Price Decision in Multi-Channel Supply Chain under the Impact of Dual-Channel Retailer'S Internal Strategy

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Abstract: In the horizontal competition of multi-channel supply chain composed of a dominant dual-channel retailer and an online-retailer, a Stackelberg game model with the dominant dual-channel retailer as leader was established. Then the effects of relative market shares on price decision were studied under centralized and decentralized strategies of dual-channel retailer. Finally, the changing trend of channel prices and profits were discussed with numerical analysis. The results show that the price of the dual-channel retailer is lower but the profit is higher under decentralized strategy, and the online channel is more profitable from the e-commerce market expansion, decentralized strategy is more beneficial to dual-channel retailer. The price of online-retailer is lower under centralized strategy, but the profit is higher.

1. Introduction

With the rapid development of information technology and the widespread popularity of the Internet, electronic commerce has got unprecedented opportunities for development. At the same times, some "power retailers" such as Wal-Mart, Suning(China), as the price leaders in supply chain [1, 2], began to construct their own e-commerce to compete with new online-retailers and to consolidate their pricing power. These retailers gradually become dominant dual-channel retailer, that is, a retailer has two channel resources of brick-and-mortar channel and online channel, and dominant in pricing. According to the statistics from a research center, in the household appliance market of China, 21.1% products sold in Suning through two channels, and 13.9% in Jingdong, a pure online-retailer. More than 30% products were sold through online channels [3]. That means competition between pure online-retailers and powerful dual-channel retailers has gradually become an important part of the retail industry. The pricing strategies of dual-channel retailer may have different impacts on its profits and the whole supply chain, how the dual-channel retailer make pricing decision is the main focus of this research.

In the rest of this paper, we discuss related literatures. We describe the supply chain structure and formulate the model. Then, we analyze the price decisions under centralized and decentralized strategies. Furthermore, we provide numerical examples to study the profits. Finally, we conclude the results and limitations.

2. Literature Reference

Plenty of works on dual-channels have focused on channel model and channel selection. Chiang et al. [4] find manufacturers can guide market prices by online direct channels, which is helpful to improve the overall revenue of supply chain. Liu et al. [5] find that for traditional retailers, price consistency on channels plays a decisive role in preventing the entry of online retailers. Cai[6] further studies the pricing decision under the conditions of adding new channel and different contract types based on four different channel types. Lu et al.[7] Analyze the effects of e-channel efficiency and the acceptance of the traditional channel on members. Wang et al. [8] show that little operation cost gap and small product differentiation between online and offline are good for manufacturer.

Most of the above studies are based on the vertical competition model composed of manufacturer's direct channel and traditional retailers. However, with the further development of e-commerce, the horizontal competition model of dual-channel retailers and online-retailers has attracted much attention. Zhou et al. [9] compare the pricing problems under different pricing time strategies, and show the pricing strategies under different decision priorities. Geylani et al. [10] and Dan et al. [11] introduce a dominant retailer into multi-channel supply chain, and study the influence of market share on pricing decision. Agnihotri [12] show the threshold resources for the successful transformation of the entity retailer into a dual-channel retailer.

With the supply chain structure more and more complex, the pricing strategies of supply chain members become diversified. Chiang et al. [4] argue that vertical integrated direct channel is better than decentralized situation. Ma et al. [13] show that only manufacturer can benefit from wholesale price dominance, but both manufacturer and retailer can benefit when retailer dominant channel price. Ding et al. [14] compare the performance of supply chain under master-slave game with manufacturer as the main player, and Nash equilibrium and centralized decision-making. Chen et al. [15] take product quality into consideration and analyze the profits under centralized and decentralized situation. For dual-channel retailer, which has two different channel resources, its internal pricing strategy not only affects itself but the pricing of external retailer and performance of the supply chain. Thus, we assume the dual-channel retailer has two strategies, referring to centralized and decentralized situations in this paper.

In this paper, we assume a multi-channel supply chain consisting of a dominant dual-channel retailer and a pure online-retailer. Then we present a Stackelberg game model dominated by dual-channel retailer, and provide equilibrium price under centralized and decentralized decision making of dual-channel retailer. Then we analyze the impact of game process and market share on price decision and profits of supply chain members.

3. The Model

In this paper, we consider a multi-channel supply chain consisting of a dominant dual-channel retailer and a pure online-retailer as shown in Figure 1. Dual-channel retailer has traditional offline channel and online channel, and is in a strong position in the supply chain system with priority pricing rights. Simple homogeneous products are sold through three channels at the same time. Channel demand is affected by both channel prices and other channel prices.

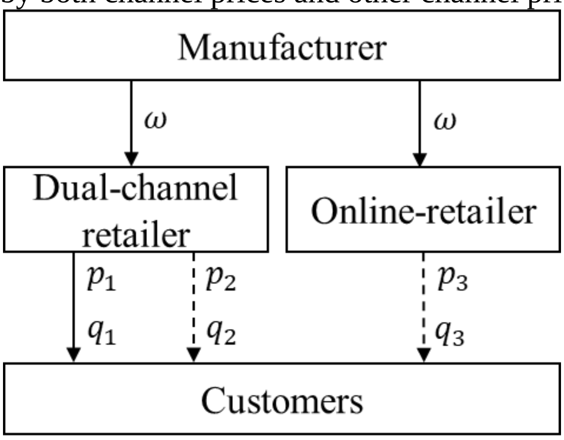


Fig. 1 Model of multi-channel supply chain

Each channel sells the product at price p_i. Let q_i denote customer demand. And a_i represent the potential demand of each channel. The parameter t is the coefficient of price elasticity, it reflects the degree to which the goods sold via the two channels are substitutes, and we assume that internal channel price is more effective than external channel price, so $0<t<1$. We use linear demand function based on Dan, Kurata, Huang [16, 17, and 18] to show the relationship between demand and price. The corresponding demand functions to the offline channel and online channel of dual-channel retailer and online-retailer are described as follows:

$$q_1 = a_1 - p_1 + tp_2 + tp_3 \tag{1}$$

$$q_2 = a_2 - p_2 + tp_1 + tp_3 \tag{2}$$

$$q_3 = a_3 - p_3 + tp_1 + tp_2 \tag{3}$$

So, the profit of dual-channel retailer and online-retailer are determined by:

$$\pi_r = (p_1 - \omega) q_1 + (p_2 - \omega) q_2 \tag{4}$$

$$\pi_o = (p_3 - \omega) q_3 \tag{5}$$

The parameter ω is the wholesale price provided by manufacturers, we assume it as exogenous variable and is the same at each channels. Besides, we assume a as total potential demand, let α represents the degree of customer loyalty to the e-commerce market, and λ means the degree of customer loyalty to the online channel of dual-channel retailer in the e-commerce market. In that way, the corresponding potential demand of each channels are described as follows:

$$a_1 = (1-\alpha) a \tag{6}$$

$$a_2 = \lambda \alpha a \tag{7}$$

$$a_3 = (1-\lambda) \alpha a \tag{8}$$

4. Model Calculation and Analysis

Dominant dual-channel retailer has priority in decision-making, so a Stackelberg master-slave game model with dual-channel retailer as leader is established. The dual-channel retailer determines its two channel's prices at first, then the online-retailer confirms its price. But dual-channel retailer can make decisions under centralized and decentralized strategies.

4.1 The centralized scenario.

The dual-channel retailer takes the overall profit as the goal, makes centralized decision, determines p_1 and p_2, then online-retailer determines p_3. Thus the optional price of each channels in centralized scenario as follows:

$$p_1^{C*} = \left[\left(2-t^2\right)a_1 + \left(2t+t^2\right)a_2 + \left(t+t^2\right)a_3 + \left(2-t-2t^2\right)(1+t)\omega \right] \Big/ \left[4\left(1-2t^2-t^3\right) \right] \tag{9}$$

$$p_2^{C*} = \left[\left(2t+t^2\right)a_1 + \left(2-t^2\right)a_2 + \left(t+t^2\right)a_3 + \left(2-t-2t^2\right)(1+t)\omega \right] \Big/ \left[4\left(1-2t^2-t^3\right) \right] \tag{10}$$

$$p_3^{C*} = \left[ta_1 + ta_2 + \left(2-t-2t^2\right)a_3 + \left(2-3t^2-2t^3\right)\omega \right] \Big/ \left[4\left(1-t-t^2\right) \right] \tag{11}$$

Where $0 < t < \frac{\sqrt{5}-1}{2}$ ensuring $p_i > 0$.

4.2 The decentralized scenario.

The two channels within the dual-channel retailer make decentralized decision with the goal of optimizing their respective profits, determines p_1 and p_2 respectively, then online-retailer determines p_3. The optional price of each channels in centralized scenario as follows:

$$p_1^{D*} = \left[4\left(2-t^2\right)a_1 + 2\left(2t+t^2\right)a_2 + \left(4t+2t^2-t^3\right)a_3 + \left(4+2t-t^2\right)\left(2+t-t^2\right)\omega \right] \Big/ \left[\left(4+2t-t^2\right)\left(4-2t-3t^2\right) \right] \tag{12}$$

$$p_2^{D*}=\left[2\left(2t+t^2\right)a_1+4\left(2-t^2\right)a_2+\left(4t+2t^2-t^3\right)a_3+\left(4+2t-t^2\right)\left(2+t-t^2\right)\omega\right]\Big/\left[\left(4+2t-t^2\right)\left(4-2t-3t^2\right)\right] \quad (13)$$

$$p_3^{D*}=\left[2ta_1+2ta_2+\left(2-2t-t^2\right)a_3+\left(4+2t-t^2-2t^3\right)\omega\right]\Big/\left(4-2t-3t^2\right) \quad (14)$$

Proposition 1: Under two scenarios, p_1^* are negatively correlated with α, and positively correlated with λ.

5. Appendix

5.1 The calculation of the prices in the centralized scenario.

Substituting (3) into (5), we have $\pi_o=\left(p_3-\omega\right)\left(a_3-p_3+tp_1+tp_2\right)$. Then taking the first-order partial derivatives of π_o with p_3, and letting the derivative be zero, we have

$$p_3=\frac{1}{2}\left(a_3+tp_1+tp_2+\omega\right) \quad (15)$$

Substituting (1) and (2) and (15) into (4), then taking the first-order partial derivatives of π_r with p_1 and p_2 respectively and we letting the derivatives be zero, we have

$$\begin{cases} p_1=\dfrac{2a_1+ta_3+2\left(2t+t^2\right)p_2+\left(2-2t^2-t\right)\omega}{2\left(2-t^2\right)} \\ p_2=\dfrac{2a_2+ta_3+2\left(2t+t^2\right)p_1+\left(2-2t^2-t\right)\omega}{2\left(2-t^2\right)} \end{cases} \quad (16)$$

When taking the second-order partial derivatives of π_r with p_1 and p_2 respectively and we letting the derivatives be zero, we have the Hessian matrix $H=\begin{pmatrix} t^2-2 & t^2+2t \\ t^2+2t & t^2-2 \end{pmatrix}$, since $\partial^2\pi_r/\partial p_1^2=t^2-2<0$ and $|H|>0$ when $0<t<\frac{\sqrt{5}-1}{2}$, π_r is strictly jointly concave in p_1 and p_2. According to (16), we have p_1^{C*} and p_2^{C*}, the substituting p_1^{C*} and p_2^{C*} into (15), we have p_3^{C*}.

5.2 The calculation of the prices in the centralized scenario.

The calculation of online-retailer is the same as that in the centralized decision making. We divide (4) into $\pi_1=\left(p_1-\omega\right)q_1$ and $\pi_2=\left(p_2-\omega\right)q_2$. Substituting (1) and (2) and (15) into π_1 and π_2, then taking the first-order partial derivatives of π_1 with p_1, π_2 with p_2, and letting the derivatives be zero, we have

$$\begin{cases} p_1=\dfrac{2a_1+ta_3+\left(2t+t^2\right)p_2+\left(2+t-2t^2\right)\omega}{2\left(2-t^2\right)} \\ p_2=\dfrac{2a_2+ta_3+\left(2t+t^2\right)p_1+\left(2+t-2t^2\right)\omega}{2\left(2-t^2\right)} \end{cases} \quad (17)$$

According to (17), we have p_1^{D*} and p_2^{D*}, substituting p_1^{D*} and p_2^{D*} into (15), we have p_3^{D*}.

5.3 Proof of *Proposition 1*

Under centralized scenario, from equations (6) (7) (8) and (9), we have $\dfrac{\partial p_1^{C*}}{\partial\alpha}=\dfrac{2t^2+\left(\lambda+1\right)t-2}{4\left(1+t\right)\left(1-t-t^2\right)}a$, letting $C = 2t^2 + (\lambda+1)t - 2 < 2t^2 + 2t - 2 = 2[(t+\frac{1}{2})^2 - \frac{5}{4}] \le 0$, so $\partial p_1^{C*}/\partial\alpha < 0$; $\frac{\partial p_1^{C*}}{\partial\lambda} = \frac{\alpha t a}{4(1+t)(1-t-t^2)} > 0$.

Under decentralized scenario, from equations (6) (7) (8) and (12), we have $\frac{\partial p_1^{D*}}{\partial\alpha} = \frac{\frac{26}{3} - 6(t+\frac{1}{3})^2 + (1-\lambda)t^3}{\left[(t-1)^2 - 5\right]\left[\frac{13}{3} - 3(t+\frac{1}{3})^2\right]} a < 0$ and $\frac{\partial p_1^{D*}}{\partial\lambda} = \frac{\alpha t^3}{\left[(t-1)^2 - 5\right]\left[3(t+\frac{1}{3})^2 - \frac{13}{3}\right]} a > 0$.

5.4 Proof of *Proposition 2*

From equations (6)(7)(8) and (10), we have $\frac{\partial p_2^{C*}}{\partial\alpha} = \frac{2\lambda - t - t\lambda - 2t^2\lambda}{4(1+t)(1-t-t^2)} a$, letting $D = 2\lambda - t - t\lambda - 2t^2\lambda$, when $\lambda > t/(2-t-2t^2)$, $D > 0$, then $\partial p_2^{C*}/\partial\alpha > 0$; when $\lambda < t/(2-t-2t^2)$, $\partial p_2^{C*}/\partial\alpha < 0$.

Proof of *Proposition 3* is similar to *Proposition 2,* so we omit it.

5.5 Proof of *Proposition 4*

Under centralized scenario, from equations (6) (7) (8) and (11), we have $\frac{\partial p_3^{C*}}{\partial\alpha} = \frac{[\frac{17}{4} - (t+\frac{3}{2})^2](1-\lambda)}{4(1-t-t^2)} a > 0$, $\frac{\partial p_3^{C*}}{\partial\lambda} = \frac{[(t+\frac{3}{2})^2 - \frac{17}{4}]}{4(1-t-t^2)} a < 0$. Under decentralized scenario, from equations (6) (7) (8) and (14), we have $\frac{\partial p_3^{D*}}{\partial\alpha} = \frac{\left[8-(t+2)^2\right](1-\lambda)}{2\left[\frac{13}{3} - (t+\frac{1}{3})^2\right]} a > 0$, $\frac{\partial p_3^{D*}}{\partial\lambda} = \frac{\left[8-(t+2)^2\right]\alpha}{2\left[(t+\frac{1}{3})^2 - \frac{13}{3}\right]} a < 0$

With the expansion of e-commerce market, traditional retailer needs to cope with competition with low-price strategy; however, whether dual-channel retailer chooses centralized decision or decentralized decision, the development of online channel can help offline channel maintain price levels, so dual-channel retailer should promote the development of online channel to expand their share in the e-commerce market.

Proposition 2: Under centralized scenario, when $\lambda > t/(2-t-2t^2)$, p_2^{C*} is positively correlated with α; when $\lambda < t/(2-t-2t^2)$, p_2^{C*} is negatively correlated with α.

Proposition 3: Under decentralized scenario, when $\lambda > t^3/(8-4t-6t^2+t^3)$, p_2^{D*} is positively correlated with α; when $\lambda < t^3/(8-4t-6t^2+t^3)$, p_2^{D*} is negatively correlated with α.

Combining *Proposition 2* and *Proposition 3,* if dual-channel retailer wants to benefit from the expansion of the e-commerce market, the market share of it needs to reach a certain proportion in the e-commerce market. And because of $\frac{t}{2-t-2t^2} > \frac{t^3}{8-4t-6t^2+t^3}$, dual-channel retailer's online channel is more likely to benefit from the expansion of overall e-commerce market share under the decentralized scenario.

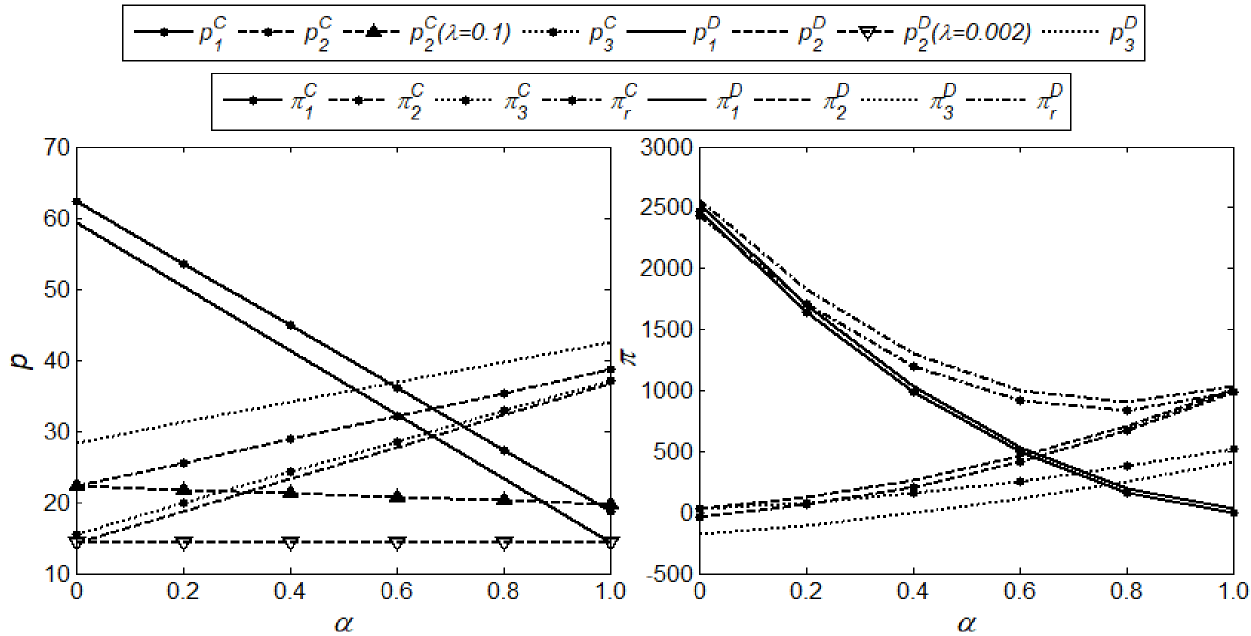
Proposition 4: Under two scenarios, p_3^* are positively correlated with α, and negatively correlated with λ.

The price of online-retailer is affected by the scale of e-commerce market and its share in e-commerce market comprehensively. The expansion of e-commerce market is conducive to improving the price level of online-retailer, but at the same time, online-retailer should compete with dual-channel retailer to seize market share. From the growth law of e-commerce enterprises, they often gain competitive advantage by low-price strategy at the initial stage of entering the market; when the market position is gradually established, there is no need to reduce prices blindly.

All the calculations and proofs of propositions are given in **Appendix**.

6. Numerical Analysis

6.1 The impact of α.



(a) Impact of α on prices (b) Impact of α on profits

Fig. 2 Impact of α on prices and profits

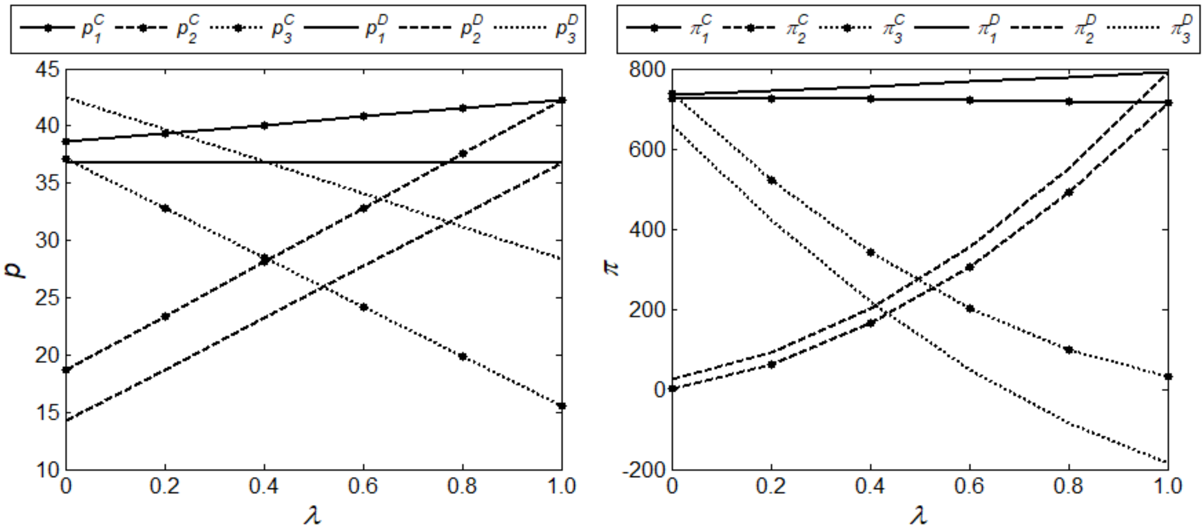
($a=100$, $\omega=10$, $t=0.25$, $\lambda=0.6$, $\lambda_0=0.1$, $\lambda_1=0.002$, $\alpha\in[0,1]$)

α Means the share of e-commerce market in the total market. With α increasing, the share of traditional offline channel decreases, and the equilibrium price decreases accordingly. However, the emerging online-retailer benefits from it and the channel price increases. If the online channel of dual-channel retailer wants to benefit from the e-commerce market expansion, its share in the e-commerce market needs to reach a certain proportion, and this proportion is higher under centralized scenario. In real life, considering the dual-channel retailer takes advantage of market, its online channel occupies a relatively high share in e-commerce market, therefore, whether it is centralized or decentralized scenario, the expansion of e-commerce market helps to increase the prices of the two online channels, but not always good for the offline channel's price.

Under centralized scenario, the equilibrium prices of two channels within dual-channel retailer are higher than that of decentralized scenario, but the profits of each channel, and of course the overall profit, are lower. Under centralized scenario, the price of online-retailer is lower, but the profit is higher. Dual-channel retailer dominates the supply chain system and has pricing priority, therefore, it is better for dual-channel retailer to adopt decentralized decision. On the one hand, low prices and high profits help to expand the market and increase revenue, on the other hand, it forces online-retailer to set high price, at the same times, reduces online-retailer's revenue. As a price follower, online-retailer should have set high price, but in order to expand its market, it will follow the low-price strategy and break out price war with dual-channel retailer.

6.2 The impact of λ.

Whether it is centralized or decentralized scenario, both the online channel and offline channel of dual-channel retailer can profit with λ increasing. Therefore, when the e-commerce market develops to a certain scale, dual-channel retailer should pay attention to the online channel, invest more resources to expand its share and promote its position in the e-commerce market. The dual-channel retailer could improve its overall performance by this way.



(a) Impact of λ on prices (b) Impact of λ on profits

Fig. 3 Impact of λ on prices and profits

($a=100$, $\omega=10$, $t=0.25$, α=0.5 , $\lambda\in[0,1]$)

7. Conclusion

In this paper, we study the pricing decision in a multi-channel supply chain under centralized and decentralized strategies of dual-channel retailer. We found that online channel of dual-channel retailer is more likely to benefit from the development of e-commerce market under centralized scenario. Besides, the price of dual-channel retailer is lower under decentralized strategy, but the overall profit is higher. Therefore, dual-channel retailer prefers to decentralized decision making and low-price strategy. However, the price of online-retailer is higher, but the profit is lower under decentralized strategy. In order to expand its market share and pursue higher profits, online-retailer wants the dual-channel retailer make centralized strategy, if not, online-retailer may follow the low-price strategy and break out price war with dual-channel retailer.

Our model only considers the competition between retailers, we can take manufacturer into consideration and design cooperation contracts to improve the supply chain on the whole. Furthermore, it would be interesting to `construct a dynamic differential game model to describe the competition and pricing decision. These will be the focus of our research in the future.

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