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# RESEARCH ON OPTIMIZATION DECISION-MAKING OF SUPPLY CHAIN WITH EXPERIENCE SERVICE QUALITY OF CO-CREATED PRODUCTS

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Abstract. *With the development of artificial intelligence and information technology, customer engagement and product co-creation are increasingly used. The offline service experience becomes an important factor affecting consumers' purchasing decisions. In practice, the experience store can be established by the platform or the manufacturer. This paper explores the relevant issues by establishing and comparing three kinds of Stackelberg game models: 1) The platform and the manufacturer will not share the service costs of the showroom; 2) The platform and the manufacturer will share service costs; 3) The platform and the manufacturer collaborate and make centralized decisions. The results show that the platform will share the cost of the co-created product showrooms with the manufacturer when the service experience effect is high and the price sensitivity is low, or the price sensitivity is high and the brand spillover effect is low. Moreover, service cost-sharing can effectively motivate manufacturers to improve service quality and achieve Pareto improvement for the supply chain members.*

**Keywords:** Smart manufacturing, Product showrooms, Service quality, Brand spillover effect, Service cost-sharing, Price sensitivity

1. **Introduction.** With the development of artificial intelligence and information technology, smart manufacturing has shifted from "standardization", "homogenization", and "scale" in the past to "personalization", "customization", and "intelligence". The co-created products emerge to satisfy the consumers' higher pursuits of personalized expression. Since the development of online platforms gives consumers more chances to co-create products with manufacturers [1,2], consumers need to experience products and receive services in offline showrooms before final purchase decision making [3]. Therefore, online and offline integration has been widely adopted as a new strategy in co-created products [4-6]. Xiaomi is one of the largest intelligent manufacturing platforms in China. It sold products online and provided consumer service through official experience stores. In the co-creation process, first, Xiaomi publishes information about its new products on its online channel (i.e., MIUI community). Second, consumers contribute design ideas for new products. Then, consumers are encouraged to experience Xiaomi's co-created products in the offline channel. After experiencing the product, consumers can make an offline purchase immediately or an online purchase later. Official experience stores have offered Xiaomi's consumers a better, high-quality shopping experience, as well as brought great success to the company [7,8]. Realizing the importance of offline experience, companies other than Xiaomi, such as Amazon, Alibaba, JD.com, Apple, Foton Motor and Bonobos, have begun establishing offline showrooms to improve shopping experiences and enhance supply chain competitiveness [9-11]. However, the builders of the offline showrooms have to bear high service costs to ensure a high level of experience service quality. The questions

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concerning this situation are as follows. First, how does the service quality of co-created product showrooms affect consumers' purchasing behaviors? Second, how does the offline experience affect consumers' brand perceptions? Third, should platforms partner with manufacturers for co-created product showrooms?

The recent research on product co-creation mainly focuses on the channel [12,13], influencing factors [14-16], the process [17-20], customer experience [3,21], and the results [22-24]. We can conclude from these studies that the process of value co-creation emphasizes the enhancement of consumer satisfaction throughout the supply chain interaction to achieve value addition. In terms of research methods, most scholars choose the case study [20,21] and empirical research [12,13,21], but few of them choose constructed Stackelberg game models to analyze. In terms of the impact of value co-creation on supply chain performance, existing research subjects are upstream and downstream companies, or companies and consumers, while few research focuses on the interaction among customers, companies, and platforms.

The research on offline experience mainly focuses on the influence of consumer behaviors [5,25,26], channel costs [27-30] and supply chain members [30-33]. Liu et al. explored the online channel and offline service opened (invested in) by the manufacturer or the retailer by establishing Stackelberg game models [30]. Li et al. found that a high level of showroom feasibility (i.e., relatively low setup cost and high proportion of local consumers) is more likely to increase the profit of the retailer who establishes physical showrooms [34]. Li and Zhang studied an online-and-offline supply chain that an offline showroom advertises to attract consumers to evaluate the product offline and buy it online [35]. However, the above literature does not address the impact of the service quality of co-created product showrooms on supply chain members and the related issues of cooperatively opening offline showrooms.

Therefore, based on the existing research literature, this paper aims to improve the service quality of offline showrooms and promote the integration of online and offline. To answer the three questions mentioned above, we establish three kinds of Stackelberg game models to discuss: 1) The platform and the manufacturer will not share the service costs of the showroom; 2) The platform and the manufacturer will share service costs; 3) The platform and the manufacturer collaborate and make centralized decisions.

The rest of the paper is organized as follows. Section 2 will describe problems, explain preliminaries and establish basic models. Section 3 will show the main results of this research. Section 4 will analyze the impact of various influencing factors on the supply chain, and explore the conditions for the platform and the manufacturer to share the service cost of co-created product showrooms. Section 5 concludes the paper.

2. **Problem Statement and Preliminaries.** This paper considers a supply chain system consisting of a manufacturer who offers co-created products and a retail platform. The relationship is shown in Figure 1, in which both the manufacturer and the platform are risk-neutral and completely rational; they will make decisions based on maximizing expected profits. The manufacturer is the leader of the supply chain while the platform is the follower. The manufacturer produces a product with a unit cost of $c$ and sells it to the platform at wholesale prices $w$; then the platform resells this product to a consumer at retail price $p$. After the final co-creation design is finalized, the manufacturer sets up a co-created product showroom. The consumers can experience the co-created products after the co-creation processes and decide whether transfering to an online channel to buy them.

The basic assumptions are as follows.

1) The service cost of the co-created products showroom is $C_S(S)$, where the quality of service is $S$. Without loss of generality, suppose $C_S(S) = \frac{1}{2}\eta S^2$ [36]. To simplify the research process, it is assumed that the service cost coefficient $\eta$ satisfies $\eta = 4$.

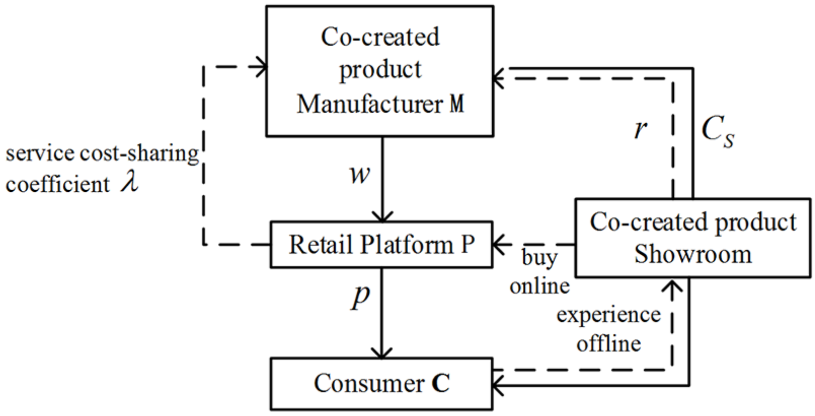


Figure 1. Supply chain relationship

2) The market demand $d$ is given by $d = a - bp + kS$, where $a$ represents the potential market size; $b$ $(0 \le b \le 1)$ represents the customers' sensitivity to the retail price of the co-created products; $k$ is the offline service experience effect which indicates the influence of the service quality on market demand. The larger the value of $k$, the better the service experience effect. To ensure the research is meaningful, it is assumed that $0 < k < \bar{k}$, where $\bar{k} = \min\left(2\sqrt{2b}, 1\right)$ if $b \le 0.125$, $\bar{k} = 2\sqrt{2b}$ if $b > 0.125$, $\bar{k} = 1$.

3) If the manufacturer builds an offline showroom, assume that the unit brand spillover benefit brought to the manufacturer is $r$, which represents the brand spillover effect. Thus, the total brand spillover effect on the manufacturer is given by $rkS$ [37].

4) Without loss of generality, the fixed construction costs of the showroom and the production costs of the co-created products are supposed to be 0.

5) Since the quality of the $t$ experience service provided by the manufacturer will directly affect the market demand, the platform shares a percentage of the service costs to encourage the manufacturer to provide consumers with better service quality. The service cost-sharing coefficient of the platform is $\lambda$ $(0 \le \lambda < 1)$.

6) The subscript "$P$" represents the platform, "$M$" represents the manufacturer and "$T$" represents the supply chain. The superscript "$N$" indicates the situation of no cooperative decision-making (the platform and manufacturer will not share the service costs of the showroom), "$S$" indicates the situation of service cost-sharing and "$C$" indicates centralized decision-making situation.

The profit functions of the platform and the manufacturer in each situation are as follows.

### 2.1. Situation *N*: No cooperative.

$$\pi_P^N = (p - w)(a - bp + kS) \tag{1}$$

$$\pi_M^N = w(a - p + kS) + rkS - 2S^2 \tag{2}$$

When the platform and the manufacturer do not share the service cost $(\lambda = 0)$, both the platform and the manufacturer have positive profits; the following Proposition 2.1 can be obtained.

**Proposition 2.1.** *In situation $N$, the equilibrium decisions are as follows:*

$$p^{N^*} = \frac{3(4a + k^2 r)}{16b - k^2} \tag{3}$$

$$w^{N^*} = \frac{2(4a + k^2 r)}{16b - k^2} \tag{4}$$

$$S^{N^*} = \frac{k(a + 4br)}{16b - k^2} \tag{5}$$

$$\pi_P^{N^*} = \frac{b(4a+k^2r)^2}{(16b-k^2)^2} \tag{6}$$

$$\pi_M^{N^*} = \frac{4a^2+2k^2r(a+2br)}{2(16b-k^2)} \tag{7}$$

2.2. **Situation *S*: Service cost-sharing.**

$$\pi_P^S = (p-w)(a-bp+kS) - 2\lambda S^2 \tag{8}$$

$$\pi_M^S = w(a-bp+kS) + rkS - 2(1-\lambda)S^2 \tag{9}$$

When the platform and the manufacturer decide to share the service costs, both the platform and the manufacturer have positive profits; the following Proposition 2.2 can be obtained.

**Proposition 2.2.** *In situation S, the equilibrium decisions are as follows:*

$$p^{S^*} = \frac{3((32b-k^2)a+4bk^2r)}{4b(32b-3k^2)} \tag{10}$$

$$w^{S^*} = \frac{(32b-k^2)a+4bk^2r}{2(32b-3k^2)} \tag{11}$$

$$S^{S^*} = \frac{2k(a+2br)}{32b-3k^2} \tag{12}$$

$$\lambda^{S^*} = \frac{(a+8br)k^2-64b^2r}{32b(a+2br)} \tag{13}$$

$$\pi_P^{S^*} = \frac{(32b+k^2)a^2+16brk^2(a+br)}{16b(32b-3k^2)} \tag{14}$$

$$\pi_M^{S^*} = \frac{(32b-k^2)a^2+4brk^2(3a+4br)}{8b(32b-3k^2)} \tag{15}$$

2.3. **Situation *C*: Centralized decision-making.**

$$\pi_T^C = p(a-bp+kS) + rkS - 2S^2 \tag{16}$$

From the perspective of profit maximization of the supply chain, the following Proposition 2.3 can be obtained.

**Proposition 2.3.** *In situation C, the equilibrium decisions are as follows:*

$$p^{C^*} = \frac{4a+k^2r}{8b-k^2} \tag{17}$$

$$S^{C^*} = \frac{k(a+2br)}{8b-k^2} \tag{18}$$

$$\pi_T^{C^*} = \frac{4a^2+2k^2r(a+br)}{2(8b-k^2)} \tag{19}$$

3. **Main Results.** The following corollaries can be obtained through the comparative analysis of relevant results under three situations.

**Corollary 3.1.** $\frac{\partial Y^{X^*}}{\partial b} < 0$, $\frac{\partial Y^{X^*}}{\partial k} > 0$, $\frac{\partial Y^{X^*}}{\partial r} > 0$; $X = N, S, C$, $Y = p, w, S$.

Corollary 3.1 shows that as the price sensitivity increases, both the platform and the manufacturer will reduce the retail prices, and the manufacturer will correspondingly reduce the quality of service to ensure its profit. With the increase of service experience effect or brand spillover effect, the manufacturer gains product premiums, increase wholesale prices and provide consumers with higher-quality experience services. The platform will increase the retail price of the products to ensure its profits.

**Corollary 3.2.** $\frac{\partial \pi_Z^{X^*}}{\partial b} < 0$, $\frac{\partial \pi_Z^{X^*}}{\partial k} > 0$, $\frac{\partial \pi_Z^{X^*}}{\partial r} > 0$; $X = N, S, C$, $Z = P, M, T$.

Corollary 3.2 shows that under different decision situations, the profits of the platform, the manufacturer and the supply chain will decrease as price sensitivity increases. With the rise of the service experience effect and brand spillover effect, the profits of the platform, the manufacturer and the supply chain will increase. Moreover, the supply chain members all benefit from the increase of service experience effect and brand spillover effect.

**Corollary 3.3.** *(i) if* $k_1 < k < \bar{k}$, *when* $b \leq 0.125$ *or* $b > 0.125$, $r < a/8b(8b-1)$, $\lambda^{S^*} > 0$, $k_1 = 8b\sqrt{r/(a+8br)}$; *(ii)* $\frac{\partial \lambda^{S^*}}{\partial b} < 0$, $\frac{\partial \lambda^{S^*}}{\partial k} > 0$, $\frac{\partial \lambda^{S^*}}{\partial r} < 0$.

Corollary 3.3 shows that when the service experience effect is significant, the price sensitivity is low, or the brand spillover effect is low even if the price sensitivity is high, the platform will share a part of the experience service costs for the manufacturer. The cost-sharing coefficient increases with the increase of service experience effect and decreases with the increase of price sensitivity and brand spillover effect. Corollary 3.3 implies that price sensitivity, service experience effect and brand spillover effect are essential factors that can affect the platform's cost-sharing decisions. This is because, for the platform, the high price sensitivity will make it lower the retail price; suppose the brand spillover effect is also high at this time, the manufacturer will increase the wholesale price to ensure its profits, and platforms will reduce or not share costs with the manufacturer.

**Corollary 3.4.** $S^{C^*} > S^{S^*} > S^{N^*}$.

Corollary 3.4 shows that the experience service quality provided by the manufacturer is the lowest when the platform and the manufacturer will not share the service costs of the showroom (situation $N$); in service cost-sharing situation (situation $S$), the experience service quality will be improved, and in centralized decision-making situation (situation $C$), the experience service quality is the highest. It implies that cooperation among supply chain members is beneficial for consumers to obtain a better experience of product co-creation to increase satisfaction and brand favorability.

**Corollary 3.5.** *(i)* $\pi_P^{S^*} > \pi_P^{N^*}$, $\pi_M^{S^*} > \pi_M^{N^*}$; *(ii)* $\pi_T^{C^*} > \pi_T^{S^*} > \pi_T^{N^*}$.

Corollary 3.5 shows that when the platform and the manufacturer will not share the service costs of the showroom (situation $N$), the profits of both the platform and the manufacturer are higher than the profits in the service cost-sharing situation (situation $S$). It means that the cost-sharing service can effectively improve the earnings of both the platform and the manufacturer, which achieves a win-win situation through cooperation. In addition, the optimal profit of the supply chain is the highest in centralized decision-making situation (situation $C$), which means that making decisions from the overall supply chain can further improve the optimal profits of the system.

4. **Result Analysis.** To further illustrate conditions of service cost-sharing, we assume the potential market demand $a = 10$, and then the following figures are obtained.

4.1. **Analysis of service cost-sharing.** Figure 2(a) shows that if the price sensitivity is low ($b = 0.1 < 0.125$) and the service experience effect is high ($k > 0.44039$), even if the brand spillover effect is high ($r = 4$), the platform will share the service costs with the manufacturer.

Figure 2(b) shows that when the price sensitivity is high ($b = 0.3 > 0.125$), as long as the brand spillover effect is low ($r = 2 < a/8b(8b-1)$) and the service experience effect is high ($k > 0.88226$), the platform will still share a part of the service cost for the manufacture when the cost-sharing coefficient is greater than zero.

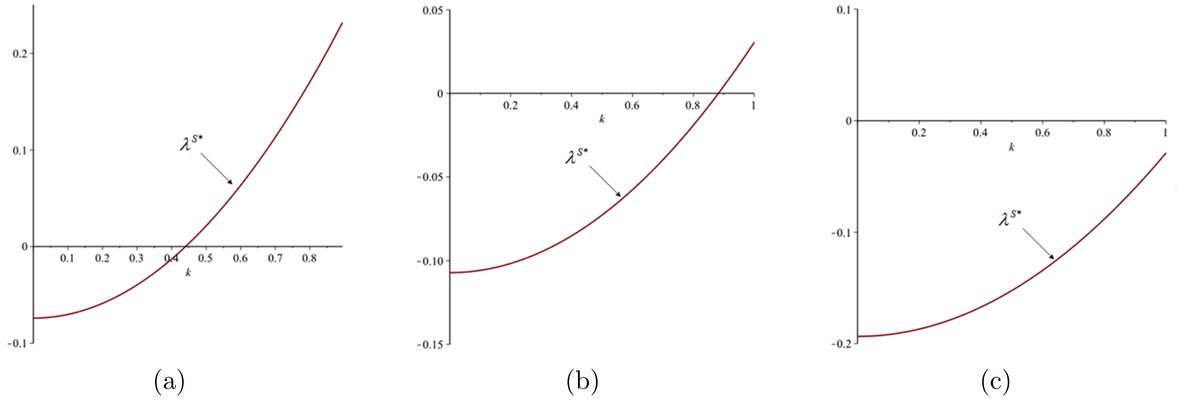


FIGURE 2. The impact of service experience effect on the cost-sharing coefficient

Figure 2(c) shows that if the price sensitivity is high ($b = 0.3 > 0.125$) and the brand spillover effect is high ($r = 4 \geq a/8b(8b-1)$), whatever the cost service experience effect is, the platform will not share the cost with the manufacturer.

4.2. **Comparative analysis of optimal profit and optimal service quality.** Let $b = 0.1$ and $r = 4$, we compare the profit of supply chain members before and after cost-sharing, profit of the supply chain system and service quality in three situations.

From Figure 3, it can be found that 1) the optimal profit function after the service cost-sharing between the platform and the manufacturer is above the optimal profit function without sharing, and 2) the vertical distance of the manufacturer's optimal profit is slightly larger than the vertical distance of the platform's optimal profit; it reflects that both platform and the manufacturer can achieve Pareto improvement by service cost-sharing, and the improvement effect on the manufacturer's optimal profit is better than that of the platform. Since the platform helps the manufacturer share a certain proportion of service costs, the manufacturer will improve the service quality of the offline showroom, and consumers will enhance their satisfaction. The growing market demand will make up for the service cost shared by the platform and the manufacturer.

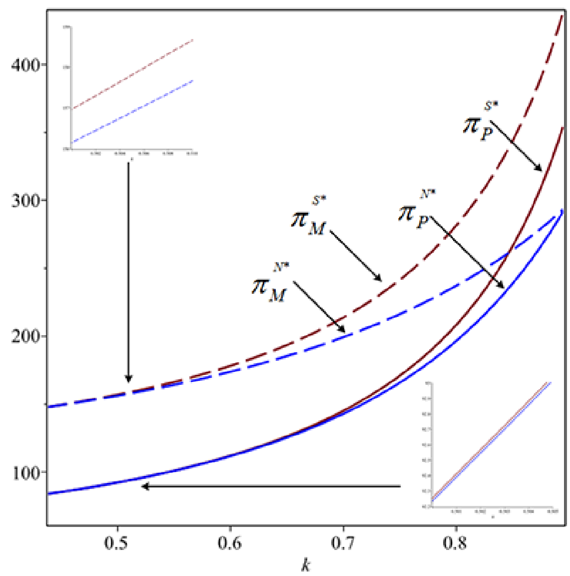

FIGURE 3. Profit comparison of supply chain members before and after cost-sharing

Figure 4 reflects the profit comparison of the supply chain system under the three situations. It can be seen from Figure 4 that 1) the profit of the supply chain system in the centralized decision-making situation (situation $C$) is significantly higher than that in the other two situations; the cost-sharing can make the supply chain achieve Pareto improvement, which verifies the conclusion of Corollary 3.5. 2) The graph steepness of each function shows that the total profit growth in the centralized decision-making situation (situation $C$) is slightly faster than that of the other two situations.

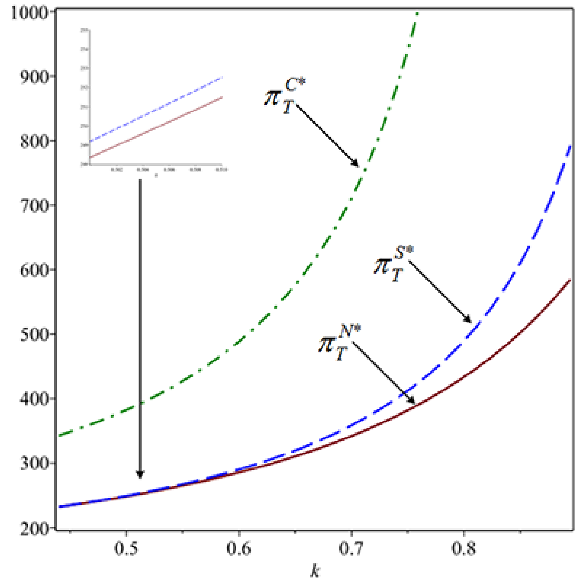


FIGURE 4. Profit comparison in three situations

Figure 5 shows that in the centralized decision-making situation (situation $C$), the quality of service is the highest, the quality of service in the service cost-sharing situation (situation $S$) is the second-worst, while the quality of service is the worst when the platform and the manufacturer will not share the service costs of the showroom (situation $N$).

According to the analysis in the previous paragraphs, it can be found that the experience service cost-sharing between the platform and the manufacturer is not only conducive to

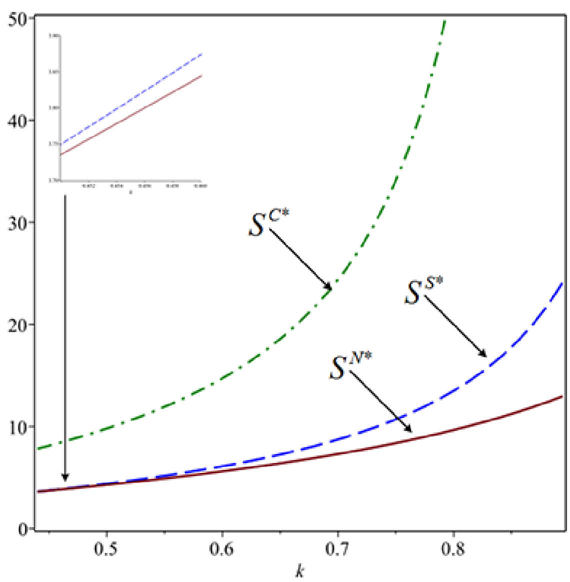


FIGURE 5. Service quality comparison in three situations

improving its profits but also brings better experience services to consumers; it is a win-win situation for the supply chain members. Although the centralized decision-making situation (situation $C$) is better than the other two situations, it is more difficult to realize fully; it can be used as an ideal decision-making situation to provide some reference and inspiration for supply chain members.

4.3. **The influence of relevant parameters on the profits of supply chain members.** When other parameters are specified, the optimal profits of the platform and the manufacturer are positively correlated, constantly increasing with $k$ which means that a higher service experience effect benefits both the platform and the manufacturer. Further, taking the service cost-sharing situation (situation $S$) as an example, discuss the relationship between price sensitivity, brand spillover and optimal profits of the platform and the manufacturer.

Let $k = 0.6$, $r = 4$, Figure 6 shows that the profits of both the platform and the manufacturer in three situations ($\pi_P^{S*}$ and $\pi_M^{S*}$) always decrease with the increase of $b$, and price sensitivity is negatively related to the platform's and the manufacturer's optimal profits. The increased price sensitivity will lead to decreased profits for both the platform and the manufacturer.

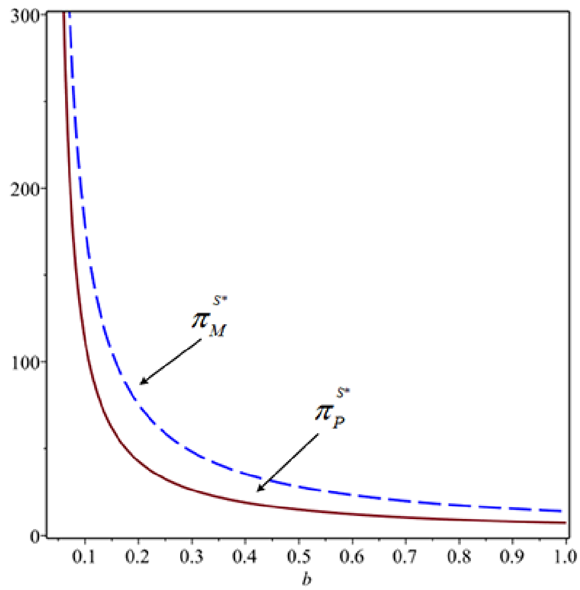


FIGURE 6. The effect of $b$ on the profits in service cost-sharing situation

Let $k = 0.6$, $b = 0.1$, Figure 7 shows that the profits of both the platform and the manufacturer in three situations ($\pi_P^{S*}$ and $\pi_M^{S*}$) always increase whit the increase of $r$, that is to say, the brand spillover effect is positively correlated with the profits of both the platform and the manufacturer; they will benefit from the increase in the brand spillover effect.

5. **Conclusions.** In this paper, we study a smart manufacturing services supply chain, in which the products are co-created by the manufacturer and the customer and the service is provided jointly by the manufacturer and the platform. Three situations of no cooperation, cost-sharing and cooperation are discussed.

We find some interesting results. First, the situations of service cost-sharing and centralized decision-making situation are better than the situation of no cooperation, which can achieve the goals of improving service quality and the profits of the manufacturer, the platform and the supply chain. Second, service cost-sharing is affected by price sensitivity, brand spillover effect and service experience effect; if price sensitivity is low, the

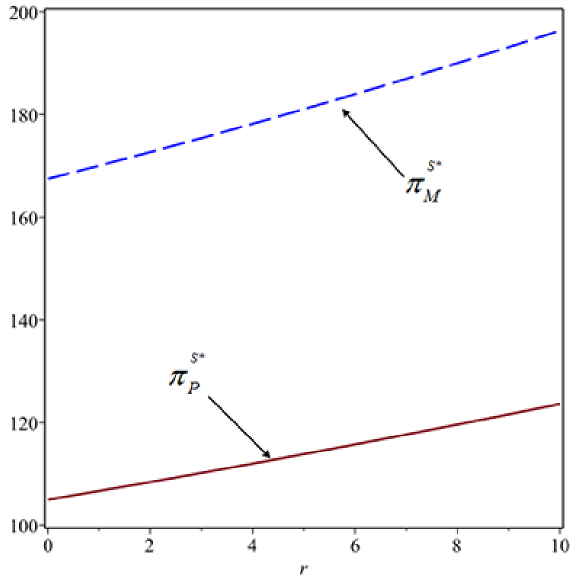


Figure 7. The effect of $r$ on the profits in service cost-sharing situation

cost-sharing between the platform and the manufacturer will not be affected by the brand spillover effect; however, if price sensitivity is high, cost-sharing can also be achieved as long as brand spillover is low, which means that a high brand spillover effect is not conducive to the realization of cost-sharing.

The results in this paper provide critical managerial implications on how the manufacturer and the platform should make decisions when they establish the co-created product showroom. However, in the future, we can study how the co-created product showroom with sales functions affects consumers' purchasing behavior.

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