Pricing Research for a Dual-channel Supply Chain with Free Riding Behavior

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Abstract. As the science and technology are leaping forward, online channels progressively gain the favor of customers based on their unique shopping experience that differs from the traditional retail channels, and establish a dual-channel retail model with the traditional retail channels. The differences between channels will enable consumers to first experience products or services offline, and then buy products online at a cheaper price. This has formed a free-riding effect. Under such effect in dual channels, how e-commerce retailers and traditional retailers determine the price of channel products is to be discussed in this paper. Based on a brief exposition of the current economic environment, the research status of dual-channel and free-rider vehicles is first analyzed to locate the research work of this paper. Then, under this circumstance, the situation is addressed that e-commerce retailers have zero service levels, and the traditional retailer can provide services and establish a pricing game model, the product's dual-channel pricing strategy is analyzed by using the game model. Finally, the actual availability and effectiveness of the built game model are verified with the example analysis.

Introduction

The modern world is advancing in the science and technology, which has developed the E-commerce market in China, and a growing number of people have embraced the online shopping closely. The rapid development of network popularization and the increasing number of netizens make possible the development of online sale. Under the dual-channel environment, consumers can purchase products via the traditional and online retail channels. Since the online retail channel has kept pace with the development of the times, it must have its own advantages, such as the flexible arrangements of inventory and the independence of time and place. Thus, the growth of online retail channel is irreversible under the network environment. Also, the dual-channel sales model will improve the daily behaviors and shopping concepts of consumers.

As the traditional retail channel can provide face-to-face service and better perception of product, consumers may choose to go shopping in physical stores. Yet the network retail channel has saved some intermediate expense, and the price of online retail channel products may be lower than that of offline products. People will be more likely to spend money online if they recognize the product quality of network channel.

It is common that a customer at a computer store experiences a computer that he wants to buy following the introduction of the professional salesman in the computer store, and he felt that the computer was very suitable for his own requirements through the customer's own operation and experience of the computer function. It is strange that he did not buy the computer directly at the computer store. He bought the computer through an online channel at a lower price instead. In this case, the costs (store fees, sales costs, etc.) to be paid by the traditional retailers are not compensated at all. Conversely, online retailers gain benefits without pains. This is what we call free riding. The act of such a transformation results in the loss of the sales volume that is supposed to pertain to the
traditional channels that generate service fees. Yet the network channel that does not produce service charge to increase the sale without any payment. Undoubtedly, this situation will certainly raise the contradictions and the competition between channels. In this case, this paper fixates on how the enterprises of dual-channel supply chain should price in accordance with the free riding behavior to obtain the maximum profit.

Literature Review

The dual-channel pattern emerged under the development of science and technology is progressively common in real life, which has aroused a huge attention from many scholars. Also, these scholars have studied many aspects about the dual-channel. Online channel and traditional retail channel are the components of dual-channel supply chain. Conflict, coordination, pricing and channel type selection are the four aspects of dual channel supply chain management, which are also studied by plenty of scholars. The selection of online and offline channels of retailers was studied by Wang et al. (2016) from the perspective of dual-channel operation cost. Zhang et al. (2017) primarily studied the dual-channel pricing and the coordination of retailers in the short life cycle. Chen et al. (2017) and Ha et al. (2016) further compared the differences and the decisions of pricing, profit and product quality between manufacturers and retailers in the single and the dual-channel. The price decision of dual-channel supply chain was studied by Chen S (2017) under the centralized and decentralized conditions. The pricing decision and coordination contract of dual-channel supply chain were studied by Li et al. (2016) from the perspective of risk attitude. The pricing decisions of dual-channel supply chain were studied by Kalnins (2017) from the perspective of product externality, as well as the high and low quality brand signals. Ding et al. (2016) considered a dual-channel supply chain with a manufacturer and a retailer involved, and studied the pricing decision of manufacturers in three different channel structures using the stratified pricing. The manufacturers' adoption of the same and different wholesale prices for traditional retailers and online retailers was studied by Erjiang et al. (2016), respectively. Besides, the channel coordination strategies were adopted by manufacturers to mitigate these channel conflicts.

There's also a lot of studies on free riding, and it is known that this concept was first proposed by American Michael Jackson. At that time, it did not arouse any attention from all sectors of society. As the science and technology are advancing, free riding comes into people's eyes. Singley (2015) believed that the primary reason for the free riding problem was the difference in price, and the final purchase behavior of consumers did not always occur at the service retailers. In recent years, as the circular economy has been developing, and people's environmental awareness continues to increase, the carbon emission in the process of production development has aroused a growing attention. The impact of free-riding behavior on carbon emissions in dual-channel closed-loop supply chain and the influence of government e-commerce tax on carbon emissions were studied by Rongyao et al. (2016). Research suggests that free riding will bring more benefits to manufacturers but increase the carbon emissions in the supply chain. The impact of consumer free-riding behavior under the carbon emission policy on the operational efficiency of the dual-channel closed-loop supply chain was considered by He et al. (2016).

It is suggested from the above that many scholars have studied the dual-channel and free-riding problems. Besides, the relationship between channel selection and dual channel coordination, free riding and dual channel conflict and coordination was also studied. It is obvious that more studies still fixate on the conflict coordination of supply chain and other issues. Given that the operating costs of traditional retail channels and e-commerce retail channels are different, many manufacturers and retailers will eventually decide different prices for their products. Undoubtedly, it will lead to conflicts between channels, so it is important to study the conflict coordination between two channels. Yet free riding problem is comparatively more significant when put it into the channel pricing. As the online retail channel has the advantage of product price, the price pressure will be inevitably posed to the traditional retailers after the opening of the online retail channel. Yet offline retailers can provide
customers with zero-contact services, which will pose a huge pressure to online retail channels. In this case, there is a conflict between the channels, which will also lead consumers’ choice behavior to different channels. Accordingly, how the dual channel should be priced to get the maximum benefit is a noteworthy question. Yet it can be found by reading and analyzing the relevant literature of dual-channel free riding that few people consider the dual-channel free riding environment in pricing. Therefore, on the basis of previous studies, this paper considers free riding when studying dual-channel pricing. This will be beneficial for real enterprises to make pricing decisions, because free riding is an important factor influencing the pricing of two channels. It will help enterprises know how to obtain the maximum profit of their own profit or the overall profit of the channel in the future.

Model Framework

Problem Description

The paper considers a supply chain in which a manufacturer applies both a traditional channel retailer and online channel in parallel to sell a single product. This suggests that it’s a dual channel dominated by manufacturer. For the online channel, the manufacturer sells the product to the consumer directly at the price $p_1$ without going through the intermediary of traditional retailer. For the offline channel, manufacturer first sell the goods to the traditional retailer at the wholesale price of $w$, and then the traditional retailer determine their own price $p_2$ in accordance with the wholesale price, and then sell it to the final consumer at the price $p_2$. As commodities are sold to consumers on both channels, there must be a competition of price and service in both retail channels.

![Figure 1. Structure diagram of dual channel supply chain.](image)

Symbol introduction: $a$ denotes the total market size of the dual-channel; $\theta$ is the share coefficient of online retail channel in the whole market scale; $\alpha$ is the elasticity of demand to price; $\beta$ is the price cross influence coefficient between channels; $k$ is the influence coefficient of service on consumers. Assume that there is only traditional retail channel, i.e., offline channel provides consumers with the service level $v$. It is well known that a certain service level of the enterprise must pay the cost, so that $\eta$ denotes the service cost coefficient of the channel. The cost incurred by providing service level $v$ is given by $c(v)$, where $c(v)=\eta v^2/2$. $D_1$ is the demand of online retail channel, and $D_2$ is the demand of traditional retail channel. $P_1$ is the price of online retail channel, and $P_2$ is the price of traditional retail channel.

Establishment of Dual-channel Free Riding Model

On the basis of the previous studies, the demands in the online retail channel and the traditional retail channel can be determined, respectively.

$$D_1 = \theta a - \alpha p_1 + \beta p_2 - kv \quad (1)$$

$$D_2 = (1-\theta) a - \alpha p_2 + \beta p_1 + kv \quad (2)$$

The overall profit of the dual-channel supply chain can be expressed as $\pi$, and the overall profit can fall into two parts. One part is the profit of online retail channel, which is the manufacturer’s
profit, expressed as $\pi_M$. The other part is the retailer’s profit, denoted by $\pi_R$. Besides, the manufacturer’s profits can be further split into two aspects. On the one hand, it is the income from the opening online retail channel; on the other hand, it is the income from wholesales the commodities to traditional retailer.

$$\pi_M = (P_1 - c)D_1 + (w - c)D_2$$ (3)

$$\pi_R = (P_2 - w)D_2 - \frac{\eta v^2}{2}$$ (4)

**Dual-Channel Pricing Strategy**

**Dual-channel Pricing of Centralized Decision-making.** Under the sales model of dual channel, one is the traditional physical retail channel, the other is the network retail channel. When we consider the centralized decision-making, the two channels should be priced as a whole, so that the overall revenue of the dual-channel can be maximized, such a dual channel pricing is the centralized decision-making. There is no competition between the two channels in this pricing mode, each of which is based on the overall revenue of the channel. In this case, the overall benefit of the two channels is written as $\pi$:

$$\pi = \pi_M + \pi_R = (P_1 - c)D_1 + (P_2 - c)D_2 - \frac{\eta v^2}{2} = (P_1 - c)(\theta a - \alpha P_1 + \beta P_2 - kv) + (P_2 - c)(1 - \theta)\alpha a + \beta P_1 + kv - \frac{\eta v^2}{2}$$ (5)

**Proposition 1:** Under the pricing model of centralized decision-making, the total revenue $\pi$ partial derivatives of $P_1$ and $P_2$ respectively, and the optimal pricing of online and offline channel is written as $(P_1^*, P_2^*)$.

$$P_1^* = \frac{2a\beta + 2\theta a(\alpha - \beta) + 2c(\alpha^2 - \beta^2) + 2kv(\beta - \alpha)}{4(\alpha^2 - \beta^2)}$$ (6)

$$P_2^* = \frac{2\theta a(\beta - \alpha) + 2kv(\alpha - \beta) + 2c(\alpha^2 - \beta^2) + 2\alpha a}{4(\alpha^2 - \beta^2)}$$ (7)

**Dual-channel Pricing for Decentralized Decision-making.** When two channels consider pricing with the decentralized decision making, the two channels are not considered as a whole. It takes the traditional retail channel and the network retail channel to achieve the largest revenue, respectively, i.e., each from its own perspective to pricing. Nash game and Stackelberg game are two game types that should be considered in this paper.

(1) Nash game

**Proposition 2:** The Nash game with manufacturer's total return on its price $P_1$ first derivative is used. Next, the retailer's total return to its price $P_2$ derivation is used. Next, two equations obtained by simultaneous solution are combined. Finally, the most suitable price of manufacturer and retailer $(P_1^*, P_2^*)$ can be obtained.

$$P_1^* = \frac{a\beta + \theta a(2\alpha - \beta) - kv(\beta - 2\alpha) + 3\alpha\beta w + 2\alpha c(\alpha - \beta)}{4\alpha^2 - \beta^2}$$ (8)
\[ p_2^* = \frac{\theta a (\beta - 2\alpha) + kv(2\alpha - \beta) + c\beta (\alpha - \beta) + w(2\alpha^2 + \beta^2) + 2\alpha a}{4\alpha^2 - \beta^2} \]  

(9)

(2) Stackelberg game

**Proposition 3**: In this setting, the dominant manufacturer must ensure that its own interests reach the maximum value, so that he first determines the product price that meets the conditions. In the meantime, the retailer also seeks to maximize the interests, so he will determine the price that satisfies his maximum profit based on the manufacturer's price. Then, the optimal price of online retail channel and traditional retail channel can be obtained using backward induction.

Take the derivative of the traditional retailer's revenue \( \pi_r \) in accordance with \( P_2 \), and set its derivative to zero. Thus, the retailer’s best price response strategy \( P_2 \) to \( P_1 \) set by the manufacturer can be easily derived.

\[ P_2 = \frac{(1-\theta)a + \beta P_1 + kv + \alpha w}{2\alpha} \]  

(10)

Then, we plug \( P_2 \) into the manufacturer's revenue \( \pi_m \), and take the derivative of \( \pi_m \) in accordance with \( P_1 \). Set its derivative to zero, and the manufacturer’s optimal pricing is obtained as:

\[ P_1 = \frac{\theta a (2\alpha - \beta) + a\beta + kv(\beta - 2\alpha) + 2w\alpha \beta + 2c(\alpha^2 - \alpha \beta) + c\beta (\alpha - \beta)}{4\alpha^2 - 2\beta^2} \]  

(11)

Finally, by substituting the price of the online retail channel \( P_1 \) into the previous one, the final optimal price of the traditional retail channel is obtained as:

\[ P_2 = \frac{1}{2\alpha} \left[ (1-\theta)a + kv + \alpha w \right] + \frac{\beta}{2\alpha(4\alpha^2 - 2\beta^2)} \left[ \theta a (2\alpha - \beta) + a\beta + kv(\beta - 2\alpha) + 2w\alpha \beta + 2c(\alpha^2 - \alpha \beta) + c\beta (\alpha - \beta) \right] \]  

(12)

**Numerical Examples**

On the basis of the noted model, assume that \( a = 1000, \theta = 0.5, c = 5, w = 20, \alpha = 8, \beta = 4, \eta = 4 \). We assume that the network retail channel does not provide service, i.e., the service level is zero, while the traditional retail channel provides service \( v \). Assign different values to \( v \) and observe the effect of different values of \( v \) on the pricing of two channels. Here \( k = 5 \) is taken, and Table 1 and Figure 2 are yielded.(the horizontal coordinate in the figure below represents the service level \( v \), and the vertical coordinate represents the product price).

| \( v \) | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| \( P_1' \) | 65 | 64.79 | 64.58 | 64.38 | 64.17 | 63.96 |
| \( P_2' \) | 65 | 65.21 | 65.42 | 65.63 | 65.83 | 66.04 |
| \( P_1^* \) | 51 | 50.75 | 50.5 | 50.25 | 50 | 49.75 |
| \( P_2^* \) | 54 | 54.25 | 54.5 | 54.75 | 55 | 55.25 |
| \( P_1 \) | 52.14 | 51.88 | 51.61 | 51.34 | 51.07 | 50.8 |
| \( P_2 \) | 54.29 | 54.53 | 54.78 | 55.02 | 55.27 | 55.51 |

In the scenario of the centralized decision-making pricing, we can find that the manufacturer's product price decreases with the increase of the service level of offline retail channel, while the retailer's product price increases. Besides, the decrease of online retail channel prices is greater than the increase of traditional retail channel prices. In the decentralized decision-making pricing, the
manufacturer's selling price also decreases with the increase of the service level of the traditional retail channel in the Nash game, and the retailer's selling price increases with the increase of the service level of the traditional retail channel. The decrease of retail channel sales price is greater than the increase of offline retail channel product prices, which are the same as the Stackelberg game. It is found from the above point of view that the influence of the service level of one channel on another channel is larger than that on the level itself. It is known that the traditional retail channels increase the selling price of products at a higher service level under the cost of providing services. The higher the service level, the higher the cost will be.

Next, the traditional retail channel service level \( v = 5 \) is taken, and then different values of influence coefficient \( k \) of service for consumers are taken. Look at what type of impact can be exerted by the changes of \( k \) value on both sides of the price.

![Figure 2. Price of each channel under the change of service level \( v \).](image)

Figure 2. Price of each channel under the change of service level \( v \).

![Figure 3. Price of each channel under the change of \( k \) value of the influence coefficient of service on consumers.](image)

Figure 3. Price of each channel under the change of \( k \) value of the influence coefficient of service on consumers.

It is concluded from Table 2 and Figure 3 that under the centralized decision-making pricing scenario, the price of online retail channels decreases with the increase of the coefficient of influence of services on consumers \( k \), and the decrease is insignificant. The price of products in traditional retail channels increases with the increase of \( k \), and the increase is also insignificant. In the Nash game, the price of online retail channels decreases with the increase of \( k \), and the decrease is insignificant. The offline traditional retail channel product price increases with the increase of \( k \) value, and the increase is also insignificant. The same rule exists in the game of Stackelberg. It is suggested that the traditional retail channels can increase the price when the coefficient of influence of service on consumers increases. Because traditional channels provide services, he can increase the price to increase his own benefits and compensate for the cost of providing services. Online retail channels, by contrast, need to lower their prices to stay competitive because their service levels are zero.

| \( v \) | 0   | 1   | 2   | 3   | 4   | 5   |
|------|-----|-----|-----|-----|-----|-----|
| \( P_1^c \) | 65  | 64.79| 64.58| 64.38| 64.17| 63.96|
| \( P_2^c \) | 65  | 65.21| 65.42| 65.63| 65.83| 66.04|
| \( P_1^* \) | 67.67| 67.42| 67.17| 66.92| 66.67| 66.42|
| \( P_2^* \) | 54  | 54.25| 54.5 | 54.75| 55  | 55.25|
| \( P_1^p \) | 52.14| 51.88| 51.61| 51.34| 51.07| 50.8 |
| \( P_2^p \) | 54.29| 54.53| 54.78| 55.02| 55.27| 55.51|

**Conclusions**

This paper assumes that the traditional retail channels provide services, and the online retail channels do not provide services. In the present paper, how online retail channels and traditional retail channels determine their respective prices under the influence of the service level of traditional retail channels has been studied, and the game theory model is established for discussion. It is found in this paper that
the price of a channel is affected by the service level, as well as the influence coefficient of service on consumers. The price of online retail channels will decrease with the rise of service level, while the price of traditional retail channels will increase with the rise of service level when the influence coefficient of service on consumers $k$ remains unchanged and the service level $v$ takes different values. Besides, the price drop of network retail channel is bigger than that of traditional retail channel. In the other case, when service level $v$ remains unchanged, and the coefficient of influence of service on consumers $k$ is selected as different values, the same is true. In accordance with the above conclusion, it is practically known that offline retail channels to provide the service level of the $v$ is progressively higher when the $k$ value is constant, which also suggests that the cost on the service fee is higher progressively. Accordingly, our retailers can improve their prices to compensate for part of their costs. Yet the service level of online retail channel is zero. To maintain their competitive advantage, manufacturers have to lower their own prices. When $v$ is constant, and the influence coefficient of service on consumers rises, the same is true. And in double channels in the supply chain, the network retail channels can help traditional retail channels share certain operating costs to give the retailer a certain amount of economic compensation or the joint efforts of both sides to increase sales, thus avoiding the free riding.

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