Journal of Southeast University (English Edition) Vol. 38, No. 4, pp. 418 − 424 Dec. 2022 ISSN 1003—7985

Manufacturers' channel selections under the influence of the platform with big data analytics

Qiu Huaqing Zhao Lindu

(School of Economics and Management, Southeast University, Nanjing 210096, China)

Abstract: To obtain the platform's big data analytics support, manufacturers in the traditional retail channel must decide whether to use the direct online channel. A retail supply chain model and a direct online supply chain model are built, in which manufacturers design products alone in the retail channel, while the platform and manufacturer complete the product design in the direct online channel. These two models are analyzed using the game theoretical model and numerical simulation. The findings indicate that if the manufacturers' design capabilities are not very high and the commission rate is not very low, the manufacturers will choose the direct online channel if the platform's technical efforts are within an interval. When the platform's technical efforts are exogenous, they positively influence the manufacturers' decisions; however, in the endogenous case, the platform's effect on the manufacturers is reflected in the interaction of the commission rate and cost efficiency. The manufacturers and the platform should make synthetic effort decisions based on the manufacturer's development capabilities, the intensity of market competition, and the cost efficiency of the platform.

Key words: big data analytics; platform selling; channel decision-making; product design

DOI: 10.3969/j. issn. 1003 − 7985. 2022. 04. 011

Over the last decade, an increasing number of manufacturers have sold their products through e-commerce platforms. When compared to traditional retailers, e-commerce platforms are more convenient for gathering customer data. Indeed, customer data play essential roles in operational management[1], new product development[2], and channel distribution[3]. Therefore, the platforms begin sharing customer information with the sellers. For example, Tmall shared customer information with over 300 online sellers[4]. Moreover, JD started sharing information with Midea in 2015, Dell in 2016, and OPPO in 2018[5]. Manufacturers can design products that better meet the needs of their customers thanks to shared customer information.

From a platform-based perspective, several studies have examined the platform's incentives to share demand information[6-7] and information-sharing strategies[8]. Manufacturers who sell their products through a traditional reselling channel must decide whether to adopt the platform channel to capitalize on customer information. Aside from pricing issues[9], forecast information from the platform may encourage manufacturers to build a direct channel through the platform[3-4]. Inspired by these studies, we explore the manufacturers' channel selections in a competitive environment between the reselling channel and the direct online channel (via a platform). To convert large amounts of customer data into useful information, the platform in the direct online channel must invest in big data analytics technology. Manufacturers can improve product design efficiency by using customer information, which in turn improves customer satisfaction and market responsiveness[2].

Emerging studies have focused on mode selection in platform operations. For instance, a few studies explored the platform's decision to act as a reseller or a marketplace[10-11]. Moreover, the extant literature has focused on the manufacturer's decisions among different sales modes, such as direct selling, reselling, and marketplace modes[12-13], or the impact of online product reviews on platform selling[14]. In contrast to these studies, our model's direct online channel not only provides a channel for manufacturers to reach customers but also benefits the manufacturers' product design from the platform's big data analytics.

Indeed, the connotation of product design includes a variety of details, such as product appearance, function, performance, and quality[15-16]. In this paper, we define a manufacturer's design efforts as the ability to implement related design activities[15,17]. Manufacturers with high design efforts can precisely translate customer needs into product offerings and generate higher values; conversely, if a low design effort is chosen, customer needs will not be sufficiently satisfied and exert lower value. In our setting, the platform's technical efforts and the manufacturers' design efforts collaborate to promote product design in the direct online channel. The technical efforts of the platform refer to its investment in big data an-

Received 2022-07-07, **Revised** 2022-11-05.

Biographies: Qiu Huaqing (1992—), female, Ph. D. candidate; Zhao Lindu (corresponding author), male, doctor, professor, ldzhao@seu.edu.cn.

Foundation items: The National Natural Science Foundation of China (No. 72071039), the Foundation of China Scholarship Council (No. 202106090197).

Citation: Qiu Huaqing, Zhao Lindu. Manufacturers' channel selections under the influence of the platform with big data analytics[J]. Journal of Southeast University (English Edition), 2022, 38(4): 418 − 424. DOI: 10.3969/j. issn. 1003 − 7985. 2022. 04. 011.

alytics to obtain customer information, while the design efforts of the manufacturers refer to the investments in design activities to utilize customer information.

To this end, we address the following research questions: 1) Under what conditions will manufacturers choose the direct online channel? 2) How do the platform's technical efforts influence the equilibrium decisions? 3) What effects does competition have on equilibrium decisions? To answer these questions, we built a reselling supply chain comprised of two manufacturers and a retailer and a direct online supply chain comprised of two manufacturers and a platform. The direct online channel differs from the reselling channel in two ways. First, the platform gives manufacturers pricing power. Second, the platform invests in technical efforts to assist manufacturers in moving forward with product design. Then, using a game theoretic framework, we compare the reselling channel and the direct online channel.

1 Model Formulation

We study two competing manufacturers in the reselling channel (R) who are considering entering the platform-dominated direct online channel (N); j denotes the channels, $j=\{R, N\}$. By comparing their profits in different channels, the manufacturers decide whether to abandon the original reselling channel and enter the new direct channel. In both channels, each manufacturer offers a product in the same category, and the two products compete on a design level and product price. We call the manufacturer that offers product i as manufacturer i, $i=\{a, b\}$.

Manufacturers design products for the reselling channel based on their previous experiences. Manufacturer i decides his/her design efforts e_i^R and the wholesale price w_i^R, and the retailer announces the product price p_i^R. Hence, product i's design level x_i^R satisfies $x_i^R(e_i^R)=e_i^R$.

In the direct online channel, the platform contributes to the technical efforts in parallel with the manufacturers' design efforts. Manufacturer i decides his/her design efforts e_i^N and the product price p_i^N, while the platform decides the technical efforts s. The platform charges the proportion α of the manufacturer's revenue. According to Refs. [18 − 20], all parties' product improvement efforts are additive. Similarly, in our model, the product's design level is the sum of the manufacturer's design efforts and the platform's technical efforts; that is, product i's design level x_i^N is given by $x_i^N(e_i^N, s)=e_i^N+s$. Fig. 1 illustrates the structures of the supply chains.

We use a linear demand function, which is commonly adopted in operation management literature[21-22], to capture product competition in terms of design level and product price in the following way:

$$d_a^j=\theta-p_a^j+\eta p_b^j+x_a^j-\gamma x_b^j \qquad j=\{R, N\} \tag{1}$$

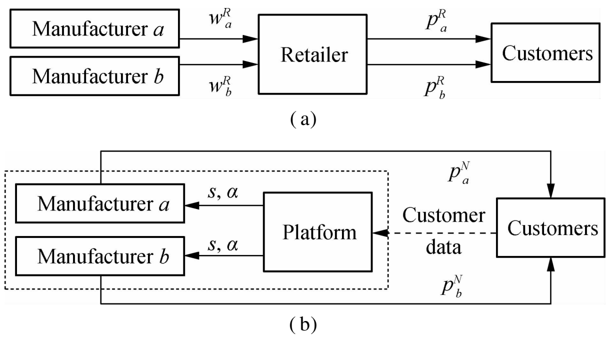

Fig. 1 Structures of the supply chains. (a) Reselling channel; (b) Direct online channel

$$d_b^j=\theta-p_b^j+\eta p_a^j+x_b^j-\gamma x_a^j \qquad j=\{R, N\} \tag{2}$$

where θ refers to the market potential; η and γ measure the competitive intensity concerning product price and design level, respectively. More precisely, customer demand d_i^j is downward sloping along product price p_i^j and is upward sloping along design level x_i^j, that is, $\partial d_i^j/\partial p_i^j<0$ and $\partial d_i^j/\partial x_i^j>0$. $\eta=\partial d_a^j/\partial p_b^j=\partial d_b^j/\partial p_a^j$ is additional customers due to the increase of competitor's product price, while $\gamma=-(\partial d_a^j/\partial x_b^j)=-(\partial d_b^j/\partial x_a^j)$ is additional customers derived from the decrease of competitor's design level. This mechanism encourages competing manufacturers to seek various ways to enhance design levels.

1.1 Problems in the reselling channel

The following is the event sequence in the reselling channel. First, the competing manufacturers decide the design efforts e_i^R and the wholesale prices w_i simultaneously. Second, the retailer decides the product price p_i^R for product i and resells them to the customers.

Following the literature on design investment decisions[23-24], manufacturer i incurs a cost of $(e_i^R)^2/(2k)$ with design efforts e_i^R. Here $k>0$ denotes the manufacturers' design capabilities. It reflects a capability-differential production environment in which a manufacturer with greater innate design capabilities can be more cost-effective in design efforts. Thus, the profits of manufacturer i and retailer r are as follows:

$$\pi_i^R=w_i d_i^R-\frac{(e_i^R)^2}{2k} \qquad i=\{a, b\} \tag{3}$$

$$\pi_r^R=(p_a^R-w_a)d_a^R+(p_b^R-w_b)d_b^R \tag{4}$$

1.2 Problems in the direct online channel

The event sequence in the direct online channel is as follows. First, the platform provides technical efforts s. Subsequently, the manufacturers decide on both the design efforts e_i^N and the product prices p_i^N simultaneously.

The following assumptions should be noted. First, in accordance with the assumption shared by the design-collaborating firms[24], the commission rate α is provided exogenously. This commission rate is usually the same for products in a common category; for example, JD.com charges a rate ranging from 5% to 12% of retail prices for most product categories[10]. Second, the platform bears the cost as $ns^2/2$ with technical efforts s, where $n > 0$ is the cost coefficient. The profits of manufacturer i and the platform (p) are derived as

$$\pi_i^N = (1-\alpha)p_i^N d_i^N - \frac{(e_i^N)^2}{2k} \qquad i = \{a, b\} \tag{5}$$

$$\pi_p^N = \alpha(p_a^N d_a^N + p_b^N d_b^N) - \frac{ns^2}{2} \tag{6}$$

2 Equilibrium and Analysis

We first solve the analytical model in this section. For the numerical simulations, we set the parameters as $\theta = 3$, $n = 2.5$, $\alpha = 0.4$, $k = 1.2$, $s = 0.8$, $\gamma = 0.5$ and $\eta = 0.4$, which satisfy the thresholds in Proposition 1.

2.1 Equilibrium results

We solve the models by backward induction. In channel R, the equilibrium results are listed in Lemma 1.

Lemma 1 In channel R, $w_i^{R*} = \frac{2\theta}{A}$, $p_i^{R*} = \frac{(3-2\eta)\theta}{(1-\eta)A}$, $e_i^{R*} = \frac{\theta k}{A}$, $d_i^{R*} = \frac{\theta}{A}$, $x_i^{R*} = \frac{\theta k}{A}$, $\pi_i^{R*} = \frac{(4-k)\theta^2}{2A^2}$, $\pi_r^{R*} = \frac{2\theta^2}{(1-\eta)A^2}$, where $A = 2(2-\eta) - (1-\gamma)k$.

In channel N, we obtain Lemma 2 when the platform's efforts are exogenous given as follows.

Lemma 2 When s is exogenous in channel N, $p_i^{N*} = \frac{U}{B}$, $e_i^{N*} = \frac{U(1-\alpha)k}{B}$, $d_i^{N*} = \frac{U}{B}$, $x_i^{N*} = \frac{U(1-\alpha)k}{B} + s$, $\pi_p^{N*} = \frac{2\alpha U^2}{B^2} - \frac{ns^2}{2}$, $\pi_i^{N*} = \frac{U^2(1-\alpha)[1-k(1-\alpha)/2]}{B^2}$, where $U = \theta + (1-\gamma)s$ and $B = 2 - \eta - (1-\gamma)(1-\alpha)k$.

In channel N, we obtain Lemma 3 when the platform's efforts are endogenous given as follows.

Lemma 3 When s is endogenous in channel N, $s^* = \frac{4\alpha(1-\gamma)\theta}{B^2 n - 4\alpha(1-\gamma)^2}$, $p_i^{N*} = \frac{Bn\theta}{4B^2 n - 4\alpha(1-\gamma)^2}$, $e_i^{N*} = \frac{B(1-\alpha)nk\theta}{B^2 n - 4\alpha(1-\gamma)^2}$, $d_i^{N*} = \frac{Bn\theta}{B^2 n - 4\alpha(1-\gamma)^2}$, $x_i^{N*} = \frac{[B(1-\alpha)nk + 4\alpha(1-\gamma)]\theta}{B^2 n - 4\alpha(1-\gamma)^2}$, $\pi_p^{N*} = \frac{2\alpha n\theta^2}{B^2 n - 4\alpha(1-\gamma)^2}$, $\pi_i^{N*} = \frac{(1-\alpha)[1-k(1-\alpha)/2]B^2 n^2 \theta^2}{[B^2 n - 4\alpha(1-\gamma)^2]^2}$.

2.2 Exogenous platform efforts

We begin by shedding light on a case in which the platform's technical efforts are exogenous. This case not only corresponds to studies that explored the impact of power structure on channel interactions[25], but it enables us to illuminate the manufacturer's direct online channel adoption conditions. Proposition 1 is derived by comparing players' profits in channel N and channel R.

Proposition 1 The sufficient conditions for the manufacturers to choose a direct online channel are as follows:

1) $k < \min\left\{\frac{2-\eta}{(1-\gamma)(1+\alpha)}, \frac{2}{1-\alpha}\right\}$.

2) $\alpha > \alpha_1$, where α_1 is the unique solution of $\pi_p^{N*} = \pi_r^{R*}$.

3) $\max\{s_1, s_2, 0\} < s < s_3$, where s_2 is the unique solution of $\pi_i^{N*} = \pi_i^{R*}$, s_1 and s_3 are the solutions of $\pi_p^* \mid_{\alpha \to 1} = \pi_r^*$.

The first condition indicates that manufacturers' design capabilities to make channel N feasible have an upper bound. This constraint is intended to prevent manufacturers from making unrestricted investments in design efforts. When the first condition is satisfied, the second condition states that the commission rate must be high enough to ensure the platform's profitability. The final condition specifies the technical effort thresholds for the platform. Recall that the platform appropriates α proportion of manufacturers' revenues but should serve them by leveraging its technical advantages. The lower bound is due to the manufacturers' need for the platform's technical assistance, while the upper bound is due to the commission rate. That is, the platform will charge a higher commission rate if it can offer more technical advantages. The manufacturers prefer a suitable interval of the platform's technical efforts to obtain the platform's technical benefits while enjoying an acceptable fee.

Fig. 2 depicts the manufacturers' profits in channels R

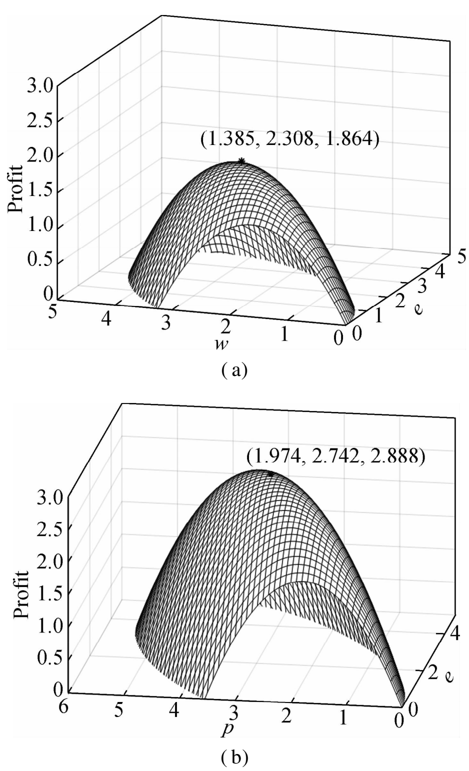

Fig. 2 Manufacturers' profits. (a) Profits in channel R; (b) Profits in channel N

and N under the conditions listed in Proposition 1. The shapes show that the manufacturers' profits in Fig. 2(b) are higher than in Fig. 2(a). Simultaneously, we derived that the retailer's profit is $\pi_r^{R*} = 3.882$, while the platform's profit is $\pi_p^{N*} = 3.937$, which can support Proposition 1.

In the following corollary, we examine the impact of the platform's technical efforts on the manufacturers' decisions.

Corollary 1 $\partial p_i^{N*}/\partial s > 0$, $\partial d_i^{N*}/\partial s > 0$, $\partial x_i^{N*}/\partial s > 0$, $\partial e_i^{N*}/\partial s > 0$, $\partial \pi_i^{N*}/\partial s > 0$.

Corollary 1 states that the platform's greater technical efforts result in higher product prices, demands, design levels, manufacturers' design efforts, and profits. Intuitively, as the platform's technical efforts increase, the platform's capabilities to assist manufacturers in achieving new product design increase, and the manufacturers have greater incentives to improve their design efforts. The advancement of the platform's technical efforts and the manufacturers' design efforts results in higher product design levels. Consequently, the manufacturers can mildly adjust product prices based on their high design levels to ensure adequate orders.

2.3 Endogenous platform efforts

This section analyzes the platform's role further by treating the platform's technical efforts as an endogenous variable. We investigate the difference in optimal solutions between channels R and N. In addition to imposing $k < \min\{(2-\eta)/[(1-\gamma)(1+\alpha)], 2/(1-\alpha), 4\}$, we also assume that the service cost coefficient satisfies $n > 4\alpha(1-\gamma)^2/B^2$ to ensure that the platform has a unique optimum. We obtain the following proposition.

Proposition 2 Comparing channel R and channel N, we have

1) $d_i^{N*} > d_i^{R*}$.

2) When $\alpha > \dfrac{(2-\eta)[k(1-\gamma)-1]}{(3-2\eta)(1-\gamma)k}$ and $n > n_1$, $p_i^{N*} < p_i^{R*}$; otherwise, $p_i^{N*} \geqslant p_i^{R*}$, where $n_1 = \dfrac{4\alpha(1-\gamma)^2(3-2\eta)}{B[2-\eta-k(1-\gamma)(2-\eta-3\alpha+2\alpha\eta)]}$.

3) When $\alpha > 1/2$ and $n > n_2$, $e_i^{N*} < e_i^{R*}$; otherwise, $e_i^{N*} \geqslant e_i^{R*}$, where $n_2 = \dfrac{4\alpha(1-\gamma)^2}{B(2\alpha-1)(2-\eta)}$.

4) When $\alpha < 1/2$ and $n > n_3$, $x_i^{N*} < x_i^{R*}$; otherwise, $x_i^{N*} \geqslant x_i^{R*}$, where $n_3 = \dfrac{8\alpha(1-\gamma)}{Bk(1-2\alpha)}$.

Result 1 of Proposition 2 shows that, when compared with channel R, channel N always gains a higher market demand. This is because the product design in channel N is better in line with the preferences of the customers. Results 2 and 3 show that when the platform's cost efficiency is relatively low (i.e., $n > n_1$ or $n > n_2$) and the commission rate exceeds α' or 1/2, channel N will have lower product prices or lower design efforts than channel R, respectively. Recall that in channel N, manufacturers gain pricing power, so they will set appropriate product prices and design efforts that will benefit their profits. Will the platform's and the manufacturer's combined efforts always be superior to the manufacturer's own efforts? Result 4 implies that design levels in channel N may be lower than in channel R. This occurs when the platform's cost efficiency and commission rate are both relatively low (i.e., $n > n_3$ and $\alpha < 1/2$). Lower design levels are used in this case because the platform is less motivated to invest in technical efforts due to the lower commission rate. In summary, Proposition 2 shows that when the platform's technical efforts are endogenous, its role in the direct online channel is reflected in the interaction of the platform's commission rate and cost efficiency.

3 Impact Analysis

This section examines the effect of key parameters on optimal decisions. We focus on three critical points. We explore the effect of the manufacturers' design capabilities on the equilibrium decisions of both channels. With a focus on channel N, we then study the influence of market competition and the platform's cost efficiency.

Proposition 3 The manufacturers' design capabilities show the following characteristics:

1) In channel R, $\partial p_i^{R*}/\partial k > 0$, $\partial e_i^{R*}/\partial k > 0$, $\partial d_i^{R*}/\partial k > 0$, $\partial x_i^{R*}/\partial k > 0$, $\partial \pi_r^{R*}/\partial k > 0$; whereas $\partial \pi_i^{R*}/\partial k > 0$ if $k < (4+2\eta-8\gamma)/(1-\gamma)$, otherwise, $\partial \pi_i^{R*}/\partial k \leqslant 0$.

2) In channel N, $\partial s^*/\partial k > 0$, $\partial p_i^{N*}/\partial k > 0$, $\partial e_i^{N*}/\partial k > 0$, $\partial d_i^{N*}/\partial k > 0$, $\partial x_i^{N*}/\partial k > 0$, $\partial \pi_p^{N*}/\partial k > 0$, and $\partial \pi_i^{N*}/\partial k > 0$.

Results 1 and 2 of Proposition 3 provide an interpretation of the manufacturers' design capabilities. The product prices, design efforts by manufacturers, demand, design levels, profits of the retailer and the platform all increase in k. However, the manufacturers' profits in channel R increase in k if and only if $k < (4+2\eta-8\gamma)/(1-\gamma)$, while in channel N, the manufacturers' profits always increase in k. This is because the reselling channel limits the profitability of manufacturers with superior design capabilities. Fig. 3 depicts numerical simulations of this proposition.

Proposition 4 Competition intensity shows the following characteristics:

1) The impact of price competitive intensity: $\partial s^*/\partial \eta > 0$, $\partial p_i^{N*}/\partial \eta > 0$, $\partial e_i^{N*}/\partial \eta > 0$, $\partial x_i^{N*}/\partial \eta > 0$, $\partial \pi_i^{N*}/\partial \eta > 0$, $\partial \pi_p^{N*}/\partial \eta > 0$.

2) The impact of design competitive intensity: $\partial s^*/\partial \gamma < 0$, $\partial p_i^{N*}/\partial \gamma < 0$, $\partial e_i^{N*}/\partial \gamma < 0$, $\partial x_i^{N*}/\partial \gamma < 0$, $\partial \pi_i^{N*}/\partial \gamma < 0$, $\partial \pi_p^{N*}/\partial \gamma < 0$.

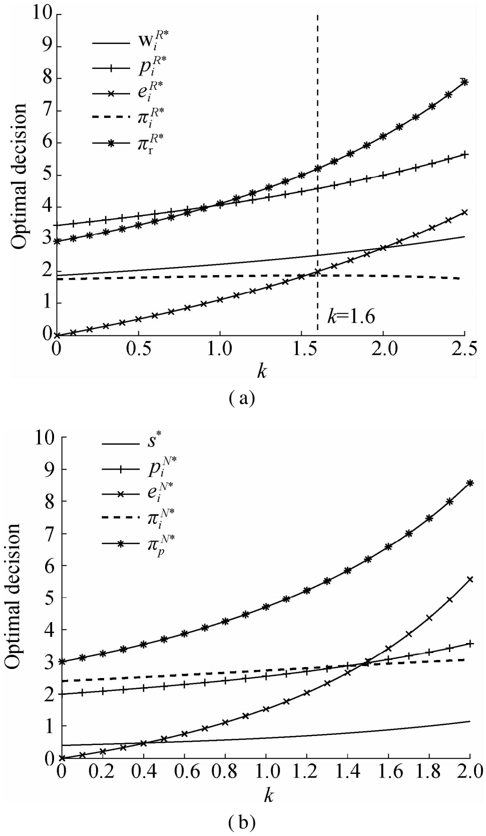

Fig. 3 Impact of k. (a) Profits in channel R; (b) Profits in channel N

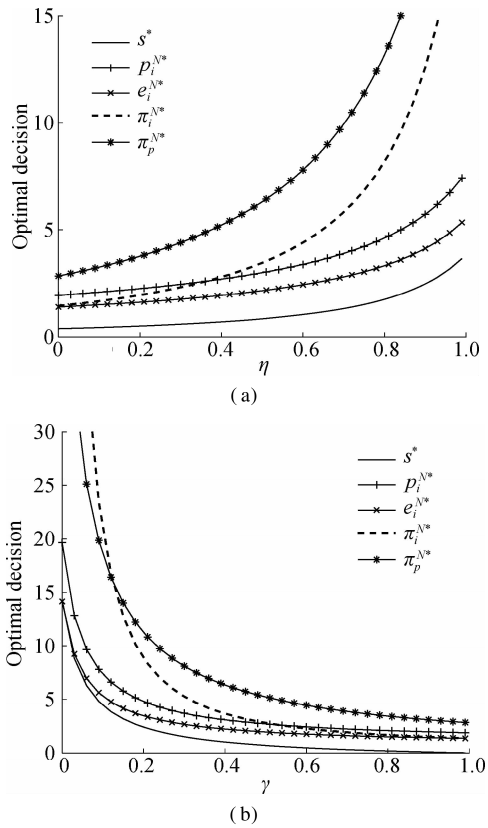

Fig. 4 Impact of η and γ. (a) Impact of η; (b) Impact of γ

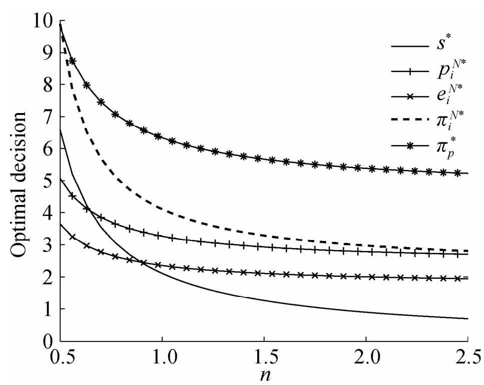

Fig. 5 Impact of n

Proposition 4 first demonstrates that strong price competition induces manufacturers to improve product prices and design efforts and the platform to improve technical efforts. Then, increasing design and technical efforts lead to an improvement in design levels, while increasing product prices lead to an increase in profits. This is due to the platform's assistance in obtaining price advantages with high design levels. However, result 2 of Proposition 4 intuitively implies that when the players engage in an intense design competition, the manufacturers should choose lower product prices and lower design efforts, while the platform should choose lower technical efforts. Furthermore, as the design competitive intensity γ increases, the profits of the manufacturers and the platform decrease. Fig. 4 vividly illustrates Proposition 4.

Proposition 5 The cost efficiency of the platform shows the following characteristics: $\partial s^*/\partial n<0$, $\partial p_i^{N*}/\partial n<0$, $\partial e_i^{N*}/\partial n<0$, $\partial x_i^{N*}/\partial n<0$, $\partial \pi_i^{N*}/\partial n<0$, $\partial \pi_p^{*}/\partial n<0$.

Proposition 5 posits that a lower cost efficiency of the platform (i. e., a higher value of parameter n) leads to lower platform technical efforts, product prices, manufacturer design efforts, design levels, and manufacturer and platform profits. These findings suggest that reduced cost efficiency crowds out the incentives for both manufacturers and platforms to invest in their efforts. The numerical simulation is shown in Fig. 5 to help validate this proposition.

4 Conclusions

1) The establishment of the direct online channel is related to the manufacturers' design capabilities, and platform's commission rate and technical efforts. The upper bound of manufacturers' design capabilities keeps their investment in a reasonable range, while a higher commission rate ensures the platform's profit. Under these conditions, the manufacturers will choose the direct online channel if and only if the platform's technical efforts are within a certain frame.

2) The platform's exogenously given technical efforts have a positive effect on the manufacturers. However, in the endogenous case, this effect is reflected in the interaction of the platform's commission rate and cost efficiency.

3) Price competition and manufacturer design capabilities have a positive impact on equilibrium decisions, while design competition and platform cost efficiency have an inverse impact.

4) Our findings have managerial implications for manufacturers' channel decisions. However, some limitations exist, such as the fact that the demand function is linear and deterministic, and we do not account for platform competition.

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平台大数据分析技术影响下的制造商渠道选择决策

邱华清　　赵林度

（东南大学经济管理学院，南京 210096）

摘要：为获得平台的大数据分析技术支持，传统零售渠道中的制造商需要决策是否选择线上直销渠道，故构建了传统零售供应链模式和线上直销供应链 2 种模式进行对比，其中制造商在零售供应链中独立完成产品设计，而在线上直销供应链中与平台共同完成产品设计. 通过博弈模型和数值模拟对 2 种模式进行对比分析. 研究结果表明：在约束制造商的设计能力足够低和平台费率足够高以保证线上直销渠道可行的情况下，只有平台的技术努力在特定范围内时制造商才会选择直销渠道；外生的平台技术努力正向地影响制造商决策，而当平台技术努力为内生时，平台技术努力对制造商决策的复杂影响通过平台费率和平台成本效率的交互作用反映. 制造商和平台应综合考虑制造商的开发能力、市场竞争强度和平台的成本效率，为提高产品设计水平制定各自的努力决策.

关键词：大数据分析；平台销售；渠道决策；产品设计

中图分类号：C931