Research on product customization and pricing strategy considering consumer value co-creation under uncertain environment

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Abstract. Manufacturers are increasingly embracing consumer participation in value co-creation. However, existing research pays limited attention to the uncertain aspects of consumer psychology. We employ intuitive fuzzy numbers to quantify consumers' subjective perceptions of customization attributes, reflecting their sensitivity to changes in product complexity. Furthermore, by modeling the scenario of consumer involvement in product customization, we apply cumulative prospect theory to convert perceived complexity into a definitive scalar. Based on this, we develop a consumer utility function and a manufacturer profit function, and analyze the manufacturer's optimal customization and pricing strategy through profit maximization. Finally, we validate the effectiveness and feasibility of the model using the customization case of Nike sports shoes.

Keywords: Value co-creation; Personalized customization; Fuzzy quantization; Pricing strategy.

1. Introduction

As consumers increasingly prioritize their personalized needs, they are shifting from purchasing standardized items to customized ones as designers. Accordingly, manufacturers actively seek synergies with customers, and continually introduce new services such as co-create value to better meet consumers' personalized demands. For example, Nike allows consumers to customize sneakers, and Lancôme customizes foundation to match the consumer's skin tone. Even Amazon has been exploring the possibility of selling customized clothing online, with items tailored to the measurements of individual customers. Other companies such as Adidas and Apple allow consumers to participate in the product customized process.

We analyze the impact of consumer participation in value co-creation on manufacturers' product customization, pricing, and consumer surplus. It also examines the mismatch between consumers' perceived customization complexity and the actual production complexity faced by manufacturers, while quantifying the fuzzy psychology of consumers. We aim to address the following research questions: (1) In the value co-creation activities with consumers, how can manufacturers accurately identify whether consumers are customization enthusiasts or customization averse, so as to adjust the complexity of customization in a timely manner? (2) How can manufacturers optimize pricing strategies for consumers with varying attitudes toward customization to maximize profits? (3) How to maximize consumer surplus and manufacturer's profit in the manufacturer's personalized customization considering consumer value co-creation to achieve a mutually beneficial strategic win-win situation? This paper contributes to the literature in several ways. Firstly, it analyzes the impact of consumer participation on product customization, pricing, and consumer surplus. Secondly, it explores the disparity between perceived and actual customization complexity, quantifies consumer psychology, and provides implementation guidelines for customization strategies. Moreover, the paper suggests a framework for firms to determine the optimal number of customization options, thereby better aligning with consumer preferences and maximizing overall benefits. Our analysis offers insights for manufacturers' customization and pricing strategies.

The paper is structured as follows. After the introduction, Section 2 describes our model building process, Section 3 presents our case study and the conclusion in Section 4 summarises and outlines the paper.

2. Model setup

Consider a manufacturer providing a customized product characterized by a set of indicators $A=\{a_1,a_2,\dots,a_g,\dots,a_G\}$, where a_g denotes the g-th($g\in G$)indicator. G indicates the number of customized indicators; $W=(w_1,w_2,\dots,w_g,\dots,w_G)^T$ is a vector of weights of the indicators, where w_g denotes the weight or importance of the a_g indicator that satisfies the condition $0\le w_g\le 1$ and $\sum_{g=1}^{G} w_g=1$. The complexity ψ of a manufacturer's production process is a precise measure determined by the manufacturer's technical capabilities and equipment limitations. Consumers exhibit diverse preferences for customization attributes and ambiguity in their psychological perceptions. To address these psychological uncertainties, We employ fuzzy quantification of consumers' subjective perceptions of customization attributes, including customization difficulties and preferences. This approach effectively captures the variability in consumers' psychological states. The perception degree ε of customization complexity is modeled as a fuzzy number $\varepsilon=<\mu_\varepsilon,v_\varepsilon>$where $u_\varepsilon+v_\varepsilon\le 1$. To accurately capture consumer psychology and their sensitivity to customization complexity, we integrate cumulative prospect theory to construct a value function. This function assesses consumer risk attitudes towards "gain" and "loss," transforming ε into a definitive scalar.

Assume the product complexity ψ_c of consumer participation in customization is a fuzzy number between 0 and 1. Here, $\psi_c=\langle 0,1\rangle$ indicates a preference for standard products, while $\psi_c=\langle 1,0\rangle$ signifies a strong inclination towards full customization. The customization complexity ψ_c comprises two components: the manufacturer's production complexity ψ and the consumer's perceived complexity ε, such that $\psi_c=\psi+\varepsilon$.

We construct a consumer utility function based on the product complexity ψ_c in customization. If the utility is non-negative, consumers will participate in customization and purchase the product. The paper calculates the number of such consumers, constructs the manufacturer's profit function to determine the optimal pricing P that maximizes profit, and analyzes the impact of ψ and perceived complexity ε on both the manufacturer's profit and consumer surplus.

2.1 Manufacturer Profit Model under Consumer Participation in Value Co-Creation

2.1.1 Consumer Utility

In a market with a single manufacturer and a standardized consumer size of 1, consumers have heterogeneous preferences for value co-creation, denoted by β, which follows a uniform distribution in the interval $[0,a_1]$. Let the intrinsic value of the product to the consumer be $V>0$.The value of consumer participation in customization is divided into the use value V and spillover value ΔV, where Δ represents the proportion of spillover value. Higher complexity ψ_c in customization leads to higher spillover value, but also higher cost and effort. The spillover value is expressed as $\Delta=\beta\theta\psi_c-h\psi_c$ where $h>0$ is the "trouble" coefficient, and $\theta>0$ is the "value co-creation effect" coefficient. The negative utility from participation, termed "trouble cost," is denoted by H. The positive utility of value co-creation for consumer β is $\beta\theta\psi_c$, and the negative utility of trouble cost per unit is $h\psi_c$. The manufacturer charges a price P, leading to the consumer utility function:

$$U_B=V+\beta\theta\psi_c V-h\psi_c V-P. \tag{1}$$

2.1.1.1 Value function

To better understand consumers' customization preferences or expectations, we use a value function to quantify their satisfaction with the performance or characteristics of customized products. This transforms the fuzzy number of consumer preferences for each attribute (e.g., color, size, functionality) into a specific numerical value. Let the intuitionistic fuzzy number $\varepsilon=(\mu_\varepsilon,\nu_\varepsilon)$ and ε_0 serve as a reference point for decision-making. The value function of ε is defined as:

$$F = f(\varepsilon) = \begin{cases} \left(d(\varepsilon, \varepsilon_0)\right)^{\alpha} & \varepsilon > \varepsilon_0, \\ -\rho\left(d(\varepsilon, \varepsilon_0)\right)^{\sigma} & \varepsilon \leq \varepsilon_0. \end{cases} \quad (2)$$

Here, α and σ reflect consumer sensitivity to advantages and disadvantages, and ρ indicates higher sensitivity to loss compared to gain. The parameters α, σ, and ρ are constrained by $\alpha > 0$, $\sigma < 1$, and $\rho > 1$.

2.1.1.2 Cumulative Prospect Theory

We incorporate cumulative prospect theory to further analyze consumer behavior in customization. In the face of risk and uncertainty, consumers' perceptions of gains and losses are nonlinear, manifested as ambiguity and uncertainty in intuitionistic fuzzy numbers. We employ cumulative prospect theory to transform these nonlinear perceptions into specific and definite values, thereby more accurately reflecting consumers' actual customization willingness and risk preferences. Assuming the different customization options ϕ available to consumers consist of a series of combinations (x_i, p_i), where x_i denotes the specific content of the $i-th$ customization option (e.g., color, size, functional configuration). For simplicity, let the outcomes x_i be sorted in increasing order. A positive subscript indicates that the final customization result meets or exceeds the consumer's expectations, a negative subscript indicates that it falls short, and 0 indicates a neutral customization result. $when\ 0 \leq i < n, \pi_i^+ = w^+(p_i + \cdots + p_n) - w^+(p_{i+1} + \cdots + p_n)$; $when\ -m < i \leq 0, \pi_i^- = w^-(p_{-m} + \cdots + p_i) - w^-(p_{-m} + \cdots + p_{i-1})$; $\pi_n^+ = w^+(p_n)$; $\pi_{-m}^- = w^-(p_{-m})$. Here, $w^+(p) = \frac{p^\gamma}{[p^\gamma + (1-p)^\gamma]^{\frac{1}{\gamma}}}$ and $w^-(p) = \frac{p^\delta}{[p^\delta + (1-p)^\delta]^{\frac{1}{\delta}}}$. The parameters γ and δ control the sensitivity of the weighting function to gains and losses, respectively. p_i denotes the actual probability of the *i-th* customization option occurring, p_n denotes the probability that the customized product's performance or characteristics meet or exceed the consumer's desired state, and p_{-m} denotes the probability that the performance or characteristics fall short. π_i^+ is the positive cumulative decision weight function for gains, and π_i^- is the negative cumulative decision weight function for losses. Therefore, the cumulative prospect value *(CPV)* of different customization options K can be expressed as: $CPV = CPV^+ + CPV^-$, Where $CPV^+ = \sum_{i=1}^{n} \pi_i^+ \rho(x_i)$ represents the cumulative prospect value of gains, and $CPV^- = \sum_{i=-m}^{0} \pi_i^- \rho(x_i)$ represents the cumulative prospect value of losses.

Considering the consumer's purchase decision, if the expected utility from the product is non-negative, the consumer will choose to buy the product. According to equation (2), the marginal consumer is $\beta = \frac{P-V+h\psi_c V}{\theta\psi_c V}$, where there is no difference between purchasing and not purchasing the product. Thus, consumers will purchase the product within the interval $\left[\frac{P-V+h\psi_c V}{\theta\psi_c V}, a_1\right]$, and the number of consumers purchasing the product is $a_1 - \frac{P-V+h\psi_c V}{\theta\psi_c V}$. Market demand arises when $0 \leq \beta' \leq 1$; the market is fully covered when $\beta = 1$. For partial or complete market coverage, the price must satisfy $(1 - h\psi_c)V \leq P \leq (1 - h\psi_c + \theta\psi_c)V$. The corresponding market demand D is $1 - \beta$, and consumer surplus $r = \int_{\frac{P-V+h\psi_c V}{\theta\psi_c V}}^{1} (V + \beta\theta\psi_c V - h\psi_c V - P) dF(\beta) = \frac{(p_N - (1 - h\psi_c + \theta\psi_c)V)^2}{2\theta\psi_c V}$.

2.1.2 Manufacturer Profit

For the manufacturer, higher customization complexity ψ increases both the unit cost c and the fixed cost f, reducing profit. Conversely, a greater number of consumers leads to greater product similarity, reducing complexity and production costs, thereby increasing the manufacturer's utility. Thus, the manufacturer's profit $\pi = P\left(1 - \frac{P-V+h\psi_c V}{\theta\psi_c V}\right) - \psi c - \frac{1}{2}\psi^2 f$. Where P is the manufacturer's pricing to consumers. Using the conversion method described in section 4.1, the fuzzy number ε representing the consumer's perceived complexity is converted to a definite scalar

CPV, yielding the equilibrium price that maximizes the manufacturer's profit is given by: $P^* = V\frac{1+(\theta-h)(\psi+cpv)}{2}$.

2.2 Manufacturer's Profit Model When Consumers Do Not Participate in Value Co-Creation

If the consumer chooses to buy the standard product directly, let λ be the loss coefficient when the consumer does not participate in value co-creation. The consumer utility function $U_B{}' = V - P - \lambda\beta$. If the manufacturer only produces the standard product, the Manufacturer's profit $\pi' = P\left(1-\frac{V-P}{\lambda}\right) - \beta c - \frac{1}{2}\beta^2 f$. According to the optimal solution of the model, the equilibrium price that maximizes the manufacturer's profit is: $P' = \frac{\lambda+2P-V}{\lambda}$.

3. Analysis of the Arithmetic Example

Consider the customization and pricing strategies for Nike's sports shoes. The company offers customized options across 15 metrics such as Base, Tongue, and others, as shown in Figure 1.

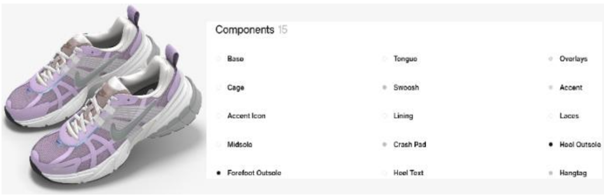

Fig. 1 Nike's exclusive customised running shoes

The complexity of producing a pair of customized sports shoes by Nike is an exact number ψ in the range of $[0,100]$, evaluated by the company based on production equipment and technical processes. Using the fuzzy number $\varepsilon_0 = (0.5,0.5)$ as a reference, the value function is calculated to measure the consumer's perceived complexity against the actual complexity.

Table 1. Fuzzy numbers and weights of consumers for each customisation indicator

ψ_i	ε_i	w_i	ψ_i	ε_i	w_i	ψ_i	ε_i	w_i
ψ_1	<0.8,0.2>	0.4	ψ_6	<0.8,0.1>	0.02	ψ_{11}	<0.3,0.6>	0.02
ψ_2	<0.5,0.4>	0.05	ψ_7	<0.8,0.1>	0.02	ψ_{12}	<0.1,0.8>	0.01
ψ_3	<0.7,0.2>	0.1	ψ_8	<0.4,0.5>	0.04	ψ_{13}	<0.1,0.8>	0.01
ψ_4	<0.5,0.4>	0.05	ψ_9	<0.5,0.4>	0.05	ψ_{14}	<0.8,0.1>	0.1
ψ_5	<0.6,0.3>	0.07	ψ_{10}	<0.4,0.6>	0.04	ψ_{15}	<0.5,0.4>	0.02

Using cumulative prospect theory: First, calculate the value function of indicator 3 as $v(\varepsilon_3, \varepsilon_0) = 0.2$. Calculate the weighting function to get the final *CPV* value of the indicator, which is 0.1318. By weighting the individual *CPV* values, the final *CPV* value is 0.26, and the value of ψ_c is 1.03. This indicates that when the perceived complexity of the consumer's Overlays customization indicator is 0.26, the actual complexity of consumer participation in the customization of this product is 1.03.

3.1 Effect of changes in ψ on π^* and r^*

Consider the cases $h > \theta$ and $h < \theta$. The impact of changes in ψ on the manufacturer's profit and the consumer surplus is shown in Figures 2 and 3, respectively.

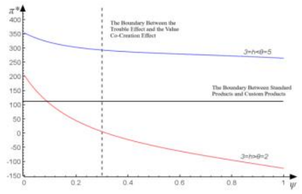
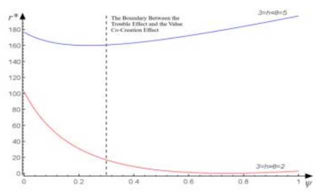

Fig. 2 Impact of changes in ψ on π* Fig. 3 Impact of changes in ψ on r*

From Figure 2, When $h > \theta$, as the complexity of product customization increases, the consumer's willingness to participate in value co-creation decreases. This leads to fewer product sales and lower profits for the manufacturer, who then prefers to produce the standard product directly. Thus, manufacturers will consider a higher degree of value co-creation strategy, i.e., producing customized products, only when the value co-creation effect is significant and the complexity of product production is low. From Figure 3, when $h < \theta$ and product customization complexity is below a certain threshold, consumers prefer standard products, resulting in a decrease in consumer surplus. However, as consumer participation in value co-creation increases, consumer surplus rises. Thus, when the value co-creation effect is substantial, increasing the number of customization indicators and the complexity of consumer participation generally benefits consumers.

3.2 Impact of changes in ε on π* and r*

Examining the impact of changes in ε on manufacturers' profits and consumer surplus, we use the transformed ε (i.e. *CPV* value) for the analysis and the results are shown in Figures 4 and 5.

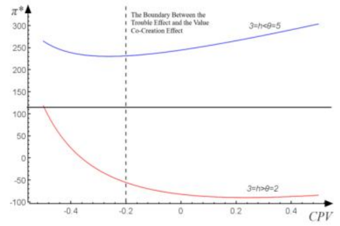
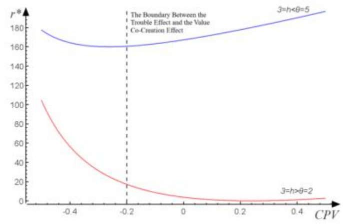

Fig. 4 Impact of changes in ε on π* Fig. 5 Impact of changes in ε on r*

From Figure 4, when $h > \theta$ and the consumer's perception of product complexity is low, consumers find the product too simple to customize, reducing the advantages of participating in value co-creation. Consequently, fewer consumers buy customized products, leading to lower sales and declining manufacturer profits. In such cases, manufacturers prefer to produce standard products directly. When $h < \theta$, the profit from participating in value co-creation is consistently higher than that from producing standard products, making manufacturers more inclined to produce customized products. From Figure 5, when $h > \theta$, increased consumer perception of product complexity leads to a decline in consumer surplus. Conversely, when $h < \theta$, consumer surplus initially decreases and then increases. For enthusiasts of customization complexity, greater perception of complexity enhances the sense of achievement from value co-creation, thereby increasing consumer surplus.

3.3 The impact of changes in *h* and *θ* on π* and r* when ψ is an endogenous variable

When ψ is an endogenous variable, the increased complexity of product production leads to higher production costs and, consequently, higher prices. we assume that P is an increasing function of ψ . Specifically, we consider a linear relationship $P = 2000\psi + 500$ and a non-linear relationship $P = \psi^3 + 2000$. The manufacturer's profit is positive and maximized under these conditions. When $h = \theta$, the manufacturer's profit is π_0 and the consumer surplus is r_0 .When $h \neq \theta$, the manufacturer's profit is π_1 and the consumer surplus is r_1 . We analyze the impact of changes in h and θ on the manufacturer's profit and consumer surplus in these scenarios.

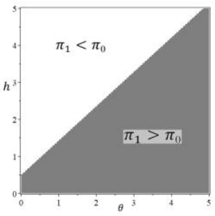

Fig. 6 The impact of changes in h and θ on π*

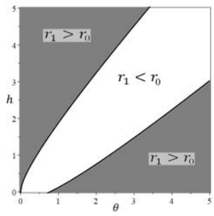

Fig. 7 The impact of changes in h and θ on r*

From Figure 6, when $h > \theta$, the profit is smaller. This indicates that consumers' willingness to participate in value co-creation increases, leading to higher numbers of purchasers, greater sales, and increased profits for manufacturers. From Figure 7, when $h > \theta$, consumers who enjoy designing products experience greater consumer surplus with increased participation in value co-creation, while those who do not prefer design products tend to buy standard products directly. Conversely, when $h < \theta$, the consumer surplus from participating in value co-creation is higher. When the difference between the value co-creation effect and the trouble effect is small, consumers prefer to buy standard products directly. For consumers who favor more customization options, increasing the number of customization indicators enhances their willingness to participate and increases consumer surplus, regardless of the values of h and θ. For consumers who prefer fewer customization options, increasing the number of customization indicators is beneficial if $h < \theta$.

4. Conclusions

We address the critical mismatch between consumers' perceived complexity in value co-creation and the actual complexity of production processes. By developing an integrated product customization and pricing model, we uncover key insights into how value co-creation shapes customization decisions. We find that: (1) under strong value co-creation effects and high consumer participation complexity, manufacturers are inclined to adopt extensive co-creation strategies to maximize profit; (2) under weak co-creation effects, simplifying customization and reducing options can enhance consumer surplus; and (3) increasing customization options attracts customization-oriented consumers, promoting greater participation and surplus, regardless of the presence of hassle or co-creation effects. These findings have practical implications for product customization, including digital interface design, dynamic pricing for personalized offerings, and the configuration of production systems to support varying customization levels.

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