost  $z$ ,  $z > 0$  for the customer. This cost comes with each customized attribute. If, for example, a customer with ideal preferences  $(x, y)$  buys a product from Firm  $A$  that customizes Attribute  $X$ , her gross utility is  $U_{A,X}(x, y) = V - y - z$ , whereas it is  $U_{A,\text{Both}}(x, y) = V - 2z$  if she buys a product from Firm  $A$  where both attributes are customized. Of course, if the interaction cost  $z$  exceeds a customer’s reservation value  $V$ , she refuses to buy a customized product. Then, customization is not profitable, and both firms offer only their standard product. Hence, we assume  $z < V$  for our discussion. Moreover, if a customer decides not to buy one of the products, her utility is  $U(x, y) = 0$ .

In sum, the interaction of firms and customers is a game in four stages: At  $t = 0$ , both firms  $i \in \{A, B\}$  offer their standard products by setting prices  $(p_A, p_B)$  simultaneously. At  $t = 1$ , both firms simultaneously decide whether to expand their business by choosing a customization strategy  $c_i \in \{\text{No}, X, Y, \text{Both}\}$ . After observing the customization strategy of the other firm at  $t = 2$ , both firms simultaneously set a price  $p_i(c_A, c_B)$  for the customized product in customization scenario  $(c_A, c_B)$ . In the last stage,  $t = 3$ , customers then decide whether to buy a product and from which firm. Since firms’ price setting and customers’ purchasing decisions in the customization scenario (No, No) at  $t = 1$  are identical to the outcome at  $t = 0$ , we solve the game by backward induction as follows: For a given customization scenario  $(c_A, c_B)$  as a strategy profile of both firms at  $t = 1$ , we first consider the optimal price-setting behavior in  $t = 2$ , taking the customers’ optimal purchasing decisions in  $t = 3$  as given. We then use the results on the optimal prices and profits for all scenarios to derive the firms’ optimal customization strategies at  $t = 1$ .

## 4 Market expansion with uniform pricing

Let  $(c_A, c_B)$  be a customization scenario where both firms  $i \in \{A, B\}$  simultaneously choose a customization strategy  $c_i \in \{\text{No}, X, Y, \text{Both}\}$ . Ignoring the symmetry between the two attributes, seven different customization scenarios are then possible.

Before we discuss which of these customization scenarios can occur in equilibrium, consider a firm’s demand changes when it decides to customize its product: When offering a standard product, its demand is given by a isosceles triangle with the standard product at its right angle, such as for Firm  $B$ . Introducing customization of one attribute

then transforms the firm's demand into a rectangle with the entire attribute space as its longer edge, such as for Firm A.

Considering now the seven different customization scenarios, some of these possibilities can never be equilibrium scenarios:

- The scenario (Both,Both), where both firms offer full customization can never be optimal because it leads to Bertrand competition with prices and profits equal to 0.
- Differentiated partial customization ( $X, Y$ ), where both firms customize different attributes, can never be an equilibrium because it implies a market segment of customers willing to buy from either firm. However, both firms are engaged in competitive pricing, leading to lower marginal profits than in the scenario ( $X, X$ ) of matched partial customization. Switching to matched partial customization, therefore, increases a firm's profit.
- The scenario ( $X, \text{No}$ ) can also never be part of an equilibrium. If the customer segments of both firms do not overlap, the firm with the lower profits is incentivized to switch to the other firm's customization strategy. Suppose the demand areas for both firms do overlap. In that case, both are engaged in competitive pricing as in scenario ( $X, Y$ ) so that each firm is incentivized to match the other firm's customization strategy to avoid such fierce competition.

Before we discuss in the following under which market constellations the other four customization scenarios are equilibrium scenarios, it is important to see how customers' reservation value  $V$  affects firms' pricing strategies. Consider, for example, scenario ( $X, X$ ) and suppose that customers' interaction cost  $z$  are sufficiently low to render partial customization profitable,  $z < V$ . If  $V$  is small, that is  $V \in (z, 1 + z)$ , both firms act as monopolists. Each firm sets a monopoly price which keeps the marginal customers indifferent between buying its product or not to buy. Increasing  $V$  in this range increases a firm's demand and its monopoly price. However, the market is not covered and customers in the rectangle around  $y = \frac{1}{2}$  do not buy from either firm. If  $V = 1 + z$ , all customers buy one of the customized products and firms' demand areas intersect. The corresponding segment of customers which can buy from either firm - defined as the combat zone of competition - are those customers with  $y = \frac{1}{2}$ . However, they are also indifferent about whether to buy at all since both firms still demand monopoly prices. If  $V$  then is in an intermediate range, that is  $V \in (1 + z, 3/2 + z)$ , each firm still prices its customized product to keep the customers in the combat zone indifferent about whether or not to buy. This limit pricing is beneficial since it extracts all rents from customers with  $y = \frac{1}{2}$  and implies the highest profit margins. Lowering its price would not be beneficial because this would reduce the firm's profits in its home market without gaining equally from the corresponding market expansion. Of course, if  $V$  then is sufficiently high,  $V > 3/2 + z$ , both firms engage in competitive price. They now compete for the customers in the combat zone, which implies that customers with  $y = \frac{1}{2}$  can keep some of their rent.

The four customization scenarios (No,No), (X, X), (Both,No) and (Both,X) then can induce a Nash equilibrium, depending on the underlying market constellation ( $V, z$ ). The next proposition shows this result:

**Proposition 1** Consider market constellations ( $V, z$ ) such that  $z < V \leq 3/2$  (Fig. 1). Then the following customization scenarios  $(c_A^*, c_B^*)$  are Nash equilibria:

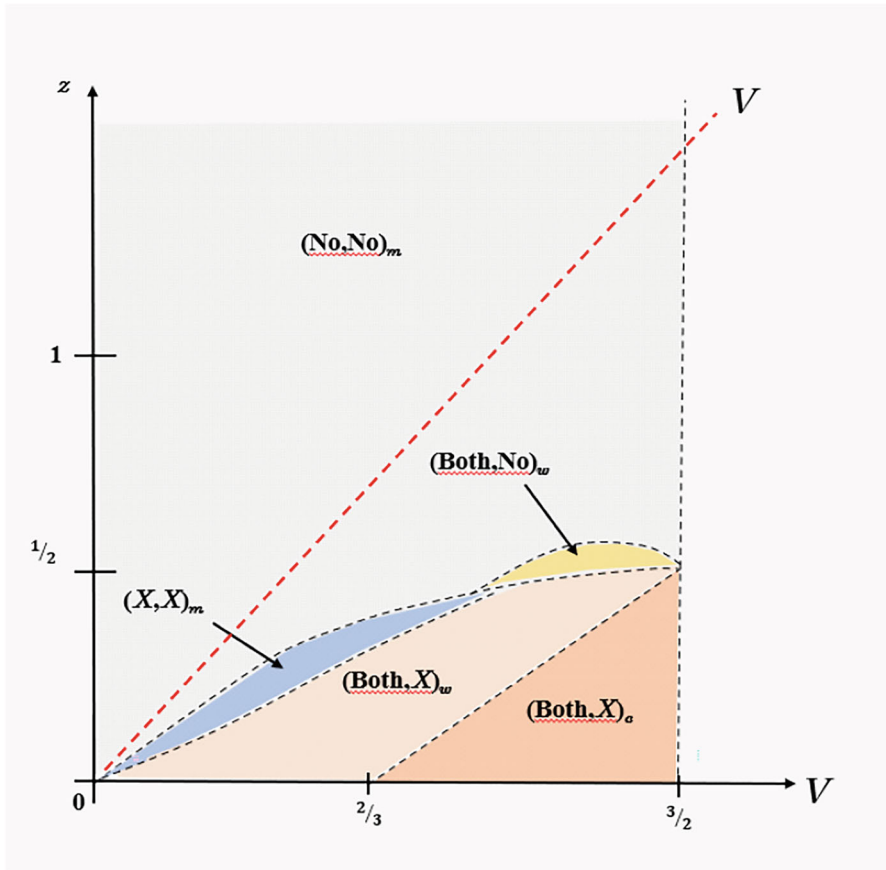
$$(c_A^*, c_B^*) = \begin{cases} (No, No) & \text{for } z \geq \max \left\{ V - \sqrt{\frac{8}{27} V^3}, \frac{V}{6} \left( \frac{27-8V^2}{9-2V^2} \right) \right\} \\ (X, X) & \text{for } z \in \left[ \frac{4}{5}(V-1) + \frac{1}{5}\sqrt{V^2-12V+16}, V - \sqrt{\frac{8}{27} V^3} \right] \\ (Both, No) & \text{for } z \in \left[ V - \sqrt{\frac{8}{27} V^3}, \frac{V}{6} \left( \frac{27-8V^2}{9-2V^2} \right) \right] \\ (Both, X) & \text{for } z \leq \min \left\{ \frac{4}{5}(V-1) + \frac{1}{5}\sqrt{V^2-12V+16}, V - \sqrt{\frac{8}{27} V^3} \right\} \end{cases}$$

**Proof** See Online-Appendix. □

Of course, if the interaction cost  $z$  is sufficiently high and close to customers' valuation  $V$ , customization cannot be part of an equilibrium. Then both firms only operate in their home market and offer their standard products for a monopoly price  $p_i^* = V/3$ . This results in profits  $\pi_i^*(No, No) = 2V^3/27$ .

If the interaction cost  $z$  decreases relative to  $V$ , customization of one attribute becomes an option. However, as soon as it is beneficial for one firm to customize one attribute, the other firm also has an incentive to customize the same attribute in order to increase its profits. In this case, both firms still serve separate parts of the market, that is, for  $V \leq 1 + z$ , they both can act without competition and offer the customized product for a monopoly price  $p_i^* = (V - z)/2$ , resulting in profits  $\pi_i^*(X, X) = (V - z)^2/4$ . Such a matched partial customization then is preferred to the scenario without customization whenever  $z$  is low relative to  $V$  for the following two reasons: First, the price under matched partial customization ( $X, X$ ) is then higher than the price in scenario (No,No). And second, the demand under ( $X, X$ ) increases compared to (No,No). Moreover, if customization is preferred by one firm because the interaction cost  $z$  for customization is sufficiently low relative to  $V$ , it also implies that ( $X, X$ ) becomes an equilibrium: each firm has the incentive to switch to customization of one attribute since its resulting profits are higher than the profits without customization.

If the interaction cost decreases even further,  $z < V/2$ , firms might consider full customization as a possible customization strategy. Consider, for example, the scenario (Both,X). Although this customization scenario implies that both firms compete for all customers in the combat zone, limit pricing ensures that Firm A enjoys a higher profit than under partially matched customization if  $z$  is sufficiently small. Note that Firm B, in this case, still earns monopoly profits and has no incentive to deviate from partial customization simply because full customization leads to zero profits and no customization to fewer profits. This observation holds even if both firms are engaged in competitive pricing: Again, choosing full customization leads to a higher profit than partial customization if the other firm has already customized one attribute, even if



**Fig. 1** Market constellations and equilibrium scenarios in customization under uniform pricing

monopoly profits under  $(X, X)$  could be achieved. Switching to no customization as a response to full customization is not a valid option because it implies a combat zone greater than the one under  $(\text{Both}, X)$ .

This, however, changes if we consider market constellations  $(V, z)$  for which firms' profits under the customization scenario  $(\text{No}, \text{No})$  are higher than the profits under partial matched customization  $(X, X)$ . For  $z \geq V/2$ , the only equilibrium is not to customize for both firms. If the interaction cost  $z$  decreases, the incentive to customize increases. Since partial customization leads to lower profits than no customization, full customization becomes an equilibrium strategy if  $z$  is sufficiently small.<sup>9</sup>

From a consumer's perspective, the result of Proposition 1 could be bad news. Indeed, if customization is profitable for both firms, they will usually engage in limit pricing. Although all customers become consumers, those buying the fully customized product lose all their consumer rents compared to the case where firms price compet-

<sup>9</sup> If a firm customizes in equilibrium, retaining its standard product is beneficial. This result follows because the interaction costs of customers close to its initial location are higher than their misfit costs.

itively. Moreover, some customers willing to buy one of the standard products might not consume under matched partial customization because the higher market penetration due to customization leads to higher prices for the customized product so that the marginal customers without any disutility for the non-customized attribute fall out of the market. The following proposition then shows under which market constellations consumers benefit from customization.

**Proposition 2** *Consider market constellations  $(V, z)$  such that  $z \leq V \leq 3/2$ . Then the following equilibrium customization scenarios  $(c_A^*, c_B^*)$  improve consumer surplus compared to the scenario (No, No) without customization:*

$$(c_A^*, c_B^*) = \begin{cases} (X, X) & \text{for } z \in \left[ \frac{4}{5}(V-1) + \frac{1}{5}\sqrt{V^2 - 12V + 16}, V - \sqrt{\frac{16}{27}V^3} \right] \\ (\text{Both}, X) & \text{for } z \leq \min \left\{ \frac{4}{5}(V-1) + \frac{1}{5}\sqrt{V^2 - 12V + 16}, V - \sqrt{\frac{32}{27}V^3} \right\} \end{cases}$$

**Proof** See Online-Appendix.  $\square$

Overall, consumers benefit from customization in those market constellations  $(V, z)$  where both firms customize and reservation value  $V$  and interaction cost  $z$  are sufficiently low. If, for example, scenario  $(X, X)$  is an equilibrium, consumer surplus increases from customization only as long as  $z \leq V - \sqrt{16V^3/27}$ . And, if scenario  $(\text{Both}, X)$  is an equilibrium, a higher consumer surplus requires  $z \leq V - \sqrt{32V^3/27}$ . In both cases, customization leads to a Pareto-improvement for all parties involved.

## 5 Market expansion with discriminatory pricing

Customization and the personalization of a standard product according to a customer's preferences allow a firm to use this information also for personalized pricing. In practice, firms increasingly use Artificial Intelligence (AI) to collect information about consumer preferences. This information enables firms to offer different consumers different prices based on their individual preferences.<sup>10</sup> Indeed, according to a recent study by OECD (2018), such personalized pricing has been documented in a wide range of industries, including retailing, travel, and personal finance.

To analyze the use of price discrimination based on customers' preferences, suppose a firm customizes an attribute of its standard product. If, for example, a firm customizes attribute  $X$  and a customer with preferences  $(x, y)$  buys its customized product, the firm learns the customer's preference for  $X$ , whereas her preference for attribute  $Y$  remains unknown to the firm. The firm can discriminate prices according to  $x$ . Of course, a firm that offers a standard product cannot price discriminate.

How does the possibility of price discrimination change the scope of market expansion? Do customers benefit from price discrimination, or does it make them worse off?

<sup>10</sup> In practice, personalized pricing is usually hard to detect because firms try to avoid a potential consumer backlash. Instead, many firms use personalized discounts sent by email or smartphone app to customers to conceal their personalized prices. Nevertheless, there is some suggestive evidence. See, for example, Hannak et al. (2014) or Aparicio et al. (2021).

To answer these questions, consider the effect of price discrimination on the equilibrium customization scenarios under uniform pricing. Then firms' equilibrium profits in the scenarios (No,No) and  $(X, X)$  will not change: In the first case, none of the customers reveal their preferences. In the second case, when both firms choose matched partial customization in equilibrium, price discrimination leads to uniform pricing. To see this note that, for a given  $x \in [0, 1]$ , all customers with preferences  $(x, y)$  such that  $y \in [0, 1]$  pay the same price  $p_i(x)$ . Hence, only those customers buy, for example, from Firm  $A$  for which

$$y \leq V - z - p_A(x).$$

But then the optimal price for this customer group is given by Firm  $A$ 's monopoly price, as in the case of uniform pricing.

Price discrimination, however, changes the attractiveness of the two other equilibrium scenarios (Both, $X$ ) and (Both,No), in different directions. Consider first scenario (Both, $X$ ). Under uniform pricing, Firm  $A$ , which fully customizes its product, charges the highest possible price that matches customers' maximal willingness to pay, whereas Firm  $B$  charges a price that makes all customers with preferences  $(x, y)$  such that  $x \in [0, 1]$  and  $y = 1 - (V - z)/2$  just indifferent to buy its product or not to buy. Under discriminatory pricing, Firm  $A$  can now price discriminate along both attributes and, therefore, perfectly discriminate each customer according to her preferences  $(x, y)$  by setting  $p_A = p_A(x, y)$ . Since the lowest price for which it can offer a customized product equals its marginal production costs which are assumed to be zero, Firm  $B$  only reaches customers  $(x, y)$  for which

$$V - 2z \leq V - z - (1 - y) - p_B(x).$$

The optimal price of Firm  $B$  then is  $p_B^* = z/2$ , and all customers with  $y \geq 1 - z/2$  buy  $B$ 's product. Compared to the case of uniform pricing, Firm  $B$  then is worse off: It has to charge a lower price as an answer to Firm  $A$ 's pricing, and its demand reduces likewise. Overall, its equilibrium profits decrease from  $(V - z)^2/4$  to  $z^2/4$  under price discrimination. However, although Firm  $A$  can expand its market under price discrimination, it does not benefit compared to uniform pricing: Since Firm  $B$  charges a lower price than under uniform pricing, the market area where Firm  $A$  can charge customers' maximal willingness to pay decreases. In particular, the market area where customers now pay less - all customers with  $(x, y) \in [0, 1] \times [1 - (V - 3z/2), 1 - (V - z)/2]$  - is of the same size as the market expansion area - all customers with  $(x, y) \in [0, 1] \times [1 - (V - z)/2, 1 - z/2]$ . Since Firm  $A$ 's pricing is linear in these areas, its profits under discriminatory pricing are identical to the ones under uniform pricing.<sup>11</sup>

The situation changes when we consider scenario (Both,No): As in scenario (Both, $X$ ), the possibility to perfectly price discriminate its customers makes Firm  $B$  worse off: It reduces the market area of Firm  $B$  to those customers for which

$$V - 2z \leq V - (1 - x) - (1 - y) - p_B.$$

<sup>11</sup> Note that the assumption of linear misfit cost directly drives the optimality of a linear pricing scheme.

The lower pricing by Firm A then implies a reduction in its pricing from  $V/3$  under uniform pricing to  $2z/3$  under discriminatory pricing, together with a reduction in demand by those customers with preferences  $(x, y)$  with  $x + y \in [2 - 2V/3, 2 - 4z/3]$ . These customers now buy from Firm A. Similar to scenario (Both,X) the lower pricing of B's product implies that the market area decreases where Firm A can charge customers' maximal willingness to pay. Different to the scenario (Both,X), however, Firm A now profits from its discriminatory pricing: Although its pricing  $p_A(x, y)$  is still linear increasing in the area with  $x + y \in [2 - V + 2z/3, 2 - 4z/3]$ , the area of market expansion with a relative low price is not as big as the area where A can charge a higher price. This makes discriminatory pricing in scenario (Both,No) profitable for Firm A (Fig. 2).

**Proposition 3** Consider market constellations  $(V, z)$  such that  $z < V \leq 3/2$ . Under price discrimination, the following customization scenarios  $(c_A^*, c_B^*)$  are Nash

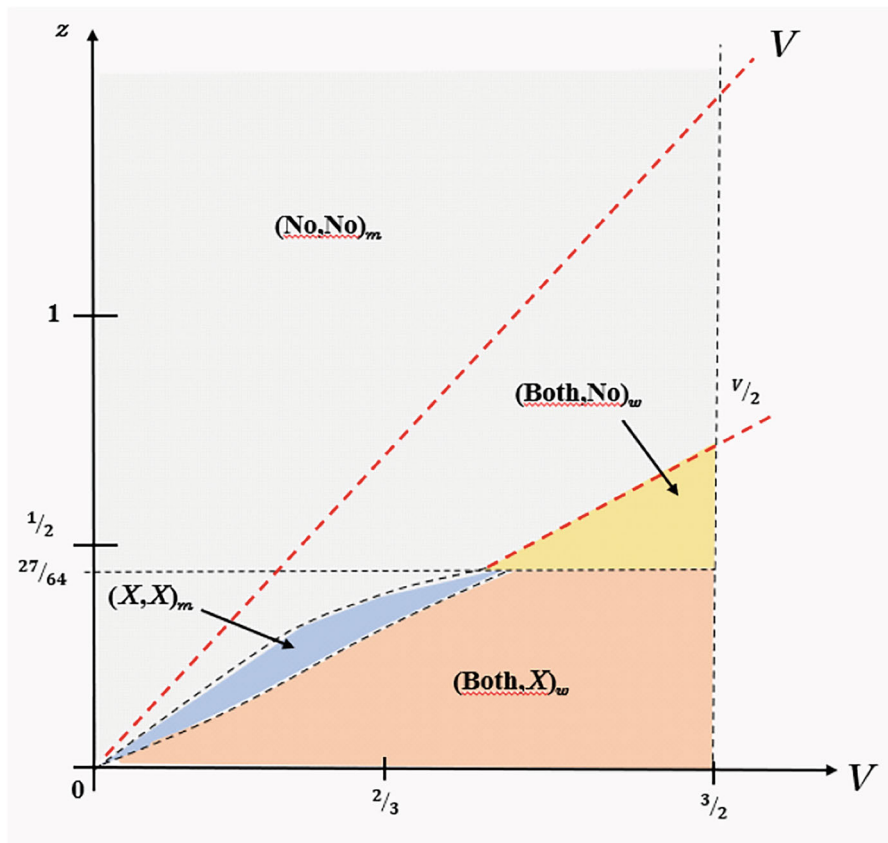


Fig. 2 Market constellations and equilibrium scenarios in customization under discriminatory pricing

*equilibria:*

$$(c_A^*, c_B^*) = \begin{cases} (No, No) & \text{for } z \geq \max \left\{ V - \sqrt{\frac{8}{27} V^3}, \frac{V}{2} \right\} \\ (X, X) & \text{for } z \in \left[ \frac{4}{5} (V - 1) + \frac{1}{5} \sqrt{V^2 - 12V + 16}, V - \sqrt{\frac{8}{27} V^3} \right] \\ (Both, No) & \text{for } z \in \left[ \frac{27}{64}, \frac{V}{2} \right] \\ (Both, X) & \text{for } z \leq \min \left\{ \frac{V}{2}, \frac{4}{5} (V - 1) + \frac{1}{5} \sqrt{V^2 - 12V + 16} \right\} \end{cases}$$

**Proof** See Online-Appendix.  $\square$

Proposition 3 is a direct consequence of our discussion above. If Firm *B* chooses not to customize, full customization increases Firm *A*'s profits under price discrimination, whereas no customization does not affect its profits. Hence, the scenario (Both, No) is an equilibrium scenario for more market constellations  $(V, z)$ . And if Firm *A* chooses full customization, choosing not to customize under discriminatory pricing becomes a better option for Firm *B* than partial customization if the interaction cost is sufficiently high,  $z \in [27/64, 1/2]$  because Firm *B*'s loss in profits when choosing not to customize instead of partial customization is relatively smaller under price discrimination than under uniform pricing.

Not surprisingly, discriminatory pricing is good news for consumers: Whenever one of the firms adopts full customization, this firm has the possibility of lowering its discriminatory price for specific customers up to its marginal production costs. This reduction leads to fierce price competition between the two firms. However, since the firm which does not use full customization cannot perfectly price discriminate, its lower pricing is also better for all its potential customers - those who still buy its product because of the firm's lower pricing, and those who now switch to the fully customized product but do not have to pay their maximal willingness to pay as under uniform pricing. For example, in scenario (Both, X), those customers with preferences  $(x, y) \in [0, 1] \times [1 - z/2, 1]$  still buy Firm *B*'s product but the price decreased from  $(V - z)/2$  to  $z/2$ ; those customers with preferences  $(x, y) \in [0, 1] \times [1 - (V - z)/2, 1 - z/2]$  now buy Firm *A*'s full customized products and have higher utility

$$U_{A, \text{Both}}(x, y) = V - 2z - \left( (1 - y) + \frac{z}{2} \right) > U_{B, X}(x, y) = V - z - (1 - y) - \frac{(V - z)}{2};$$

and those customers with preferences  $(x, y) \in [0, 1] \times [1 - (V - 3z/2), 1 - (V - z)/2]$  pay a lower price for Firm *A*'s customized product than under uniform pricing.

**Proposition 4** *From a consumer's perspective, full customization by one firm in equilibrium leads to a Pareto improvement under price discrimination compared to the corresponding equilibrium under uniform pricing.*

**Proof** See Online-Appendix.  $\square$

## 6 Extensions of the basic model

So far, we derived our results in a simple and stylized model in which firms and customers were identical except for firms' initial locations of their standard products and customers' individual preferences for the products' attributes. In the following, we will consider several extensions of the basic model and their influence on the scope of market expansion. We concentrate our discussion on how differences in the demand and supply side of the market affect our main findings.

**Differences in the size of the new market** In the basic model, both firms had a home market of size  $2V^2/9$  so that they can expand their business to  $1 - 4V^2/9$  new customers. Now suppose that customers with their preferences are uniformly distributed over the square  $[0, M] \times [0, M]$  so that the size of the new market becomes  $M^2 - 4V^2/9$ , with  $M \geq 1$ . Varying  $M$  then has the following implications on firms' customization strategies. First, the region of market constellation without customization becomes smaller with greater  $M$  because firms' profits in scenario  $(X, X)$  increase by factor  $M$  but remain unaffected in scenario  $(\text{No}, \text{No})$ . And second, the region of market constellations with full customization by one of the firms is also increasing in  $M$  because demand increases by a factor of  $M^2$  whereas partial customization increases demand only by factor  $M$ .

**Differences in the heterogeneity of customers' preferences** Suppose that customers have a diversity  $d > 1$  for one of the two attributes, say Attribute  $Y$ , in the sense that customers' preferences  $(x, y)$  are now distributed on the rectangle  $[0, 1] \times [0, d]$ . Then both firms have the incentive to customize Attribute  $Y$  before Attribute  $X$  simply because the market expansion in the first case is higher than in the second. Moreover, a higher diversity increases the region of market constellations where partially matched customization  $(Y, Y)$  is an equilibrium because firms' equilibrium prices do not change, but customization profits become  $d(V - z)^2/4$  whereas profits in scenario  $(\text{No}, \text{No})$  are unaffected by  $d$ .

**Differences in customers' misfit costs** Suppose that customers' misfit costs for not having an ideal product  $(x, y)$  are greater for attribute  $Y$  than for attribute  $X$  by a factor  $m > 1$ . That is if she would buy, for example, the standard product of Firm A, her gross utility would be  $U_A = V - x - my$ . Then firms' profits in the no customization scenario decrease to  $2V^3/27m$  because fewer customers are willing to buy the standard product for its equilibrium price. However, by customizing Attribute  $Y$ , each customer can buy his ideal product concerning  $Y$  so that misfit costs  $m$  do not change the corresponding profits. Hence, customization happens even with higher interaction costs. Moreover, both firms will first customize Attribute  $Y$  than  $X$ . This is because partial matched customization  $(X, X)$  now leads to equilibrium profits  $(V - z)^2/4m$  which are decreasing in  $m$  whereas profits in scenario  $(Y, Y)$  do not change.

**Differences in customers' interaction cost** Suppose that interaction costs differ for both attributes and are  $z_X$  and  $z_Y$  for Attribute  $X$  and  $Y$ , respectively, with  $z_X \geq z_Y > 0$ . Then a firm that customizes only one attribute in equilibrium chooses the attribute with the lower interaction costs for customers. To see this note that all customers with preferences  $(x, x)$  have a higher gross utility when attribute  $Y$  instead of attribute  $X$  is customized,  $U_{A,Y}(x, x) > U_{A,X}(x, x)$ . But then firms can charge a higher price in

scenario  $(Y, Y)$  than in scenario  $(X, X)$ , resulting in higher profits,  $(V - z_Y)^2/4 > (V - z_X)^2/4$ .

**Differences in customers' support** We draw a different conclusion if we assume that customers' interaction costs differ between both firms. Suppose that interaction cost are  $z_A$  and  $z_B$  for Firm A and B, respectively, with  $z_A \geq z_B > 0$ . Of course, the lower interaction cost for its products allows Firm B to charge a higher price than Firm A when customizing the same attribute. With a higher demand for its customized product, Firm B is inclined to introduce customization, whereas Firm A still offers its standard product. This happens whenever  $\pi_B^*(\text{No}, X) = (V - z_B)^2/4 > \pi_A^*(\text{No}, \text{No}) > \pi_A^*(X, X) = (V - z_A)^2/4$ . The differences in customer support imply that Firm B is more profitable and has a greater market expansion than Firm A. This asymmetry between the two firms persists even if Firm A also customizes its product in case full customization becomes beneficial.

**Differences in customers' valuations** A similar conclusion follows if we introduce a vertical differentiation into our basic model. For, suppose that the reservation values are  $V_A$  and  $V_B$  for Firm A and B, respectively, with  $V_B \geq V_A > 0$ . As before, the higher reservation value for its product allows Firm B to charge a higher price than Firm A. Different from the extension with different interaction costs, however, this advantage of Firm B not only comes in the case of customization but also when offering its standard product. The differences in customers' valuations imply that Firm B is always more profitable and has a higher market share than Firm A. Moreover, Firm B has a higher incentive to customize an attribute than Firm A simply because customization is more profitable the higher the reservation value. As a consequence, scenario  $(\text{No}, X)$  now becomes an equilibrium scenario.

**Differences in the location of standard products** We also assumed in the basic model, that both firms offer their standard products on locations  $(0, 0)$  and  $(1, 1)$ . Both firms are maximally differentiated regarding the attributes  $X$  and  $Y$  before market expansion becomes possible. To modify this assumption, suppose that the initial differentiation is only on one attribute and that, for example, Firm B's standard product is positioned at location  $(1, 0)$ . To discuss this extension, note that both firms only have their own territories and do not compete with each other with their standard products if customers' reservation value is sufficiently low,  $V \leq 3/4$ . Hence, the incentive to customize on Attribute  $X$  is higher for both firms and customization comes with higher interaction cost  $z$ .

**Differences in firms' customization costs** Another simplified feature of our basic model is the assumption that both firms incur no additional cost when customizing their standard product. Customization, however, may introduce higher production costs for a firm. Consider first the extension in which customizing one attribute comes with positive fixed cost, say  $F_A > 0$  for Firm A, whereas Firm B has no such fixed cost. Of course, Firm A's decision whether or not to customize an attribute requires lower interaction cost  $z$  than Firm B's decision. That is,  $\pi_A^*(X, X) > \pi_A^*(\text{No}, \text{No})$ , whenever  $z \leq V - \sqrt{8V^3/27 + 4F}$ . Since the same argumentation holds for the decisions to fully or only partially customize the standard product, the market constellations where  $(X, X)$  or  $(X, \text{Both})$  are equilibria become less and the regions where  $(\text{No}, X)$  or  $(\text{No}, \text{Both})$  are equilibria become greater. We arrive at a similar conclusion if we

consider variable customization costs. For suppose, Firm  $A$  has customization cost that depends on the level of its demand  $D_A$ . For simplicity, assume that  $c(D_A) = aD_A^2$  with  $a > 0$ . If Firm  $A$  customizes one attribute its profits decrease to  $(V - z)^2 / 4(1 + a)$ .<sup>12</sup> But this implies that Firm  $B$  customizes in the presence of interaction cost  $z$  where Firm  $A$  will not do so.

## 7 Insights for business

What are the insights of our analysis for the competitive behavior of brand manufacturers in different product markets? How can we explain with our results that one brand customizes more than another? Of course, although it is impossible to match market conditions with our duopoly model and its assumptions, we will explore its practical implications in the following.

Consider first product markets in which one firm fully customizes product attributes whereas its competitor still offers standard products, scenario (Both,No). The classic example here is the competition between Dell and Compaq at the end of the last century.<sup>13</sup> Both firms were brand manufacturers of personal computers. Still, they had different customization strategies: Dell focused on a direct-to-customer approach where customers placed their orders via phone or the internet and produced and shipped each customized product within four to eight hours after receiving the order. On the other hand, Compaq positioned itself as a company with a broad spectrum of computer products and supported customers in deploying those computers to meet their needs. Unlike Compaq, Dell's flexible manufacturing process and sophisticated just-in-time system enabled the company to keep its manufacturing costs low. As discussed above, these differences in firms' customization costs supported their customization strategies. Dell's discriminatory pricing policy also contributed significantly to the company's success, in line with our discussion above. Another example of scenario (Both,No) is the competition between Mars and Nestlé in the market for chocolate candies.<sup>14</sup> Mars, Inc. initially allowed customers to customize only the color of their M&M's, and later on, extended customization attributes to allow for personalized writing or adding an image. Nestlé, the producer of Smarties offers no customization. Why do both firms have such different customization strategies, although M&M's and Smarties' main ingredients are almost identical? One difference is that Smarties use natural colors from plant extracts, whereas M&M's contain artificial colors. Another difference was the development of new technologies for printing on My M&M's. Similar to Dell, the lower customization costs of Mars enabled the customization of its candies. However, unlike computers, the low valuation of candies makes discriminatory pricing less attractive for M&M's as discussed above.

A product market in which one brand customizes more than another brand is the competition between Adidas and Nike in the market for athletic footwear, scenario

<sup>12</sup> Firm  $A$ 's profits are then given by  $p_A(V - z - p_A) - a(V - z - p_A)^2$  which are maximized by a price  $(V - z)(1 + 2a) / 2(1 + a)$ .

<sup>13</sup> See Saloner et al. (2001, p. 4ff) for this example.

<sup>14</sup> See <https://www.mms.com/en-us/history> and Meyer et al. (2008) for this case study.

(Both,  $X$ ).<sup>15</sup> Both firms launched their customization platforms at the beginning of the new millennium, NikeiD in 2000 and miadidas in 2001, in response to the growing heterogeneity of customer needs. Suppose we focus on fit (which includes the length and the width of each foot), performance (which incorporates seasonal upper material, outer sole, and insole options), and design (color options) as crucial attributes of sports shoes. In that case, midadidas' customization offerings include all three options, whereas NikeiD only offers design customization. Whereas for online sales, the design attributes are easily accessible to customers, an online configurator cannot provide all options concerning fit and performance. To lower customers' interaction costs for all its customization options, Adidas allows customers to re-use their respective customer data from a first sale of a customized shoe in a brick & mortar store to re-order the identical shoe online or configure a new one. This integration ensures customers can better use all miadidas' customization options and gives Adidas a first-mover advantage. Even if NikeiD offered comparable customization options as Adidas, a customer would have to repeat the initial process of gathering his data, lowering her incentive to switch.

Finally, consider the scenario  $(X, X)$  of matched partial customization in which two firms customize several identical attributes  $X$  but do not customize one specific attribute  $Y$ . Several product markets exhibit such competitive customization strategies.<sup>16</sup> In the bicycle market, for example, Parlee Cycles and Ventana enable customers to design their bikes with individual components and looks. However, they do not extend the categories of their bikes concerning their intended use: Parlee Cycles offers on-road bikes but does not manufacture mountain bikes, whereas Ventana offers off-road bikes and allows customization within the scope of mountain bikes. In the shoe market, for example, the two competitors, Nike and Vans, enable customers to customize their shoes' material, pattern, and color. However, they do not extend the category of their shoes to the other firm's type: Nike offers shoes with a performance orientation, whereas Van's shoes have a street-style emphasis. As a third industry example, consider the market for sunglasses and the customization strategies of Oakley and Ray-Ban. Both firms offer similar attributes to customize, such as lenses or color options for the front and temple. Still, their model offerings are separate: Sunglasses by Oakley range from outdoor-sporty to casual-oriented styles, whereas Ray-Ban's offerings range from sporty designs to fashion-led classes. According to our discussion, these matched partial customization scenarios result from differences in firms' customization costs (extending bikes into the other category is too costly) or customers' valuations (offering shoes or sunglasses in different categories are valued less).

## 8 Conclusion

The present paper developed a model to examine when a firm should expand its business by serving new customers with a customized product. We analyzed this tradeoff

<sup>15</sup> See Piller et al. (2012) for this case study.

<sup>16</sup> See Yazdani et al. (2020) for the following examples.

between market expansion and expected competition in a basic two-dimensional model for uniform and discriminatory pricing. Depending on the size of their own home markets, we showed that, in most market constellations, one firm fully customizes its standard product. In contrast, the other firm customizes maximally only one dimension. The region where this customization scenario is an equilibrium is greater under price discrimination than under uniform pricing. Because competition is greater under price discrimination, price discrimination is always a Pareto improvement for customers.

An interesting extension of our basic model would be the endogenization of the customization scope. In our modeling, we assumed that if a firm customizes an attribute of its standard product, the customized product can be tailored to all customers for their preferences for this attribute. The customization scope, defined as the group of customers whose preferences are matched when buying the customized product, is then exogenously fixed to One. Now, suppose that each firm can choose the range of customers who can buy their ideal product concerning the attribute considered for each attribute. Since a higher customization scope is always beneficial because it increases demand, increased production cost would be a counterbalancing effect determining the optimal degree of market expansion in this dimension. In addition, we could endogenize customers' interaction costs by assuming that tailoring a product to one's needs implies some effort. That is, a customer has to participate actively in co-designing the customized product. However, those extensions are beyond the scope of this paper and are left to future research.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s11002-023-09675-6>.

**Funding** Open Access funding enabled and organized by Projekt DEAL.

## Ethics declarations

The author did not receive support from any organizations for the submitted work and has no competing interests to declare that are relevant to the content of the submitted work. This research also does not involve human participants.

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