Pricing of Dual Channel Supply Chain Based on Manufacturer Network Channel Selection Research on Service Decision Making

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Abstract. This article considers a network distribution model consisting of offline retail physical sales and online retail online sales, as well as a network consignment model consisting of offline retail physical sales and cooperation with third-party e-commerce platforms. Research on manufacturer mode selection and supply chain optimal pricing and service decision-making under free riding behavior. Research has shown that manufacturers' channel selection strategies are related to the degree of free riding behavior, consumer preference for online channels, and price sensitivity. Especially when price sensitivity is the same, manufacturers will choose the online sales channel model.

Keywords: dual channels; Pricing; Free riding; Channel selection; Intro-duction

1 Introduction

In recent years, with the development of e-commerce platforms and new retail, the dual channel model of coexistence between online and offline has gradually matured, and three dual channel sales models have been developed. For manufacturers, adopting a dual channel supply chain structure to maximize their own profits is an important issue they face. Domestic and foreign scholars have conducted extensive research on the selection and influencing factors of manufacturers' online channels. Rodriguez and Aydin[1] found that a manufacturer's dual channel structure can attract more customers. Ryan et al.[2] studied the decision choice problem of manufacturers building their own direct sales channels or selling products through online retailers' online channels based on the consumer utility model. Liang Xi et al.[3] studied the pricing decisions and channel selection issues of manufacturers under three dual channels: online direct sales, online distribution, and online consignment. Yang Lei et al.[4] studied the supply chain channel selection and emission reduction decision-making problem under four dual

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decision model for manufacturers to choose marketing channels under the premise of retailers having dual channels. They found that opening up online direct sales channels by manufacturers will be beneficial for improving the performance of manufacturers, retailers, and the supply chain. However, manufacturers may not necessarily benefit from the introduction of online channels[6].

Due to the homogeneity of products sold by manufacturers through dual channels, consumers will choose between different channels when purchasing products. At the same time, many consumers engage in "free riding" behavior, that is, after enjoying free trial services in physical stores, product displays and explanations, they go to online channels to purchase products. According to research by Van Ball et al.[7], up to 20% of consumers in a dual channel supply chain consisting of physical and end of network channels exhibit free riding behavior.Xing and Liu[8] studied the effectiveness of coordinating sales efforts under different contracts under the influence of consumer free riding behavior. Li Jianbin et al.[9] studied the optimal pricing and sales effort level decision-making of a dual channel supply chain under the situation of two-way free riding. Zhou et al.[10] studied the effects of "free riding" behavior on differential pricing and consistent pricing in a dual channel supply chain Few scholars have paid attention to the impact of free riding behavior on manufacturers' dual channel model selection, which will be the main research content of this article.

The above review indicates that scholars have rarely explored the issue of manufacturer channel model selection. Therefore, this article studies the problem of manufacturers choosing two dual channel models, online distribution and online consignment, under the "free riding" behavior, and analyzes the pricing of the supply chain and the channel selection of manufacturers under these two dual channel models.

2 Problem Description and Symbols

This article considers a network distribution model consisting of offline retail physical sales and online retail online sales, as well as a network consignment model consisting of offline retail physical sales and cooperation with third-party e-commerce platforms. Research on manufacturer mode selection and supply chain optimal pricing and service decision-making under free riding behavior. In the two dual channel models of online distribution or online consignment, manufacturers sell the same product through traditional retail channels and online channels.

In the dual channel model of online distribution, manufacturers sell their products to traditional retail channels and online retailers at wholesale prices w. Then traditional retail channels sell products to consumers at selling prices p_r and provide them with service levels s, while online retailers sell products directly to consumers at prices p_d; In the dual channel model of online sales, manufacturers sell products to traditional retailers at wholesale prices w, provide consumers with service levels s, and sell to consumers at prices p_r. At the same time, manufacturers entrust sales agents to consumers at online prices p_d. In this model, manufacturers decide their own sales prices,

e-commerce platforms are only responsible for sales, and manufacturers need to pay a certain commission(see Fig 1).

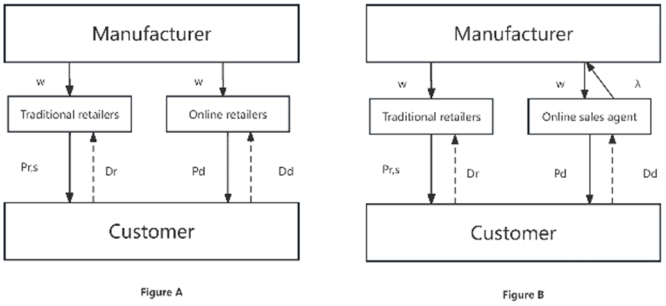

Fig. 1. A shows the dual channels of online distribution, and Figure B shows the dual channels of online consignment sales

Due to free riding behavior and price competition across different sales channels, establish a demand function:

Network channel requirements:

$$D_d = \theta a - b_1 p_d + e_1 p_r + \beta s \tag{1}$$

Traditional channel demand:

$$D_r = (1-\theta)a - b_2 p_r + e_2 p_d + (1-\beta)s \tag{2}$$

Among them, $a_1 = \theta a$、$a_2 = (1-\theta)a, \theta(0 < \theta < 1)$ represents the degree of consumer preference for online channels and a represents the basic consumer group. $b_1$and b_2 respectively represent the price sensitivity coefficients of consumers to demand from online channels and traditional channels. e_1 and $e_2$are the cross elasticity coefficients of prices, and$e_1 = e_2 = e$ $(b_1, b_2 > e)$. $\beta(0 < \beta < 1)$ indicates the degree of free riding behavior. Assuming the unit production cost of a manufacturer's product is c, the service cost function of a traditional retailer is $\eta s^2/2$,λ the commission fee that the manufacturer needs to pay for selling unit products. Important parameter settings are shown in Table 1.

Table 1. Description of Parameters and Symbols

Parameter	Symbol Description	Parameter	Symbol Description
w	Wholesale price	p_r	Traditional channel sales prices
p_d	Online channel sales price	s	Service level of traditional retailers
D_r	Traditional channel demand	D_d	Network channel demand
β	The degree of "free riding" behavior	θ	Consumer preference for online channel

b_1	Consumer price sensitivity coefficient to online channel demand	b_2	Consumer price sensitivity coefficient to traditional channel demand
e	Price cross elasticity coefficient	π_r	Traditional retailer profit function
π_d	Online retailer profit function	π_m	Manufacturer profit function

3 Models

3.1 Dual Channel Network Distribution for Manufacturers

In this model, traditional retailers first decide their service level s. Then the manufacturer decides the wholesale price w with the goal of maximizing their own profits. Finally, traditional retailers and online retailers decide their own sales prices separately P_d. The profit functions of traditional retailers and manufacturers are respectively.

The profit function of traditional retailers is:

$$\pi_r^I = (p_r - w)D_r - \eta s^2/2 \tag{3}$$

The profit function of online retailers is:

$$\pi_d^I = (p_d - w)D_d \tag{4}$$

The profit function of the manufacturer is:

$$\pi_m^I = (w - c)(D_r + D_d) \tag{5}$$

Proposition 1: For a given service level of traditional retailers, the inverse solution method can be used to determine the optimal wholesale price, traditional channel retail price, and online channel retail price, which are:

$$w^I(s) = \frac{(R_1 s + R_2)}{R} \tag{6}$$

$$p_r^I(s) = \frac{(2b_1 - 2\beta b_1 + \beta e)R + (2b_2 e)b_1 R_1}{(4b_1 b_2 - e^2)R} s + \frac{2a_2 b_1 + a_1 e)R + (2b_2 + e)b_1 R_2}{(4b_1 b_2 - e^2)R} \tag{7}$$

$$p_d^I(s) = \frac{2\beta b_2 + e - \beta e)R + (2b_1 + e)b_2 R_1}{(4b_1 b_2 - e^2)R} s + \frac{2a_1 b_2 + a_2 e)R + (2b_1 + e)b_2 R_2}{(4b_1 b_2 - e^2)R} \tag{8}$$

$$R = 4b_2 b_1^2 - 2b_2 e^2 + b_1(4b_2^2 - 2e^2 4b_2 e) \tag{9}$$

$$R_1 = 2b_1 b_2 + (1 - \beta)b_1 e + \beta b_2 e \tag{10}$$

$$R_2 = 2b_1 b_2(a_1 + a_2 + b_1 c - ce) + a_2 b_1 e + a_1 b_2 e + b_1 c(b_2^2 - e^2) + b_2 c(b_1 b_2 - e^2 \tag{11}$$

Proposition 1 indicates that the optimal wholesale prices for manufacturers, as well as the sales prices for traditional and online channel retailers, are determined given the level of service provided by traditional retailers. With the increase of traditional retail service levels, the wholesale prices of manufacturers and the sales prices of traditional and online retailers have also increased.

Question 1: For a given service level s, in online distribution channels, the degree of "free riding" behavior and consumer preference for online channels vary with the size of s. The following conclusion can be drawn:

$$b_2 \geq b_1, \frac{dw^{I*}(s)}{d\beta} \geq 0, \frac{dw^{I*}(s)}{d\theta} \geq 0, b_1 > b_2, \frac{dw^{I*}(s)}{d\beta} < 0, \frac{dw^{I*}(s)}{d\theta} < 0 \tag{12}$$

$$\frac{dp_d^{I*}(s)}{d\beta} > 0, \frac{dp_d^{I*}(s)}{d\theta} > 0 \tag{13}$$

$$\frac{dp_r^{I*}(s)}{d\beta} < 0, \frac{dp_r^{I*}(s)}{d\theta} < 0 \tag{14}$$

Question 2: For a given service water usage s, analyze the impact of "free riding" behavior and network channel preference on price setting strategies in the dual channel network distribution, and draw the following conclusions.

$$b_2 \geq b_1, H_1 < 0, \frac{dp_r^I(s)}{d\beta} > \left|\frac{dw^I(s)}{d\beta}\right| > \frac{dp_d^I(s)}{d\beta} > 0, H_2 > 0, \frac{dp_r^I(s)}{d\beta} > \frac{dp_d^I(s)}{d\beta} > \left|\frac{dw^I(s)}{d\beta}\right| > 0 \tag{15}$$

$$b_2 \geq b_1, H_2 < 0, \frac{dp_r^I(s)}{d\beta} > 0 \left|\frac{dw^I(s)}{d\beta}\right| > \frac{dp_d^I(s)}{d\beta} > 0, H_2 > 0, \frac{dp_r^I(s)}{d\beta} > \frac{dp_d^I(s)}{d\beta} > \left|\frac{dw^I(s)}{d\beta}\right| > 0 \tag{16}$$

$$H_1 = 8b_1^3 b_2 + 3b_2 e^3 + 8b_1^2 b_2^2 + b_1 e^3 - 6b_1^2 b_2 e - 3b_1^2 e^2 - 10b_1 b_2^2 e - b_1 b_2 e^2 \tag{17}$$

$$H_2 = 8b_2^3 b_1 + 3b_1 e^3 + 8b_1^2 b_2^2 + b_2 e^3 - 6b_2^2 b_1 e - 3b_2^2 e^2 - 10b_2 b_1^2 e - b_1 b_2 e^2 \tag{18}$$

3.2 Dual Channel Network Sales for Manufacturers

In the online sales model, traditional retailers first determine the service level s, manufacturers then decide the wholesale price w and the sales price of the online sales platform p_d, and finally traditional retailers decide the offline sales price p_r.

The profit function of traditional retailers, consignment platforms, and man-ufacturers in the sub model is:

The profit function of traditional retailers:

$$\pi_r^{II} = (p_r - w)D_r - \eta s^2/2 \tag{19}$$

Manufacturer's profit function:

$$\pi_m^{II} = (w - c)D_r + (p_d - c - \lambda)D_d \tag{20}$$

Proposition 2: For a given level of service for traditional retailers, the inverse solution method can be used to determine the optimal wholesale price $w^{II}(s)$, traditional channel sales price $p_r^{II}(s)$， and online channel sales price $p_d^{II}(s)$as :

$$w^{II}(s) = (As + M + c)/2 \tag{21}$$

$$p_d^{II}(s) = (Bs + F + c + \lambda)/2 \tag{22}$$

$$p_r^{II}(s) = \frac{\{a_2(3b_1b_2-e^2)+b_1b_2(b_2c+ce+e\lambda+3s-3s\beta)-e[-2a_1b_2+b_2(ce-2s\beta)+e(ce+e\lambda+s-s\beta)]\}}{4b_2(b_1b_2-e^2)} \tag{23}$$

$$\mathrm{A} = \frac{e\beta+b_1(1-\beta)}{b_1b_2-e^2}, B = \frac{e(1-\beta)+b_2\beta}{b_1b_2-e^2}, F = \frac{b_2\theta a+e(1-\theta)a}{b_1b_2-e^2}, M = \frac{e\theta a+b_1(1-\theta)a}{b_1b_2-e^2} \tag{24}$$

Introduction 3: For a given level of service provided by traditional retailers, analyze the impact of the degree of free riding behavior and preference for online channels on pricing changes under the dual channel model of online consignment sales. The following conclusions can be drawn:

$$\frac{dw^{II*}(s)}{d\beta} < 0, \frac{dw^{II*}(s)}{d\theta} < 0, \frac{dp_d^{II*}(s)}{d\beta} > 0, \frac{dp_d^{II*}(s)}{d\theta} > 0, \frac{dp_r^{II*}(s)}{d\beta} < 0, \frac{dp_r^{II*}(s)}{d\theta} < 0 \tag{25}$$

Introduction 4: For a given level of service provided by traditional retailers, analyze the impact of free riding behavior and preference for online channel consumption on pricing strategies under the dual channel model of online sales, as follows:

$$b_1 \geq b_2, \frac{\partial p_d^{II}(s)}{\partial \beta} < \left|\frac{\partial w^{II}(s)}{\partial \beta}\right| < \left|\frac{\partial p_r^{II}(s)}{\partial \beta}\right| \tag{26}$$

$$b_1 < b_2, \left|\frac{\partial w^{II}(s)}{\partial \beta}\right| < \left|\frac{\partial p_r^{II}(s)}{\partial \beta}\right| < \frac{\partial p_d^{II}(s)}{\partial \beta} \tag{27}$$

3.3 Comparative Analysis

In the dual channel model of manufacturer's online distribution and online consignment, the selection strategy of the dual channel model will be explored, and the impact of service level s on the wholesale prices of manufacturers and the sales prices of two retailers under each model will be compared.

Proposition 4: Given the service level of traditional retailers, when $G_1 \geq G_2$, $\pi_m^I \leq \pi_m^{II}$, the manufacturer will choose the online sales model; When $G_1 < G_2$, $\pi_m^I > \pi_m^{II}$manufacturers will choose online distribution mode. When $b1 = b2 = b$, the manufacturer will have to choose the online sales model. Among $G_1 = \frac{(b_1b_2+e^2)+(1-\beta)^2+4b_2e(1-\beta)+2b_2^2\beta^2}{8b_2(b_1b_2-e^2)}$, $G_2 = \frac{\beta b_2e+b_1(2b_2+e-\beta e))^2}{4(4b_1b_2-e^2)(2b_2b_1^2-b_2e^2+b_1(2b_2e-e^2))}$

Introduction 5 By comparing the two channel models of manufacturer's online distribution and online consignment, it can be seen that the service level of traditional retailers has an impact on the pricing strategies of traditional retail channels and online retail channels : $\frac{dw^i(s)}{ds} > 0, \frac{dp_r^i(s)}{ds} > 0, \frac{dp_d^i(s)}{ds} > 0, i = I, II.$

Due to the complexity of model analysis, the following text only analyzes the situation when the price sensitivity coefficient is the same.

Introduction 6 compares the impact of traditional retailer service level on wholesale and retail pricing strategies under two dual channel models, as follows:

$$0 < \beta < \frac{1}{2}, \frac{dw^I(s)}{ds} < \frac{dw^{II}(s)}{ds}, \frac{1}{2} < \beta < 1, \frac{dw^I(s)}{ds} \geq \frac{dw^{II}(s)}{ds} \tag{28}$$

$$0 < \beta \leq \frac{2b^3 - b^2e - be^2 - e^3}{4b^3 + be^2 - e^3}, \frac{dp_r^I(s)}{ds} < \frac{dp_r^{II}(s)}{ds}, \frac{2b^3 - b^2e - be^2 - e^3}{4b^3 + be^2 - e^3} < \beta < 1, \frac{dp_r^I(s)}{ds} \geq \frac{dp_r^{II}(s)}{ds} \tag{29}$$

$$\frac{dp_d^I(s)}{ds} > \frac{dp_d^{II}(s)}{ds}. \tag{30}$$

4 Data Simulation

This section explores the selection strategy of manufacturers' network chan-nel models through numerical simulation.The basic parameters are set as: a=400, e=0.4, b_1=0.6, b_2=0.5, c=0.1, λ= 0.1.

As shown in Fig 2, it can be seen that manufacturers in region A will choose to sell products through online distribution channels, while in region B, manufac-turers will choose consignment channels. Especially θ at lower levels, the distribution model is more advantageous for manufacturers and will not be affected by β The impact. When θ and β When the prices are high, the online sales model is more advantageous.

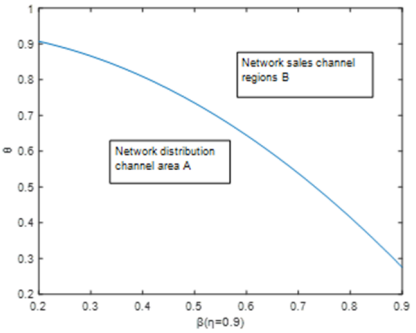

Fig. 2. The Impact of β and θ on Manufacturers' Channel Selection Strategies

5 Conclusion

This article considers two dual channel models and investigates the manu-facturer model selection and supply chain optimal pricing decisions under free riding behavior. The main conclusions are:

The channel selection strategy of manufacturers is related to the degree of free riding behavior, network preference, price sensitivity, etc. Manufacturers should choose the dual channel model of online distribution when consumers have a low preference for

online channels. At this time, free riding behavior will not affect the manufacturer's channel model selection decision. When consumers have a high preference for online channels and a high degree of free riding behavior, manufacturers should choose the dual channel model of online direct sales.

The higher the degree of consumer preference for online channels or free riding, the lower the optimal wholesale price for manufacturers and the lower the sales price for traditional retailers in both modes. Meanwhile, as the degree of free riding behavior increases, both online channel sales prices should be set lower. However, the degree of consumer preference for online channels has a different impact on the sales prices of online end channels under different modes. The greater the degree of consumer preference for online distribution channels, the lower the sales price should be set in the online distribution dual channel model, while in the online direct sales channel model, the higher the price should be set.

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