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Sales Mode Selection Strategic Analysis for Manufacturers on E-Commerce Platforms under Multi-Channel Competition

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Abstract: This paper considers a sales mode selection problem between resale and agency modes on e-commerce platforms for a manufacturer with traditional retail channel, direct selling channel, and e-commerce platform channel. By considering the factors price competition, market shares, and commission rate, we construct two leader-follower models with the manufacturer as a leader and traditional retailer and e-commerce platform as followers. To obtain optimal solutions, we discuss the conditions under which the upper and lower models are convex and then give optimal strategies for all members in the network. Through numerical experiments, we analyze the impact of price competition intensity, market shares, and commission rate on mode selection strategies and the changing trend of each member's optimal pricing and profit under different sales modes. The numerical results reveal the following revelations: If the market share of the traditional retail channel is lower than the direct selling channel, the manufacturer should choose the agency mode when the market share of the direct selling channel and price competition are lower or when the market share of the direct selling channel together with the price competition and the commission rate is higher; otherwise, the manufacturer should choose the resale mode. If the market share of the direct selling channel is lower than the traditional retail channel, the manufacturer should choose the agency mode when the price competition is weak and choose the resale mode when the price competition is strong. Under certain conditions, a win-win situation can be achieved no matter how the manufacturer chooses.

Keywords: multi-channel competition; e-commerce platform; sales mode selection; leader-follower game



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1. Introduction

With the rapid development of e-commerce, more and more consumers choose online shopping. Affected by some emergencies such as COVID-19, many enterprises encourage employees to work at home so that the online shopping demand is gradually increasing. According to the 50th Statistical Report on the Development of Internet in China released by the China Internet Network Information Center, the number of internet users in China reached 1.051 billion as of June 2022, with an internet penetration rate of 74.4%. While maintaining offline sales, many manufacturers actively expand various online sales channels, such as online direct sales and e-commerce platform sales, to attract consumers so as to form an online and offline multi-channel sales structure. For example, Haier wholesales its products offline to traditional retailers such as Gome and provides a direct selling website “Haier Smart Home” online by cooperating with e-commerce platforms such as Tmall.com and JD.com. In general, the sales modes of e-commerce platforms are divided into resale mode and agency mode [1]. Under the resale mode, e-commerce platforms purchase products from manufacturers and sell them to consumers through their own stores. For example, Panasonic, Yar, and Huawei sell products on JD.com [2], while Crocs sells footwear products through e-commerce platforms such as eBay. Under the agency mode, e-commerce platforms charge manufacturers commission rates and slotting fees to settle in the form of flagship stores and provide direct contact services with consumers.

Product prices are generally determined by manufacturers. In addition, manufacturers may choose multiple sales modes at the same time (e.g., Haier and Gree choose a mixed mode on Suning.com). Given the foregoing, it is necessary to investigate how manufacturers with online and offline multi-channel sales channels select the sales mode on the e-commerce platform. This study not only adds to the theories of multi-channel supply chain and e-commerce platform sales mode selection strategy, but it also provides manufacturers with guidance and suggestions for making the most advantageous selection strategy under various realistic environments.

To the best of our knowledge, the majority of existing research objects on sales mode selection strategy are e-commerce platforms operating within the dual-channel supply chain. Few studies consider multi-channel structure of traditional retail, direct selling, and e-commerce platform channels to explore sales mode selection strategy of manufacturers on e-commerce platforms. Therefore, in this paper, we take manufacturers with multiple online and offline sales channels as our research object and mainly focus on the following questions:

- (1) Under what conditions do manufacturers choose resale mode or agency mode?
- (2) What influence do manufacturers' sales mode selection strategies have on each member and the whole supply chain? Is it beneficial or harmful? Can we achieve a win-win supply chain?

To address the above problems, we establish leader–followers game models with the manufacturer as a leader and the traditional retailer and the e-commerce platform as followers under resale and agency modes, respectively. Furthermore, by comparing the profit differences of manufacturers under different sales modes, this paper analyzes the strategic conditions for the manufacturer choosing different sales modes. At the end, we investigate the impact of price competition intensity, market share, and commission rate on each member's optimal price and profits and further analyze the impact of conditions for manufacturers to choose different sales modes on the profit of supply chain members.

The main contributions of this paper can be summarized as follows: Firstly, current researches on channel pricing mainly focus on single-channel or dual-channel supply chains rather than multi-channel supply chains. In this paper, we consider a supply chain in which the manufacturer has multiple sales channels, including traditional retail, direct selling, and e-commerce platform sales. Secondly, most existing literature discusses the perspective of e-commerce platforms. In this paper, we study the game behaviors between traditional retailers and e-commerce platforms from the perspective of the manufacturer and establish leader–follower game models with the manufacturer as a leader and the others as followers. Through theoretical and numerical analysis, we obtain the following insights and conclusions: (1) For multi-channel supply chains, manufacturers' sales mode selection strategies are related to intensity of price competition, market share of each channel, and the commission rate. (2) Under certain conditions, only market share influences optimal prices in the same channel. (3) Under certain conditions, manufacturers can achieve a win-win situation with other members no matter what sales mode they choose. These findings may provide guidance for e-commerce platform sales mode selection strategy.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literatures. Section 3 introduces the framework and notations used later on. Section 4 builds leader–follower game models in resale and agency modes, respectively, and analyzes each member's optimal decisions. Section 5 introduces numerical experiments, which include the manufacturer's sales mode selection strategy, impact of each parameter on optimal price, and profit of supply chain members and impact of manufacturer's sales mode selection strategy on the whole supply chain. Section 6 includes some discussion and conclusions. The proofs of all propositions are given in the Appendix A.

2. Literature Review

This research is mainly related to supply chain management of channels and sales mode selection on e-commerce platforms.

2.1. Supply Chain Management of Channels

There has been a lot of research on supply chain management of channels, including channel pricing, channel selection, supply chain coordination, and so on. The closest issue to this paper is the channel pricing analysis. At present, the categories of single channel mainly include traditional retail, direct selling, online reselling, and agency selling. In addition, many scholars have conducted a lot of research on the dual-channel pricing strategy. For example, Chiang et al. [3] and Matsui [4] explored whether manufacturers should introduce online direct selling channels in addition to traditional retail. Yi et al. [5] and Wang et al. [6] discussed the selection of online direct selling and e-commerce platform agency selling for manufacturers when traditional retail channels are opened. For manufacturers, traditional retailers, online retailers and e-commerce platforms, Pu et al. [7] presented respectively the pricing decisions of manufacturers in three cases of direct selling, reselling and agency selling based on traditional retail channels and analyzed the impact of operating costs, commission rates and slotting fees on the equilibrium results. In a supply chain system of manufacturers, retailers, and platforms, Wang et al. [8] studied the selection of e-commerce platform agency mode and self-built website direct sales mode of retailers under Bertrand competition and Cournot competition, respectively. In addition, there is a small amount of research on multi-channel pricing. For example, Ma et al. [9] considered four channel structures in which manufacturers open direct selling channels and wholesale products to retailers and online retailers, where the retailers have a traditional channel and an online channel. They investigated the effects of price discount sensitivity and uncertain demand on channel pricing decisions.

As can be seen from Table 1, most research on channel pricing decisions mainly focuses on dual channels and less on multi-channels. Different from the existing works, the supply chain members considered here include manufacturers, traditional retailers, and e-commerce platforms, while the multi-channels consist of traditional retail channels, direct selling channels, and e-commerce platform channels (including resale and agency modes).

Table 1. Overview of pricing research on the supply chain management of channels.

Reference	Channel Structure	Research Focus	Type of Channel				
			Traditional Retail	Direct Selling	Reselling	Resale	Agency
[3,4]	Dual	Impact of manufacturer intrusion	✓	✓			
[5,6]	Dual	Selection of online channels	✓	✓			✓
[7]	Dual	Selection of online channels	✓	✓	✓		✓
[8]	Dual	Selection of online channels	✓	✓			✓
[9]	Multi	Bullwhip effect in a multi-channel supply chain	✓	✓	✓		
Our study	Multi	Sales mode selection of e-commerce platform	✓	✓		✓	✓

“Dual” indicates dual-channel, “Multi” indicates multi-channel, and “✓” indicates its presence.

2.2. Sales Mode Selection on E-Commerce Platforms

Our research is mainly related to sales mode selection on e-commerce platforms. Firstly, some scholars have studied whether agency mode of e-commerce platform should be introduced on the basis of resale mode. In particular, Ryan et al. [10] considered whether retailers would introduce the agency mode on e-commerce platforms and expand the consumer market on the premise of direct selling through their own websites. Mantin et al. [11] studied whether agency mode should be introduced into third-party sellers and found that manufacturers are more inclined to prevent the introduction of 3P market. Yan et al. [12] considered the impact of sales efficiency and demand information and provided conditions under which manufacturers, e-commerce platforms, and consumers can achieve a win-win situation. Ha et al. [13] studied interactions between whether manufacturers introduce the agency mode and the information sharing strategy of e-commerce platforms.

Secondly, with the intensification of competition environment, horizontal competition cannot be ignored in sales mode selection. It mainly includes platform competition [14–18] and manufacturer competition [19–24]. In terms of platform competition, Abhishek et al. [14] analyzed the influence of network spillover effect on selection strategy of sales mode from the perspective of e-commerce platform. Zhu and Yao [15] provided optimal pricing decisions for e-books and found that publishers prefer resale mode rather than agency mode by comparing profits. Li et al. [16] investigated the impact of platform performance investment and commission rate. Wei et al. [18] considered the influence of channel role, referral fees and market share of e-commerce platforms and found that the best action for manufacturers is to allow e-commerce platforms to adopt agency mode without the influence of parameters. In terms of manufacturer competition, Kward et al. [19] explored the influence of third-party online reviews on sales mode selection and found that improved accuracy of quality information and appropriate information are beneficial to the resale mode and the agency mode, respectively. Wei et al. [22] analyzed the influence of product substitution rates and different power structures, and found that the optimal selection strategy is resale mode. Based on the competition between major suppliers with large potential demand and small suppliers with small potential demand, Zenny [23] found that manufacturers choose agency mode when the product substitution rate and commission rate are both low. Zhong et al. [24] constructed leader–follower game models with e-commerce platforms as leaders and manufacturers as followers, and compared the strategic results before and after the introduction of incumbent manufacturer. In addition, some scholars have studied both platform competition and manufacturer competition. For example, Li and Ai [25] considered the formation of cross-sales between two competing manufacturers and two competing e-commerce platforms and analyzed the selection among resale mode, agency mode, and hybrid mode of e-commerce platforms.

Thirdly, some scholars have studied the influence of product substitution [26,27], information asymmetry [1,27–29], data-driven marketing [30], power structure [31], and other factors [32–34] on sales mode selection strategy. In particular, Jerath and Zhang [26] found that, when the price competition intensity is strong (weak), the e-commerce platform should choose resale (agency) mode, and when the intensity of price competition is moderate, it is more inclined to choose hybrid mode. Jiang et al. [27] studied how product demand characteristics affect sales mode selection strategy of e-commerce platforms under uncertain demand levels. Liu et al. [30] studied the impact of market size and data-driven marketing. Shi et al. [31] studied how product matching probability, profit sharing ratio, and travel cost of physical stores affect sales mode selection strategy of online retailers under three different power structures of physical stores and online retailers. Qin et al. [32] considered the interaction between e-commerce platform sales mode and logistics service strategy. Chen et al. [33] found that the manufacturers' choice of agency mode under certain conditions can achieve a win–win situation for supply chain members. Ha et al. [34] studied the selection among resale, agency and hybrid modes of e-commerce platforms by manufacturers under the influence of sales effort on demand.

Finally, some scholars have studied the sales mode selection strategy of e-commerce platform on the basis of traditional retail channels. For example, Tan and Carrillo [35] analyzed the influence of vertically differentiated products on manufacturers' choice of resale, agency, and fixed price modes and found that agency mode is better. Dennis et al. [36] considered the influence of different supply chain power structures and showed that resale mode under retailer dominance is beneficial to manufacturers. By exploring interaction between bundling sales of upstream manufacturers and sales mode selection of downstream e-commerce platforms, Geng et al. [37] showed that high commission rate is not necessarily beneficial to e-commerce platforms. Shen et al. [38] analyzed interactions between channel selection of manufacturers and sales mode selection on e-commerce platform. Zhang and Zhang [39] discussed the influence of offline entry cost, channel substitution rate, and information uncertainty on sales mode selection. Chen et al. [40] found that downstream competing e-commerce platforms prefer to choose resale mode

when the inventory levels are moderate. Lu et al. [41] studied the choice of resale and agency mode of publishers in e-bookstores and found that choosing agency mode under decentralized decisions is beneficial to publishers and e-bookstores.

The simple comparative analysis results of the literature related to our research are shown in Table 2. Recently, with the introduction of various technologies and policies, many scholars have studied their influence on the selection strategy of sales modes [42–49]. Alaei et al. [42] considered manufacturers' online store channels to provide return policies. Guo et al. [43] discussed the strategic interaction between the selection of the sales mode and the blockchain anti-counterfeit traceability service. Hao and Yang [44] and Wang et al. [45] considered the impact of livestreaming sales. In addition, Zhang et al. [48] and Chen et al. [49] focused on the impact of consumer behavior (e.g., consumer loss aversion and fairness concerns). However, these studies, like those in Table 2, had fewer sales channels that were inconsistent with this paper and focused on single or dual channels. In particular, the sales channels and research objects in literature [7] are similar to those of this paper, but they focus on the selection of online distribution channels for manufacturers under dual channels. In addition, although all the above studies have considered various factors, they have not considered the different distribution proportions of the market shares of the three channels. Most importantly, our results show that both the resale mode and the agency mode can achieve equilibrium, which is different from the traditional theoretical view.

Table 2. Overview of the most relevant research on the selection of sales mode on e-commerce platforms.

Reference	Channel Structure	Research Focus (Problem)	Leader	Type of Channel			
				T	D	R	A
[14]	Dual	When should an e-tailer use agency selling	Manufacturer			✓	✓
[18]	Dual	How to choose online sales formats for competitive e-tailers	Manufacturer			✓	✓
[20]	Dual	Online retailer's pricing model choice	Manufacturers			✓	✓
[22]	Dual	How do manufacturers choose the best sales formats	E-tailer			✓	✓
[33]	Dual	Manufacturer's online sales mode selection	Manufacturer	✓		✓	✓
[36]	Dual	Manufacturer's online sales mode selection	Manufacturer	✓		✓	✓
[37]	Single	Manufacturer's additional pricing and distribution strategy	Platform			✓	✓
[38]	Dual	The interaction between sales mode and channel choice	Dominant retailer	✓		✓	✓
[39]	Dual	Strategic interaction between e-tailer's information sharing and supplier's offline entry	E-tailer	✓		✓	✓
Our study	Multi	Manufacturer's selection of sales mode under multi-channel	Manufacturer	✓	✓	✓	✓

"Dual" indicates dual-channel, "Single" indicates single-channel, "Multi" indicates multi-channel, "T" indicates traditional retail channel, "D" indicates direct selling channel, "R" indicates resale mode, "A" indicates agency mode, and "✓" indicates its presence.

With the rapid development of retail diversification, it is necessary to manufacturers to adopt a multi-channel sales structure and it has become common to regard e-commerce platforms as distributors. In what follows, we focus on sales mode selection of e-commerce platforms under a multi-channel structure. We suppose that the manufacturer has multiple sales channels, such as traditional retail channels, direct selling channels, and e-commerce platform channels. In addition, we discuss under what conditions the manufacturer chooses resale mode and agency mode of e-commerce platforms, respectively, and analyze the influence of its sales mode selection strategy on each member.

3. Problem Formulation

Consider a multi-channel supply chain system composed of a single manufacturer, a single traditional retailer, and a single e-commerce platform. We mainly discuss sales mode selection of the manufacturer under resale and agency modes in traditional retail channels, direct selling channels, and e-commerce platform channels. The notations related to this problem are described in Table 3.

Table 3. Notations.

Notation	Description
Set	
I	Set of sales modes $i \in I = \{R, A\}$: R represents resale mode; A represents agency mode
J	Set of channels $j \in J = \{T, D, E\}$: T represents traditional retail channel; D represents direct selling channel; E represents e-commerce platform channel
Parameter	
α	Market share of traditional retail channel, $\alpha \in [0, 1]$
β	Market share of direct selling channel, $\beta \in [0, 1 - \alpha]$
$\delta_j = \delta$	Intensity of price competition, $\delta \in [0, 1]$
d	Potential market demand
λ	Commission rate in agency mode, $\lambda \in [0, 0.3]$
k	Slotting fee in agency mode
Decision variable	
w_i	Wholesale price in sales mode i
p_{iT}	Retail price of traditional retail channel in sales mode i
p_{RD}	Retail price of direct selling channel in resale mode
p_{RE}	Retail price of e-commerce platform channel in resale mode
$p_R = (p_{RT}, p_{RD}, p_{RE})$	Price vector in resale mode
p_A	Retail price of direct selling channel and e-commerce platform channel in agency mode
Dependent variable	
D_{ij}	Demand function of channel j in sales mode i
$\pi_{iM}, \pi_{iT}, \pi_{iE}$	Profit of manufacturer, retailer and e-commerce platform in sales mode i

In resale mode, the manufacturer wholesales products to the traditional retailer and e-commerce platform at a price w_R . The traditional retailer and e-commerce platform sell products to consumers at prices p_{RT} and p_{RE} , respectively. In the direct selling channel, the manufacturer sells products to consumers at a price p_{RD} through direct selling websites. The structure diagram of resale mode is shown in Figure 1a.

In agency mode, the manufacturer pays slotting fee k to the e-commerce platform and sells products to consumers at price p_A , while the e-commerce platform collects part of sales from the manufacturer at commission rate λ . Suppose that the slotting fee and the commission rate are exogenous variables and the commission rate generally does not exceed 30%. In traditional retail channel, the manufacturer gives wholesale price w_A to the traditional retailer, while the traditional retailer sells products to consumers at price p_{AT} . In the direct selling channel, the manufacturer sells products to consumers through direct selling websites at the same price p_A . The structure diagram of agency mode is shown in Figure 1b.

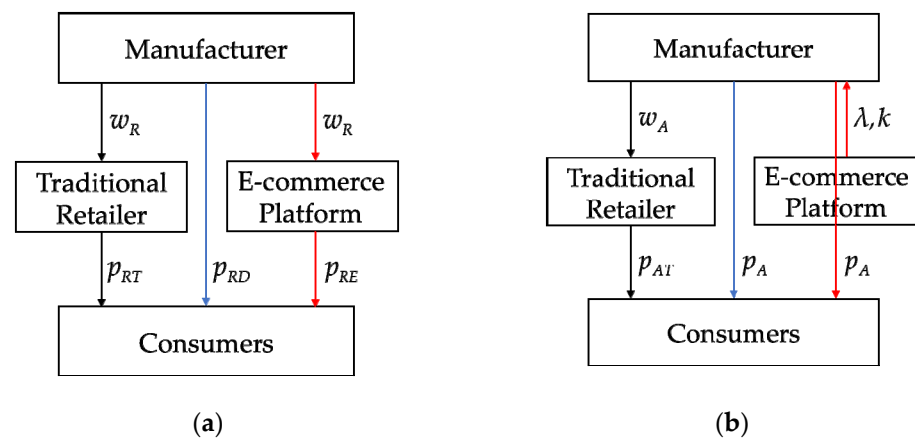


Figure 1. Supply chain structures. (a) Resale mode. (b) Agency mode.

Referring to the linear demand function expressions in Kurata et al. [50] and Dan et al. [51], we set the demand functions for three channels as follows: When the manufacturer chooses resale mode, the demand functions are

$$D_{RT} = \alpha d - p_{RT} + \delta_D p_{RD} + \delta_E p_{RE} \quad (1)$$

$$D_{RD} = \beta d - p_{RD} + \delta_T p_{RT} + \delta_E p_{RE} \quad (2)$$

$$D_{RE} = (1 - \alpha - \beta) d - p_{RE} + \delta_T p_{RT} + \delta_D p_{RD} \quad (3)$$

When the manufacturer chooses agency mode, the demand functions are

$$D_{AT} = \alpha d - p_{AT} + \delta_D p_A + \delta_E p_A \quad (4)$$

$$D_{AD} = \beta d - p_A + \delta_T p_{AT} + \delta_E p_A \quad (5)$$

$$D_{AE} = (1 - \alpha - \beta) d - p_A + \delta_T p_{AT} + \delta_D p_A \quad (6)$$

Here, d represents a potential market demand, α represents the market share of traditional retail channel, β represents the market share of direct selling channel, $1 - \alpha - \beta$ represents the market share of e-commerce platform channel, and $\delta_j \in [0, 1]$ represents the intensity of price competition (the larger the value of δ_j is, the more intense the competition among channels is).

4. The Models

For simplicity, we assume that the marginal cost of production of manufacturer is zero [21,52] and the price competition intensities of all channels are equal to δ , namely, $\delta_j = \delta$, where $j \in J = \{T, D, E\}$. We mainly analyze the manufacturer's sales mode selection strategy; that is, we construct models from the manufacturer's point of view.

4.1. The Resale Mode

In resale mode, we consider the manufacturer as a leader and the traditional retailer and e-commerce platform as followers. The manufacturer determines its wholesale price w_R to the traditional retailer and e-commerce platform and its retail price p_{RD} in the direct selling channel. The traditional retailer determines its retail price p_{RT} in the traditional retail channel. The e-commerce platform determines its retail price p_{RE} in the e-commerce platform channel.

Both followers aim to maximize their own profits, that is,

$$\max_{p_{RT} \geq w_R} \pi_{RT}(p_{RT}) = (p_{RT} - w_R) D_{RT} \quad (7)$$

$$\max_{p_{RE} \geq w_R} \pi_{RE}(p_{RE}) = (p_{RE} - w_R)D_{RE} \quad (8)$$

It is easy to see that the above two models are convex optimization problems with respect to their own decision variables p_{RT} and p_{RE} . Then, by direct calculations, when $(2 + \delta)((1 - \delta)w_R - \delta p_{RD}) \leq \min\{2\alpha + \delta(1 - \alpha - \beta), 2(1 - \alpha - \beta) + \alpha\delta\}d$, we can obtain the optimal prices of the traditional retailer and e-commerce platform as follows:

$$p_{RT}^*(w_R, p_{RD}) = \frac{2\alpha d + \delta(1 - \alpha - \beta)d}{4 - \delta^2} + \frac{1}{2 - \delta}w_R + \frac{\delta}{2 - \delta}p_{RD} \quad (9)$$

$$p_{RE}^*(w_R, p_{RD}) = \frac{2(1 - \alpha - \beta)d + \alpha\delta d}{4 - \delta^2} + \frac{1}{2 - \delta}w_R + \frac{\delta}{2 - \delta}p_{RD} \quad (10)$$

The profit function of the manufacturer is

$$\pi_{RM} = w_R D_{RT} + p_{RD} D_{RD} + w_R D_{RE} \quad (11)$$

Therefore, by maximizing the profit function, the manufacturer's model (I) is

$$\begin{aligned} \max_{w_R, p_{RD}} \quad & \pi_{RM} = \frac{1}{2 - \delta}(w_R((1 - \beta)d + 2\delta p_{RD} + 2(\delta - 1)w_R) \\ & + p_{RD}((2(1 - \delta)\beta + \delta(d + 2\delta^2 + \delta - 2)p_{RD} + 2\delta w_R)) \\ \text{s.t.} \quad & p_{RD} \geq 0, w_R \geq 0, \\ & (2 + \delta)((1 - \delta)w_R - \delta p_{RD}) \leq \min\{2\alpha + \delta(1 - \alpha - \beta), 2(1 - \alpha - \beta) + \alpha\delta\}d. \end{aligned} \quad (12)$$

We can derive the following equilibrium results for model (I).

Proposition 1. In resale mode, when $\delta \in [0, 0.5)$, $\alpha \in [0, \alpha_1)$, $\beta \in [\beta_1, \beta_2]$ or $\delta \in [0, 0.5)$, $\alpha \in [\alpha_1, 1]$, $\beta \in [0, \beta_2]$, model (I) is a convex optimization problem with respect to (w_R, p_{RD}) , and the optimal decisions of the manufacturer, the traditional retailer, and the e-commerce platform are

$$w_R^* = \frac{1 - \beta + 2\beta\delta}{4(1 - \delta - 2\delta^2)}d \quad (13)$$

$$p_{RD}^* = \frac{\beta + \delta - 2\beta\delta}{2(1 - \delta - 2\delta^2)}d \quad (14)$$

$$p_{RT}^* = \frac{2 + 8\alpha - 2\beta + 5\delta - 12\alpha\delta + 3\beta\delta - 12\alpha\delta^2 - 6\delta^3 + 8\alpha\delta^3 + 4\beta\delta^3}{4(4 - \delta^2)(1 - \delta - 2\delta^2)}d \quad (15)$$

$$p_{RE}^* = \frac{10 - 8\alpha - 10\beta - 7\delta + 12\alpha\delta + 15\beta\delta - 12\delta^2 + 12\alpha\delta^2 + 12\beta\delta^2 + 2\delta^3 - 8\alpha\delta^3 - 4\beta\delta^3}{4(4 - \delta^2)(1 - \delta - 2\delta^2)}d \quad (16)$$

$$\text{where } \alpha_1 = \frac{2 - 3\delta}{4(2 - \delta)}, \beta_1 = 1 - \frac{4\alpha(2 - \delta)}{2 - 3\delta}, \beta_2 = 1 - \frac{4\alpha(2 - \delta)}{6 - \delta}.$$

See the Appendix A for a proof of the above proposition. Proposition 1 shows that, when the intensity of price competition is low and the market shares of traditional retail channel and direct channel are different, the manufacturer has an optimal solution in resale mode. It can be seen intuitively that the optimal wholesale price and product price determined by the manufacturer have nothing to do with the market share of the traditional retail channel. It can be further inferred that the optimal profit of the manufacturer in resale mode is also unrelated to them. In addition, the above optimal prices are all related to the intensity of price competition, which indicates that the intensity of price competition may have an important impact on each member's price and profit.

It is not difficult to obtain the following result.

Proposition 2. In resale mode, the sensitivity analysis results for the optimal decisions are as follows:

- (1) $\frac{\partial w_R^*}{\partial \beta} < 0$, $\frac{\partial p_{RD}^*}{\partial \beta} > 0$, $\frac{\partial p_{RT}^*}{\partial \beta} < 0$, $\frac{\partial p_{RE}^*}{\partial \beta} < 0$;
- (2) $\frac{\partial w_R^*}{\partial \delta} > 0$, $\frac{\partial p_{RD}^*}{\partial \delta} > 0$, $\frac{\partial p_{RT}^*}{\partial \delta} > 0$, $\frac{\partial p_{RE}^*}{\partial \delta} > 0$;
- (3) $\frac{\partial w_R^*}{\partial \alpha} = 0$, $\frac{\partial p_{RD}^*}{\partial \alpha} = 0$, $\frac{\partial p_{RT}^*}{\partial \alpha} > 0$, $\frac{\partial p_{RE}^*}{\partial \alpha} < 0$.

Proposition 2 shows that, as the market share of direct selling channel increases, the direct selling channel price of the manufacturer should be set higher, while the wholesale price of the manufacturer and the product prices of the traditional retailer and e-commerce platform should be set lower; the increase in price competition is beneficial to all members to raise prices, which is consistent with the reality. The manufacturer's prices are not influenced by the market share of traditional retail channels. Moreover, as the market share of traditional retail channel increases, the traditional retailer should take advantage of the market share of the traditional retail channel to set higher product prices, while the e-commerce platform should set lower product prices.

4.2. The Agency Mode

In agency mode, we treat the manufacturer as a leader and the traditional retailer as a follower. It should be noted that, since the slotting fee k and the commission rate λ are exogenous variables [38], the e-commerce platform does not participate in decision-making so that it is not a player and its profit function is $\pi_{AE} = \lambda p_A D_{AE} + k$. The manufacturer determines its wholesale price w_A to the traditional retailer and its retail price p_A in both the direct selling channel and e-commerce platform channel. The traditional retailer determines its retail price p_{AT} in the traditional retail channel.

The lower-level model is to maximize the traditional retailer's profit function, that is,

$$\max_{p_{AT} \geq w_A} \pi_{AT}(p_{AT}) = (p_{AT} - w_A)D_{AT} \quad (17)$$

This model is a convex optimization problem with respect to p_{AT} . Then, by direct calculations, when $w_A \leq \alpha d + 2\delta p_A$, we can obtain the traditional retailer's optimal price

$$p_{AT}^*(w_A, p_A) = \frac{\alpha d}{2} + \frac{1}{2}w_A + \delta p_A \quad (18)$$

Similarly, we can express the manufacturer's profit function as

$$\pi_{AM} = w_A D_{AT} + p_A D_{AD} + (1 - \lambda)p_A D_{AE} - k \quad (19)$$

Therefore, the manufacturer's model (II) is

$$\begin{aligned} \max_{w_A, p_A} \pi_{AM} &= \frac{1}{2}(w_A(\alpha d + 2\delta p_A - w_A) + p_A(2\beta\lambda d + 2(1 - \lambda)(1 - \alpha)d \\ &\quad + (2 - \lambda)(\alpha d\delta + 2(\delta^2 + \delta - 1)p_A + \delta w_A))) - k \\ \text{s.t. } 0 &\leq w_A \leq \alpha d + 2\delta p_A, p_A \geq 0. \end{aligned} \quad (20)$$

We can derive the following equilibrium results for model (II).

Proposition 3. In agency mode, when $\delta \in [0, 0.5)$, $\lambda \in [0, 0.3]$, $\alpha \in [0, 1]$, $\beta \in [0, 1 - \alpha]$, model (II) is a convex optimization problem with respect to (w_A, p_A) , and the optimal decisions of the manufacturer and the traditional retailer are

$$w_A^* = \frac{8\alpha + 8\delta - 16\alpha\delta + \lambda(-4\alpha - 10\delta + 14\alpha\delta + 8\beta\delta - 2\alpha\delta^2) + \lambda^2(2\delta - 2\alpha\delta - 2\beta\delta + \alpha\delta^2)}{16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2}d \quad (21)$$

$$p_A^* = \frac{4 - 4\alpha + 8\alpha\delta + \lambda(-4 + 4\alpha + 4\beta - 3\alpha\delta)}{16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2}d \quad (22)$$

$$p_{AT}^* = \frac{12\alpha + 8\delta - 20\alpha\delta - 8\alpha\delta^2 + \lambda(-6\alpha - 9\delta + 15\alpha\delta + 8\beta\delta + 4\alpha\delta^2) + \lambda^2\delta(1 - \alpha - \beta)}{16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2}d \quad (23)$$

See the Appendix A for a proof of the above proposition. Proposition 3 shows that, when the intensity of price competition is low, the manufacturer has an optimal solution in agency mode. In addition, different from resale mode, the optimal price of each member in the agency mode is related to the market share of traditional retail channel. Similarly to resale mode, optimal prices are related to the intensity of price competition. It is not difficult to obtain the following result.

Proposition 4. *In agency mode, the sensitivity analysis results of the optimal decisions are*

$$\frac{\partial w_A^*}{\partial \beta} > 0, \frac{\partial p_A^*}{\partial \beta} > 0, \frac{\partial p_{AT}^*}{\partial \beta} > 0; \frac{\partial w_A^*}{\partial \delta} > 0, \frac{\partial p_A^*}{\partial \delta} > 0, \frac{\partial p_{AT}^*}{\partial \delta} > 0; \frac{\partial w_A^*}{\partial \alpha} > 0, \frac{\partial p_A^*}{\partial \alpha} > 0, \frac{\partial p_{AT}^*}{\partial \alpha} > 0.$$

Proposition 4 shows that, as the market share of direct selling channel increases, the wholesale price and the retail prices in both the direct selling channel and e-commerce platform channel should be set higher and the traditional retailer should also set higher retail prices; the increase in price competition intensity is beneficial to all members to raise prices. Moreover, as the market share of traditional retail channel increases, both wholesale price of the manufacturer and retail price of the traditional retailer should be set higher.

5. Numerical Analysis

In this section, we mainly discuss which sales mode is better for the manufacturer and how the manufacturer's sales mode selection, together with optimal pricing and profit, influence each member under different modes. We try to find some relevant management implications from numerical analysis.

In our experiments, we set the potential market demand $d = 200$ and the slotting fee $k = 0$. In order to ensure the nonnegativity of demand in each channel, we set the intensity of price competition $\delta \in [0, 0.485]$, the market share of traditional retail channel $\alpha \in [0.15, 0.65]$, the market share of direct selling channel $\beta \in [0, 0.85]$, and the commission rate $\lambda \in [0, 0.3]$. Note that, in resale mode, the optimal profit functions of the members are, respectively,

$$\pi_{RM}^* = \frac{1 + 2\delta^2 - 2\beta(1 - 2\delta)^2 + \beta^2(5 - 14\delta + 8\delta^2)}{8(\delta - 2)(-1 + \delta + 2\delta^2)}d^2 \quad (24)$$

$$\pi_{RT}^* = \frac{(2 - 8\alpha - 2\beta - 3\delta + 4\alpha\delta + 3\beta\delta)^2}{16(\delta^2 - 4)^2}d^2 \quad (25)$$

$$\pi_{RE}^* = \frac{(6 - 8\alpha - 6\beta - \delta + 4\alpha\delta + \beta\delta)^2}{16(\delta^2 - 4)^2}d^2 \quad (26)$$

In agency mode, the optimal profit functions become

$$\pi_{AM}^* = \frac{2\lambda^2\beta^2 + (4\lambda - 4\alpha\lambda + 8\alpha\delta\lambda - 4\lambda^2 + 4\alpha\lambda^2 - 3\alpha\delta\lambda^2)\beta + N_1}{16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2}d^2 - k \quad (27)$$

$$\pi_{AT}^* = \frac{(-4\alpha + 4\alpha\delta + 8\alpha\delta^2 + 2\alpha\lambda - \delta\lambda - \alpha\delta\lambda - 6\alpha\delta^2\lambda + \delta\lambda^2 - \alpha\delta\lambda^2 - \beta\delta\lambda^2 + \alpha\delta^2\lambda^2)^2}{(16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2)^2}d^2 \quad (28)$$

$$\pi_{AE}^* = \frac{4 - 4\alpha + 8\alpha\delta - 4\lambda + 4\alpha\lambda + 4\beta\lambda - 3\alpha\delta\lambda}{(16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2)^2}\lambda N_2 d^2 + k \quad (29)$$

where

$$N_1 = 2 - 4\alpha + 4\alpha^2 + \alpha\delta(8 - 10\alpha + 4\alpha\delta) + \lambda(-4 + 8\alpha - 5\alpha^2 + \alpha\delta(-11 + 12\alpha - 4\alpha\delta)) + \lambda^2(2 - 4\alpha + 2\alpha^2 + \alpha\delta(3 - 3\alpha + \alpha\delta)) \quad (30)$$

$$N_2 = 12 - 12\alpha - 12\delta + 16\alpha\delta - 24\delta^2 + 20\alpha\delta^2 - 8\alpha\delta^3 + (-4 + 4\alpha + 4\delta - 7\alpha\delta + 7\delta^2 - 4\alpha\delta^2 + 4\alpha\delta^3)\lambda + \beta(-16 + 16\delta + 32\delta^2 + 4\lambda - 4\delta\lambda - 8\delta^2\lambda) \quad (31)$$

5.1. Manufacturer's Sales Mode Selection Analysis

This subsection analyzes the influence of each parameter on the manufacturer's sales mode selection by comparing the manufacturer's profit difference between resale and agency modes. Since the optimal profits of the manufacturer in resale mode and agency mode are related to parameters δ and β , we mainly analyze how δ and β affect the manufacturer's sales mode selection by changing their values. Since the commission rate generally does not exceed 30%, we consider three cases: low commission rate with $\lambda = 0.1$, moderate commission rate with $\lambda = 0.2$, and high commission rate with $\lambda = 0.3$.

5.1.1. Low Commission Rate ($\lambda = 0.1$)

By choosing different values of the market share of traditional retail channel α , we can observe the influence of δ and β on the manufacturer's sales mode selection, as shown in Figure 2, where the blue region indicates that it is better for the manufacturer to choose resale mode and the green slash region indicates that it is better for the manufacturer to choose agency mode.

It can be seen that, when $\alpha \in [0.15, 0.35]$ and $\delta \in [0, 0.45]$, the manufacturer chooses agency mode if the market share of the direct selling channel is low and chooses resale mode if the market share of the direct selling channel is high. When $\alpha \in [0.45, 0.65]$ and $\delta \in [0, 0.45]$, the manufacturer should always choose agency mode, regardless of the market share of the direct selling channel. When $\alpha \in [0.15, 0.65]$ and $\delta \in [0.45, 0.485]$, the manufacturer should always choose resale mode.

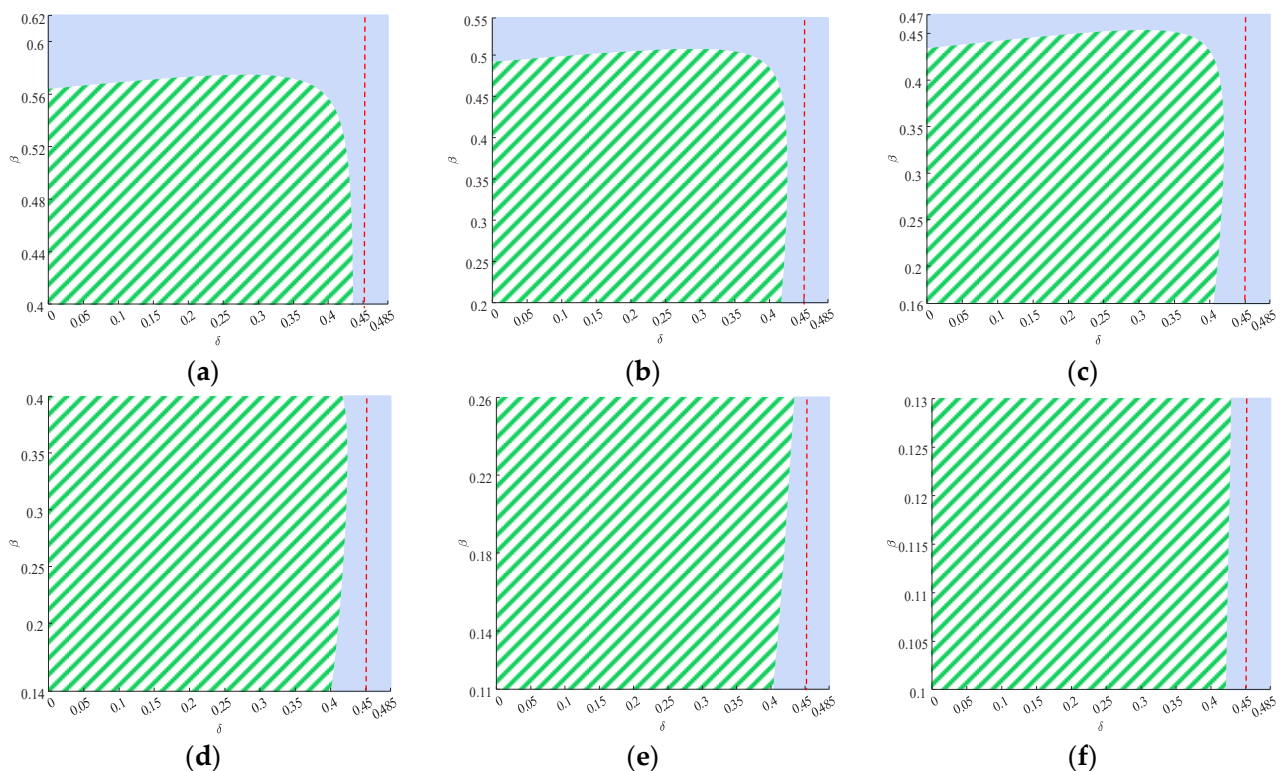


Figure 2. Manufacturer's sales mode selection for (a) $\alpha = 0.15$, (b) $\alpha = 0.25$, (c) $\alpha = 0.35$, (d) $\alpha = 0.45$, (e) $\alpha = 0.55$, and (f) $\alpha = 0.65$ under $\lambda = 0.1$.

5.1.2. Moderate Commission Rate ($\lambda = 0.2$)

The numerical results for this case are shown in Figure 3. It can be seen that, when $\alpha \in [0.15, 0.35]$ and $\delta \in [0, 0.4]$, the manufacturer chooses agency mode if the market share of the direct selling channel is low and chooses resale mode if the market share of the direct selling channel is high. When $\alpha \in [0.45, 0.65]$ and $\delta \in [0, 0.4]$, the manufacturer should always choose agency mode. When $\alpha \in [0.15, 0.65]$ and $\delta \in [0.4, 0.485]$, the manufacturer should always choose resale mode.

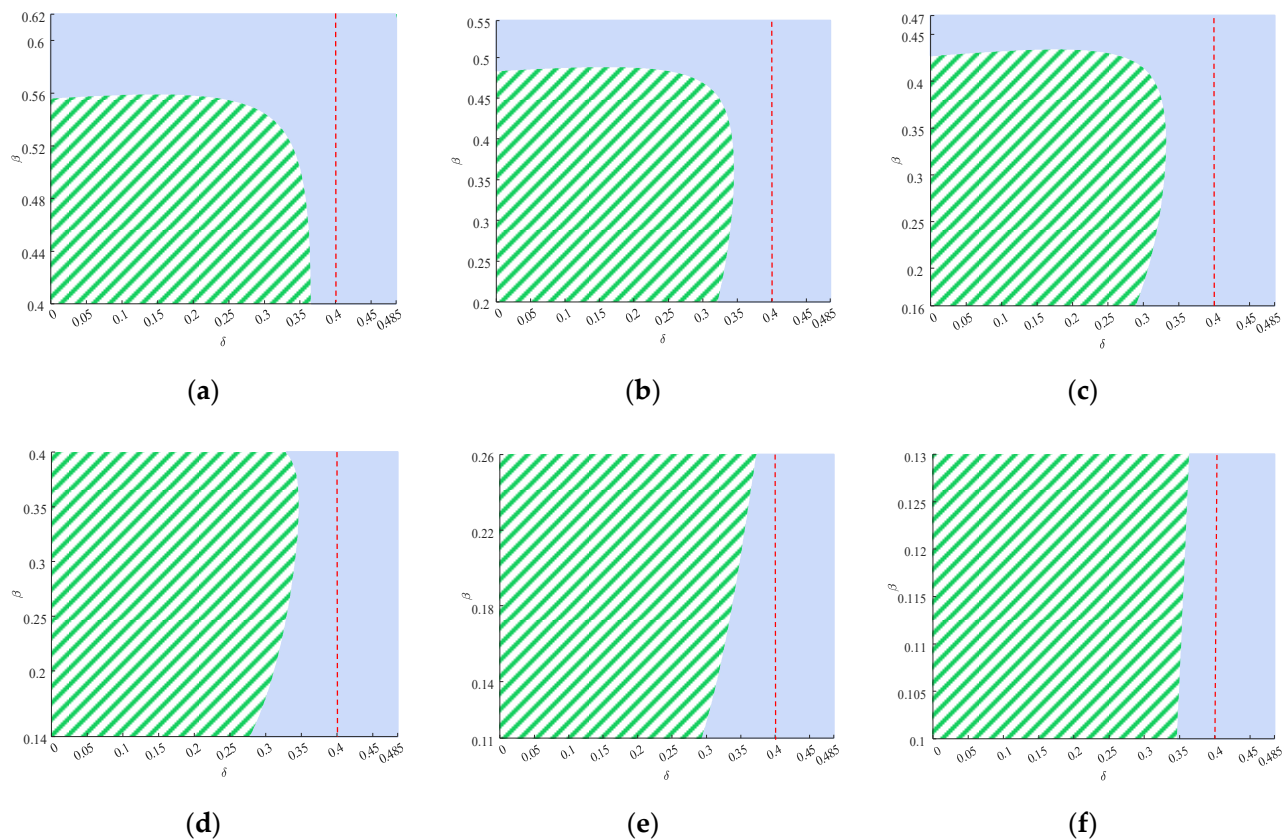


Figure 3. Manufacturer's sales mode selection for (a) $\alpha = 0.15$, (b) $\alpha = 0.25$, (c) $\alpha = 0.35$, (d) $\alpha = 0.45$, (e) $\alpha = 0.55$, and (f) $\alpha = 0.65$ under $\lambda = 0.2$.

5.1.3. High Commission Rate ($\lambda = 0.3$)

The experimental results are shown in Figure 4. The results reveal that, when $\alpha \in [0.15, 0.35]$ and $\delta \in [0, 0.35]$, the manufacturer chooses agency mode if the market share of the direct selling channel is low and chooses resale mode if the market share of the direct selling channel is high. When $\alpha \in [0.15, 0.25]$ and $\delta \in [0.45, 0.485]$, the manufacturer chooses resale mode if the market share of the direct selling channel is low and chooses agency mode if the market share of the direct selling channel is high. When $\alpha \in [0.45, 0.65]$ and $\delta \in [0, 0.35]$, the manufacturer should always choose agency mode. When $\alpha \in [0.35, 0.65]$, $\delta \in [0.35, 0.485]$ or $\alpha \in [0.15, 0.25]$, $\delta \in [0.35, 0.45]$, the manufacturer should always choose resale mode.

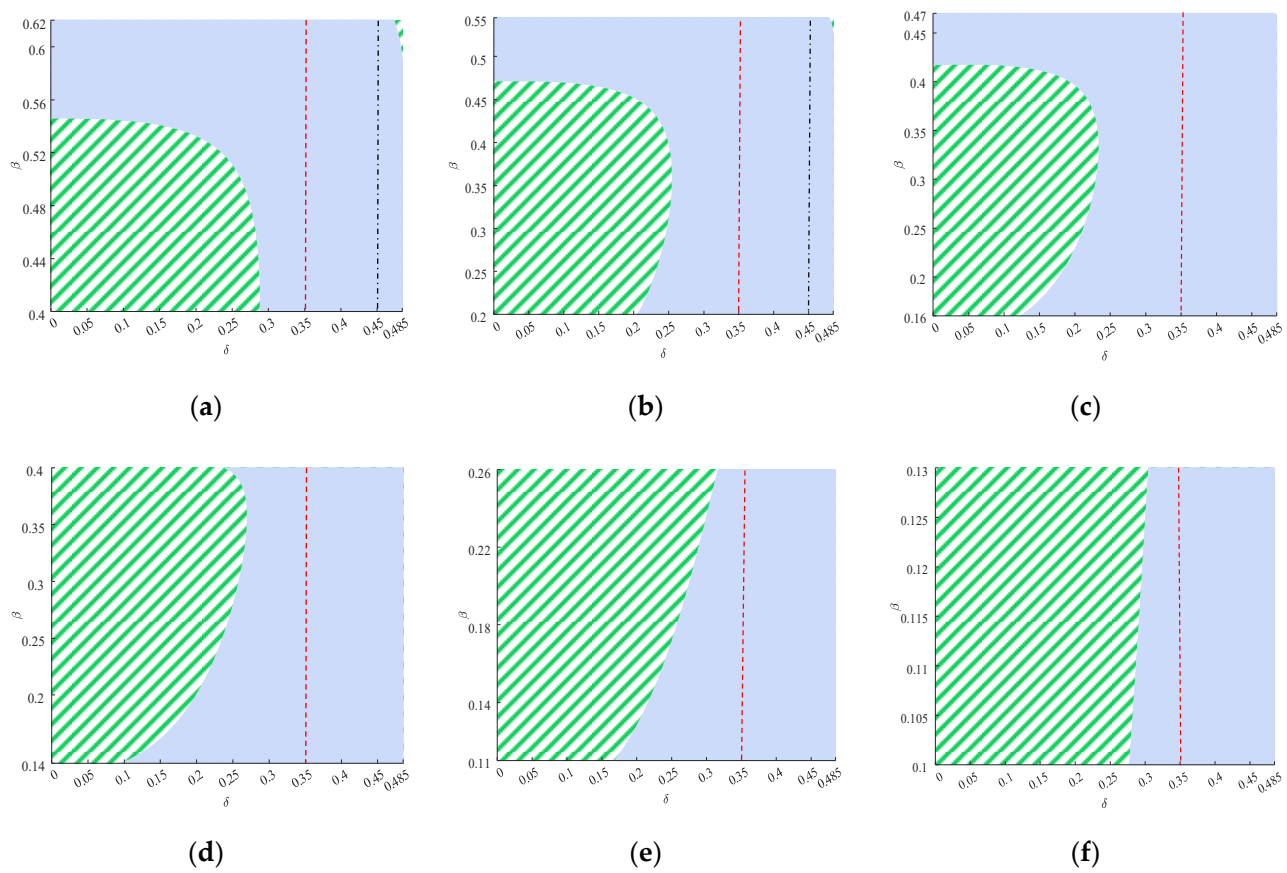


Figure 4. Manufacturer's sales mode selection for (a) $\alpha = 0.15$, (b) $\alpha = 0.25$, (c) $\alpha = 0.35$, (d) $\alpha = 0.45$, (e) $\alpha = 0.55$, and (f) $\alpha = 0.65$ under $\lambda = 0.3$.

In summary, when the intensity of price competition is strong, if the commission rate is low or moderate, the manufacturer chooses resale mode, but its sales mode selection has nothing to do with the market share; if the commission rate is high and the market share of traditional retail channel is low, the manufacturer chooses agency mode when the market share of the direct selling channel is high, otherwise it should choose resale mode. If both commission rate and market share of the traditional retail channel are high, the manufacturer always chooses resale mode. When the intensity of price competition is weak, the manufacturer's sales mode selection has nothing to do with the commission rate and, if the market share of the traditional retail channel is lower than the direct channel, the manufacturer should choose agency mode when the market share of the direct channel is low and choose resale mode otherwise. If the market share of the traditional retail channel is higher than the direct channel, the manufacturer always chooses agency mode.

By comparing the manufacturer's sales mode selection under different commission rates, we found that, with the increase in commission rate, the probability of the manufacturer to choose agency mode decreases when the market share of the direct selling channel is low and the intensity of price competition is weak. This indicates that the manufacturer tends to choose agency mode when the commission rate is low, the intensity of price competition is weak, and the market share of the direct selling channel is low and to choose resale mode when the commission rate is high, the intensity of price competition is weak, and the market share of the direct selling channel is high. Moreover, it can be seen from Figure 4a,b that the manufacturer still chooses agency mode when the commission rate and market share of the direct selling channel are high, the intensity of price competition is strong, and the market share of the traditional retail channel is low. This indicates that high commission rate may not necessarily damage the manufacturer's profit.

5.2. Impact of Each Parameter on Each Member

This subsection mainly discusses the impact of the intensity of price competition δ , the market share of the traditional retail channel α , the market share of the direct selling channel β , and the commission rate λ on optimal prices and profits. The basic parameters were set as $\delta = 0.3$, the market share of the traditional retail channel $\alpha = 0.25$, the market share of the direct selling channel $\beta = 0.2$, and the commission rate $\lambda = 0.2$.

Firstly, we analyze the impact of δ on optimal price and profit of each member. Based on the analysis results in Section 5.1, the manufacturer always chooses resale mode when $\delta \in (0.45, 0.485]$ and so we choose $\delta \in [0, 0.45]$. The experimental results are shown in Figure 5. By observing Figure 5a, it can be seen that the optimal price of each member increases exponentially with the increase in δ , which indicates that the stronger the intensity of price competition is, the higher the optimal prices of each member in two sales modes are. By comparing the optimal pricing strategies, we found that, no matter how the intensity of price competition changes, the optimal price satisfies $p_{RT}^* > p_{AT}^*, w_R^* > w_A^*$ and $p_{RE}^* > p_A^* > p_{RD}^*$, which indicates that the intensity of price competition has no influence on price changes in different sales modes in the same channel. Moreover, by observing Figure 5b, it can be seen that the profits of each member in two sales modes increase with the increase in δ . When the intensity of price competition is low, the profit of the manufacturer in agency mode is higher than resale mode, while the profit of the e-commerce platform in resale mode is higher than agency mode. No matter how the intensity of price competition changes, the profit of the traditional retailer in the agency mode is always higher than the resale mode. The manufacturer should choose agency mode, especially when the intensity of price competition is low and, in this case, the traditional retailer and manufacturer can achieve a win-win situation, but it is not beneficial to the e-commerce platform. When the intensity of price competition is high, the manufacturer should choose resale mode and, in this case, the profits of the traditional retailer and e-commerce platform in resale mode are always lower than agency mode, which is disadvantageous to both of them. When the intensity of price competition is moderate, the manufacturer's selection of agency mode is beneficial to both the traditional retailer and e-commerce platform. Therefore, when the commission rate is moderate and the market share of the direct selling channel is lower than the traditional retail channel, the manufacturer can choose agency mode under moderate price competition intensity so as to achieve a win-win situation for all members.

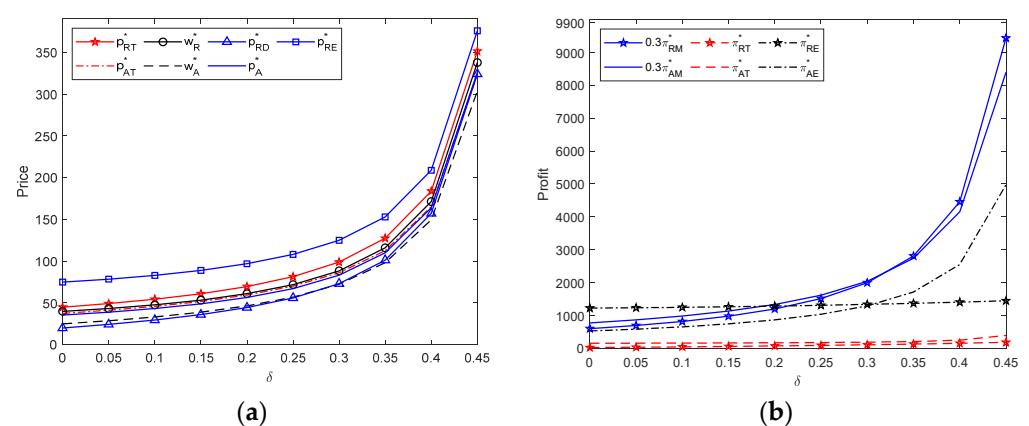


Figure 5. Impact of the intensity of price competition on (a) optimal price and (b) optimal profit.

Secondly, we now analyze the impact of the market share of the traditional retail channel α on optimal price and profit of each member. The experimental results are shown in Figure 6. By observing Figure 6a, it can be seen that, with the increase in α , p_{RE}^* and p_A^* decrease gradually, p_{RT}^* , p_{AT}^* , and w_A^* increase gradually, p_{RD}^* and w_R^* remain the same. This indicates that the higher the market share of the traditional retail channel is, the higher the price of the traditional retailer should be set in both sales modes and the lower the price of e-commerce platform should be set in resale mode. The influence of market share of

the traditional retail channel on the manufacturer's optimal price is different in different sales modes; that is, the higher the market share of the traditional retail channel is, the higher the manufacturer's optimal wholesale price should be set and the lower the selling price should be set in agency mode, while the resale mode is not affected. No matter how the traditional retail channel market share changes, there is always $p_{RE}^* > p_A^* > p_{RD}^*$, and, when the market share of traditional retail channel is low, there is $p_{RT}^* > p_{AT}^*$ and $w_R^* > w_A^*$, which indicates that the market share of traditional retail only has an impact on price change of the traditional retail channel. According to Figure 6b, with the increase in α , the manufacturer's profit in agency mode first decreases and then increases, while the profit of the e-commerce platform decreases and the profit of the traditional retailer increases. The profit of the manufacturer in agency mode is always higher than resale mode. When the market share of traditional retail channel is low, the profit of the e-commerce platform in resale mode is higher than agency mode and the profit of the traditional retailer in agency mode is higher than resale mode. Moreover, when the market share of traditional retail channels is low, the manufacturer's selection of agency mode is beneficial to the traditional retailer but not to the e-commerce platform. When the market share of traditional retail channels is high, the manufacturer's selection of agency mode is not beneficial to the traditional retailer but to the e-commerce platform. When the market share of traditional retail channel is in an appropriate range, the manufacturer's selection of agency mode is beneficial to all members. Therefore, when both the commission rate and the intensity of price competition are moderate, and the market share of the direct selling channel is lower than the traditional retail channel, the manufacturer's selection of agency mode can achieve a win-win situation for all members.

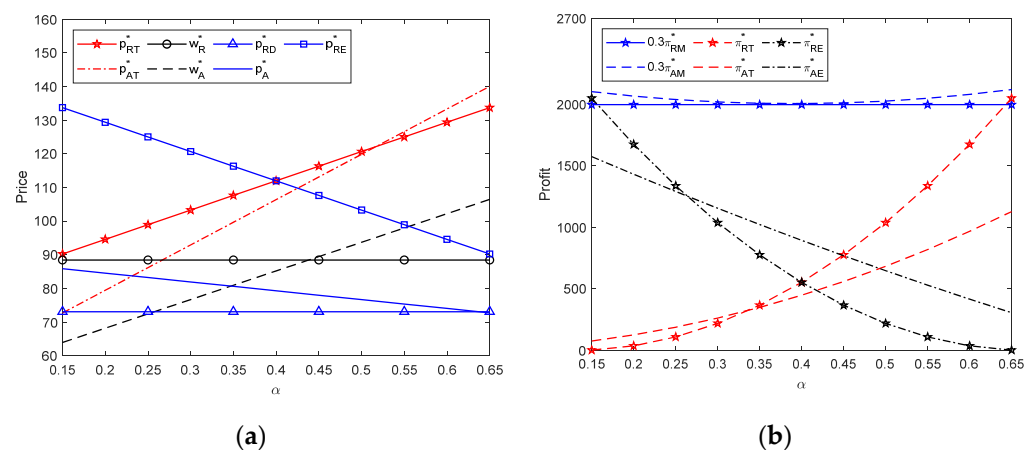


Figure 6. Impact of the market share of traditional retail channel on (a) optimal price and (b) optimal profit.

Thirdly, we analyze the impact of the market share of direct selling channel β on optimal price and profit of each member. The experimental results are shown in Figure 7. By observing Figure 7a, it can be seen that, with the increase in β , p_{RT}^* , w_R^* , and p_{RE}^* decrease gradually and the other prices increase gradually. This indicates that, with the increase in the market share of the direct selling channel, the selling price of the manufacturer in both sales modes should be set high and the selling price of the e-commerce platform in resale mode should be set low. The market share of the direct selling channel has different effects on the selling price of the traditional retailer and the manufacturer's optimal wholesale price under different sales modes. That is, the higher the market share of the direct selling channel is, the lower the selling price of the traditional retailer and the manufacturer's optimal wholesale price should be set in resale mode. No matter how the market share of the direct selling channel changes, there is always $p_{RT}^* > p_{AT}^*$. When the market share of the direct selling channel is high, there are $w_A^* > w_R^*$ and $p_{RD}^* > p_A^* > p_{RE}^*$, which indicates that the market share of the direct selling channel has no influence on price change of the

traditional retailer in different sales modes. By observing Figure 7b, it can be seen that, with the increase in β , the profits of the manufacturer and the traditional retailer increase, while the profit of the e-commerce platform decreases. When the market share of the direct selling channel is low, the profits of the manufacturer and the traditional retailer in agency mode are higher than resale mode. When the market share of the direct selling channel is relatively low or high, the profit of the e-commerce platform in resale mode is higher than that in agency mode. When the manufacturer chooses agency mode, the traditional retailer and e-commerce platform have a low market share in the direct selling channel to achieve a win-win situation with the manufacturer. When the manufacturer chooses resale mode and the market share of direct selling channel is high, it is beneficial to each member. Therefore, when both the commission rate and the intensity of price competition are moderate, if the manufacturer chooses resale mode when the market share of the traditional retail channel is lower than the direct selling channel and chooses agency mode when the market share of the traditional retail channel is higher than the direct selling channel, all members can achieve a win-win situation.

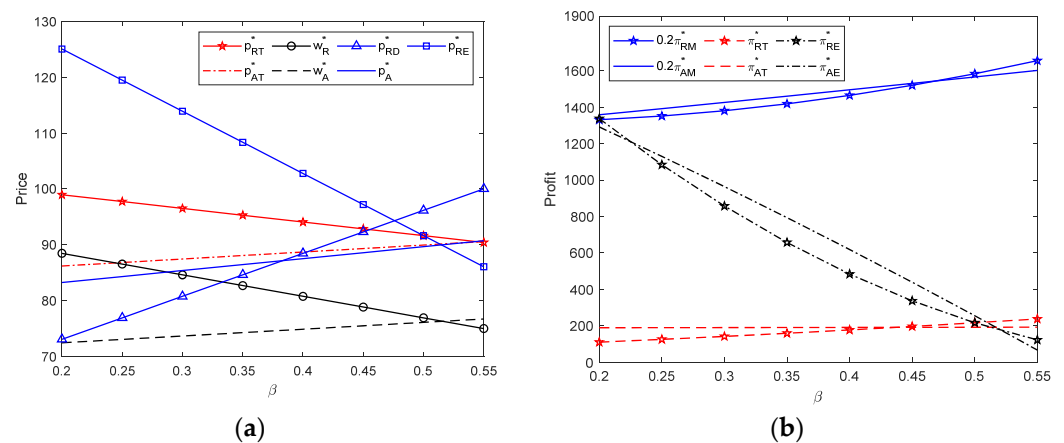


Figure 7. Impact of the market share of direct selling channel on (a) optimal price and (b) optimal profit.

Finally, we report the experimental results about impact of the commission rate λ on optimal price and profit of each member shown in Figure 8. By observing Figure 8a, it can be seen that, with the increase in λ , p_{AT}^* , w_R^* , and p_A^* decrease gradually and the other prices remain the same, which indicates that the optimal price of each member in agency mode should be set low with the increase in commission rate and the optimal price in resale mode is not affected by the commission rate. No matter how the commission rate changes, there are always $p_{RT}^* > p_{AT}^*$, $w_R^* > w_A^*$, $p_{RE}^* > p_A^* > p_{RD}^*$, which indicates that the commission rate has no effect on price changes under different sales modes in the same channel. By observing Figure 8b, it can be seen that, with the increase in λ , the profit of the manufacturer in agency mode decreases, while the profits of the e-commerce platform and the traditional retailer in agency mode increase. When the commission rate is low, the profit of the manufacturer in agency mode is higher than resale mode and the profit of the e-commerce platform in resale mode is higher than agency mode. No matter how the commission rate changes, the profit of the traditional retailer in agency mode is always higher than resale mode. Moreover, when the commission rate is low, the manufacturer's selection of agency mode is beneficial to the traditional retailer but not to the e-commerce platform. When the commission rate is high, the manufacturer's selection of resale mode is not beneficial to both the traditional retailer and e-commerce platform. When the commission rate is moderate, the manufacturer's selection of agency mode can achieve a win-win situation for all members. Therefore, when the intensity of price competition is moderate and the market share of the direct selling channel is lower than the traditional retail channel, the increase in commission rate is not necessarily beneficial to the

e-commerce platform, while the manufacturer's selection of agency mode under moderate commission rate is beneficial to both the traditional retailer and e-commerce platform.

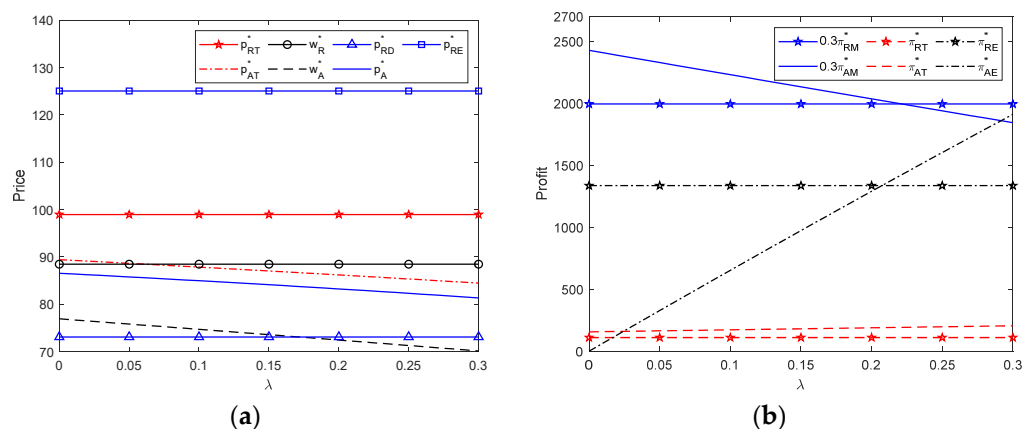


Figure 8. Impact of the commission rate on (a) optimal price and (b) optimal profit.

Based on the above analysis, the sensitivity analysis results for each parameter to price and profit of each member are summarized in Table 4. No matter how the price competition intensity and commission rate change, when the market share of the direct selling channel is lower than e-commerce platform channel, the optimal price relationship in the same channel under two sales modes is $p_{RT}^* > p_{AT}^*$, $w_R^* > w_A^*$, and $p_{RE}^* > p_A^* > p_{RD}^*$. This indicates that channel price change is only related to the market share of channel and has nothing to do with the intensity of price competition and commission rate. Compared with agency mode, when the market share of the direct selling channel is lower than e-commerce platform channel, the optimal prices in the traditional retail channel and e-commerce platform channel are high in resale mode, while the optimal price of the direct selling channel is low. Moreover, when the intensity of price competition and the commission rate are moderate, if the market share of the traditional retail channel is lower than the direct selling channel, the manufacturer's selection of resale mode is beneficial to achieve a win-win situation for all members. If the market share of the traditional retail channel is higher than the direct selling channel, the manufacturer's selection of agency mode can promote the coordination of the supply chain.

Table 4. Sensitivity analysis results of each parameter to each member's optimal price and profit.

Variables	p_{RT}^*	p_{AT}^*	p_{RD}^*	p_A^*	p_{RE}^*	w_R^*	w_A^*	π_{RM}^*	π_{AM}^*	π_{RT}^*	π_{AT}^*	π_{RE}^*	π_{AE}^*
δ	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
α	↑	↑	-	↓	↓	-	↑	-	↓↑	↑	↑	↓	↓
β	↓	↑	↑	↑	↓	↓	↑	↑	↑	↑	↑	↓	↓
λ	-	↓	-	↓	-	-	↓	-	↓	-	↑	-	↑

"↑" indicates an increase, "↓" indicates a decrease, "↓↑" indicates first a decrease and then an increase, and "-" indicates no change.

6. Discussion and Conclusions

With the diversification of sales channels and the development of e-commerce, more and more manufacturers rely on e-commerce platforms to expand the scale of market sales. However, in real life, manufacturers choose between resale mode and agency mode under different conditions (e.g., market competition intensity, commission rate). Therefore, it is necessary to study how manufacturers choose the most beneficial sales mode on the e-commerce platform.

We have studied a sales mode selection problem between resale mode and agency mode on e-commerce platforms for a manufacturer with traditional retail channels, direct selling channels, and e-commerce platform channels. We have constructed two leader–

follower game models with the manufacturer as a leader and the traditional retailer and e-commerce platform as followers. Through theoretical analysis, we have derived optimal decisions for each member and then, through numerical experiments, we have analyzed the impact of intensity of price competition, market share, and commission rate on sales mode selection and each member's optimal price and profit under different sales modes. Through these results and the inspiration of Valeri [53], our research brings some enlightenment to the field of organization management.

The main revelations can be stated as follows:

- (1) The manufacturer's sales mode selection strategy is mainly affected by price competition intensity, market share of channel, and commission rate. To be specific, when the market share of the traditional retail channel is lower than the direct selling channel, the manufacturer should choose agency mode if the market share of the direct selling channel is low and the price competition intensity is weak, or if both the market share of the direct selling channel and the commission rate are high, and the price competition intensity is strong; otherwise, the manufacturer should choose resale mode. When the market share of the direct selling channel is lower than the traditional retail channel, the manufacturer should choose agency mode if the price competition intensity is weak and choose resale mode if the price competition intensity is strong. In particular, the manufacturer is more inclined to choose the resale mode with an increased commission rate. This finding is consistent with the actual situation (e.g., merchants on the platform always want to pay as little commission rate as possible, because in this way they can obtain more profits). In addition, we find that the market share of each channel has a great impact on the sales mode selection strategy. Different from other studies that assume that the market share of the traditional retail channels is higher or lower than that of the direct selling channels, this paper presents the sales mode selection strategy under different market share distribution ratios, which is our characteristic. This finding can solve more problems and has a certain practical significance. In addition, it also provides a new idea for follow-up research on multi-channel supply chains.
- (2) By comparing the optimal prices in the same channel under two sales modes, we found that the change of channel price is only related to the market share of the channel but has nothing to do with the price competition intensity and the commission rate. Compared with agency mode, if the market share of the direct selling channel is lower than e-commerce platform channel, the optimal prices of the traditional retail channel and e-commerce platform channel are high in resale mode, while the optimal price of the direct selling channel is low. This is mainly because the price of the traditional retail channels and e-commerce platform channels decreases with the market share of the direct selling channels in the resale mode but increases with it in the agency mode. In other words, manufacturers expanding direct selling channels under the resale mode are detrimental to traditional retailers and e-commerce platforms. This goes a long way towards explaining why some distributors are reluctant to let their suppliers expand their online channels because it would hurt their profits.
- (3) When both the price competition intensity and the commission rate are moderate, the manufacturer chooses agency mode if the market share of the direct selling channel is lower than the traditional retail channel and chooses resale mode if the market share of the direct selling channel is higher than the traditional retail channel, which can achieve a win-win situation for all members and promote the coordination of the supply chain. Interestingly, references [1,14,33] show that manufacturers achieve supply chain win-wins only under the agency mode. This finding suggests that no matter what sales mode manufacturers choose, there is a possibility that traditional retailers and e-commerce platforms are willing to compete and cooperate with them, which well explains why such sales structures are prevalent in real life and makes our study meaningful.

There are some limitations to our study. We assume that the intensity of price competition is the same across all sales channels. However, it is highly likely that different situations occur in real life. Therefore, in the future, we can consider the influence of price competition intensity across different channels on sales mode selection strategy. In this study, we consider the situation of a single manufacturer and a single e-commerce platform. However, it is beneficial to study the sales mode selection strategy of multiple manufacturers on multiple e-commerce platforms, which can provide more management enlightenment for enterprises. Obviously, the models for this general case are more complicated and, especially, the number of parameters will greatly increase, which may cause some difficulties in solving the models and the corresponding sensitivity analysis. How to deal with these difficulties will be our next topic.

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Appendix A

Proof of Proposition 1: The Hessian matrix of the objective function π_{RM} in model (I) is

$$\nabla^2 \pi_{RM}(w_R, p_{RD}) = \frac{2}{2-\delta} \begin{pmatrix} 2(\delta-1) & 2\delta \\ 2\delta & 2\delta^2 + \delta - 2 \end{pmatrix}.$$

It is easy to see that, when $\delta \in [0, 0.5]$, the above matrix is negative semidefinite and hence the objective function π_{RM} is concave with respect to (w_R, p_{RD}) . Since the constraints are all linear, model (I) is a convex optimization problem. Solving $\nabla_{(w_R, p_{RD})} \pi_{RM} = 0$ yields.

$$w_R^* = \frac{1-\beta+2\beta\delta}{4(1-\delta-2\delta^2)}d, \quad p_{RD}^* = \frac{\beta+\delta-2\beta\delta}{2(1-\delta-2\delta^2)}d.$$

In order to satisfy the constraints, it requires that $4\alpha(\delta-2) + (\beta-1)(3\delta-2) \leq 0$ and $(\beta-1)(\delta-6) + 4\alpha(\delta-2) \geq 0$. Therefore, when $\delta \in [0, 0.5]$, $\alpha \in [0, \alpha_1]$, $\beta \in [\beta_1, \beta_2]$ or $\delta \in [0, 0.5]$, $\alpha \in [\alpha_1, 1]$, $\beta \in [0, \beta_2]$, (w_R^*, p_{RD}^*) is a globally optimal solution of model (I). Substituting (w_R^*, p_{RD}^*) into $p_{RT}^*(w_R, p_{RD})$ and $p_{RE}^*(w_R, p_{RD})$, we can obtain p_{RT}^* and p_{RE}^* . This completes the proof. \square

Proof of Proposition 3: The Hessian matrix of the objective function π_{AM} in model (II) is

$$\nabla^2 \pi_{AM}(w_A, p_A) = \frac{1}{2} \begin{pmatrix} -2 & (4-\lambda)\delta \\ (4-\lambda)\delta & 4(2-\lambda)(\delta^2 + \delta - 1) \end{pmatrix}.$$

When $\delta \in [0, 0.5]$ and $\lambda \in [0, 0.3]$, the above matrix is negative semidefinite and hence the objective function π_{AM} is concave in (w_A, p_A) . Since the constraints are all linear, model (II) is a convex optimization problem. By solving $\nabla_{(w_A, p_A)} \pi_{AM} = 0$, we have

$$w_A^* = \frac{8\alpha + 8\delta - 16\alpha\delta + \lambda(-4\alpha - 10\delta + 14\alpha\delta + 8\beta\delta - 2\alpha\delta^2) + \lambda^2(2\delta - 2\alpha\delta - 2\beta\delta + \alpha\delta^2)}{16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2}d$$

$$p_A^* = \frac{4 - 4\alpha + 8\alpha\delta + \lambda(-4 + 4\alpha + 4\beta - 3\alpha\delta)}{16 - 16\delta - 32\delta^2 - 8\lambda + 8\delta\lambda + 16\delta^2\lambda - \delta^2\lambda^2}d$$

Through direct calculation, when $\delta \in [0, 0.5)$, $\alpha \in [0, 1]$, $\beta \in [0, 1 - \alpha]$ and $\lambda \in [0, 0.3]$, the constraints hold and so (w_A^*, p_A^*) is a globally optimal solution of model (II). Substituting (w_A^*, p_A^*) into $p_{AT}^*(w_A, p_A)$, we can obtain p_{AT}^* . This completes the proof. \square

References

- Hagiu, A.; Wright, J. Marketplace or reseller? *Manage. Sci.* **2015**, *61*, 184–203. [\[CrossRef\]](#)
- Wei, J.; Wang, Y.; Lu, J. Information sharing and sales patterns choice in a supply chain with product's greening improvement. *J. Clean. Prod.* **2021**, *278*, 123704. [\[CrossRef\]](#)
- Chiang, W.Y.K.; Chhajed, D.; Hess, J.D. Direct marketing, indirect profits: A strategic analysis of dual-channel supply-chain design. *Manage. Sci.* **2003**, *49*, 1–20. [\[CrossRef\]](#)
- Matsui, K. When should a manufacturer set its direct price and wholesale price in dual-channel supply chains? *Eur. J. Oper. Res.* **2017**, *258*, 501–511. [\[CrossRef\]](#)
- Yi, Z.; Wang, Y.; Liu, Y.; Chen, Y.J. The impact of consumer fairness seeking on distribution channel selection: Direct selling vs. agent selling. *Prod. Oper. Manag.* **2018**, *27*, 1148–1167. [\[CrossRef\]](#)
- Wang, C.; Leng, M.; Liang, L. Choosing an online retail channel for a manufacturer: Direct sales or consignment? *Int. J. Prod. Econ.* **2018**, *195*, 338–358. [\[CrossRef\]](#)
- Pu, X.; Sun, S.; Shao, J. Direct selling, reselling, or agency selling? Manufacturer's online distribution strategies and their impact. *Int. J. Electron. Commer.* **2020**, *24*, 232–254. [\[CrossRef\]](#)
- Wang, T.Y.; Wang, X.J.; He, P.; Chen, Z.S. Retailer's selling mode choice under different competition forms. *Int. Trans. Oper. Res.* **2022**, *29*, 3712–3736. [\[CrossRef\]](#)
- Ma, J.; Lou, W.; Tian, Y. Bullwhip effect and complexity analysis in a multi-channel supply chain considering price game with discount sensitivity. *Int. J. Prod. Res.* **2019**, *57*, 5432–5452. [\[CrossRef\]](#)
- Ryan, J.K.; Sun, D.; Zhao, X. Competition and coordination in online marketplaces. *Prod. Oper. Manag.* **2012**, *21*, 997–1014. [\[CrossRef\]](#)
- Martin, B.; Krishnan, H.; Dhar, T. The strategic role of third-party marketplaces in retailing. *Prod. Oper. Manag.* **2014**, *23*, 1937–1949. [\[CrossRef\]](#)
- Yan, Y.; Zhao, R.; Xing, T. Strategic introduction of the marketplace channel under dual upstream disadvantages in sales efficiency and demand information. *Eur. J. Oper. Res.* **2019**, *273*, 968–982. [\[CrossRef\]](#)
- Ha, A.Y.; Luo, H.; Shang, W. Supplier encroachment, information sharing, and channel structure in online retail platforms. *Prod. Oper. Manag.* **2022**, *31*, 1235–1251. [\[CrossRef\]](#)
- Abhishek, V.; Jerath, K.; Zhang, Z.J. Agency selling or reselling? Channel structures in electronic retailing. *Manage. Sci.* **2016**, *62*, 2259–2280. [\[CrossRef\]](#)
- Zhu, C.; Yao, Z. Comparison between the agency and wholesale model under the e-book duopoly market. *Electron. Commer. Res.* **2018**, *18*, 313–337. [\[CrossRef\]](#)
- Li, Z.; Ho, Y.C.; Nan, G.; Li, M. Agency or resale: Effects of a platform-performance investment for frenemy platforms. *Decis. Support Syst.* **2019**, *124*, 113098. [\[CrossRef\]](#)
- Liu, B.; Guo, X.; Yu, Y.; Tian, L. Manufacturer's contract choice facing competing downstream online retail platforms. *Int. J. Prod. Res.* **2021**, *59*, 3017–3041. [\[CrossRef\]](#)
- Wei, J.; Lu, J.; Wang, Y. How to choose online sales formats for competitive e-tailers. *Int. Trans. Oper. Res.* **2021**, *28*, 2055–2080. [\[CrossRef\]](#)
- Kwark, Y.; Chen, J.; Raghunathan, S. Platform or wholesale? A strategic tool for online retailers to benefit from third-party information. *MIS Q.* **2017**, *41*, 763–786. [\[CrossRef\]](#)
- Chen, L.; Nan, G.; Li, M. Wholesale pricing or agency pricing on online retail platforms: The effects of customer loyalty. *Int. J. Electron. Commer.* **2018**, *22*, 576–608. [\[CrossRef\]](#)
- Tian, L.; Vakharia, A.J.; Tan, Y.; Xu, Y. Marketplace, reseller, or hybrid: Strategic analysis of an emerging e-commerce model. *Prod. Oper. Manag.* **2018**, *27*, 1595–1610. [\[CrossRef\]](#)
- Wei, J.; Lu, J.; Zhao, J. Interactions of competing manufacturers' leader-follower relationship and sales format on online platforms. *Eur. J. Oper. Res.* **2020**, *280*, 508–522. [\[CrossRef\]](#)
- Zenryo, Y. Strategic contracting and hybrid use of agency and wholesale contracts in e-commerce platforms. *Eur. J. Oper. Res.* **2020**, *281*, 231–239. [\[CrossRef\]](#)
- Zhong, B.; Shen, H.; Zhang, J.; Gao, X. Agency or wholesale? Retail selling format in the presence of new manufacturer introduction. *Electron. Commer. Res.* **2022**, 1–35. [\[CrossRef\]](#)
- Li, X.; Ai, X. A choice of selling format in the online marketplace with cross-sales supply chain: Platform selling or traditional reselling? *Electron. Commer. Res.* **2021**, *21*, 393–422. [\[CrossRef\]](#)
- Jerath, K.; Zhang, Z. Store within a store. *J. Mark. Res.* **2010**, *47*, 748–763. [\[CrossRef\]](#)

27. Jiang, B.; Jerath, K.; Srinivasan, K. Firm strategies in the “mid tail” of platform-based retailing. *Mark. Sci.* **2011**, *30*, 757–775. [\[CrossRef\]](#)
28. Hao, L.; Tan, Y. Who wants consumers to be informed? Facilitating information disclosure in a distribution channel. *Inf. Syst. Res.* **2019**, *30*, 34–49. [\[CrossRef\]](#)
29. Belhadj, N.; Laussel, D.; Resende, J. Marketplace or reselling? A signaling model. *Inf. Econ. Policy* **2020**, *50*, 100834. [\[CrossRef\]](#)
30. Liu, W.; Yan, X.; Li, X.; Wei, W. The impacts of market size and data-driven marketing on the sales mode selection in an internet platform-based supply chain. *Transp. Res. Pt. E-Logist. Transp. Rev.* **2020**, *136*, 101914. [\[CrossRef\]](#)
31. Shi, S.; Sun, J.; Cheng, T.C.E. Wholesale or drop-shipping: Contract choices of the online retailer and the manufacturer in a dual-channel supply chain. *Int. J. Prod. Econ.* **2020**, *226*, 107618. [\[CrossRef\]](#)
32. Qin, X.; Liu, Z.; Tian, L. The optimal combination between selling mode and logistics service strategy in an e-commerce market. *Eur. J. Oper. Res.* **2021**, *289*, 639–651. [\[CrossRef\]](#)
33. Chen, L.; Nan, G.; Li, M.; Feng, B.; Liu, Q. Manufacturer’s online selling strategies under spillovers from online to offline sales. *J. Oper. Res. Soc.* **2022**. [\[CrossRef\]](#)
34. Ha, A.Y.; Tong, S.; Wang, Y. Channel structures of online retail platforms. *Manuf. Serv. Oper. Manag.* **2022**, *24*, 1547–1561. [\[CrossRef\]](#)
35. Tan, Y.; Carrillo, J.E. Strategic analysis of the agency model for digital goods. *Prod. Oper. Manag.* **2017**, *26*, 724–741. [\[CrossRef\]](#)
36. Dennis, Z.Y.; Cheong, T.; Sun, D. Impact of supply chain power and drop-shipping on a manufacturer’s optimal distribution channel strategy. *Eur. J. Oper. Res.* **2017**, *259*, 554–563.
37. Geng, X.; Tan, Y.; Wei, L. How add-on pricing interacts with distribution contracts. *Prod. Oper. Manag.* **2018**, *27*, 605–623. [\[CrossRef\]](#)
38. Shen, Y.; Yang, X.; Dai, Y. Manufacturer-retail platform interactions in the presence of a weak retailer. *Int. J. Prod. Res.* **2019**, *57*, 2732–2754. [\[CrossRef\]](#)
39. Zhang, S.; Zhang, J. Agency selling or reselling: E-tailer information sharing with supplier offline entry. *Eur. J. Oper. Res.* **2020**, *280*, 134–151. [\[CrossRef\]](#)
40. Chen, P.; Zhao, R.; Yan, Y.; Li, X. Promotional pricing and online business model choice in the presence of retail competition. *Omega* **2020**, *94*, 102085. [\[CrossRef\]](#)
41. Lu, Q.; Shi, V.; Huang, J. Who benefit from agency model: A strategic analysis of pricing models in distribution channels of physical books and e-books. *Eur. J. Oper. Res.* **2018**, *264*, 1074–1091. [\[CrossRef\]](#)
42. Alaei, A.M.; Taleizadeh, A.A.; Rabbani, M. Marketplace, reseller, or web-store channel: The impact of return policy and cross-channel spillover from marketplace to web-store. *J. Retail. Consum. Serv.* **2020**, *65*, 102271. [\[CrossRef\]](#)
43. Guo, F.; Ma, D.; Hu, J.; Zhang, L. Optimized combination of e-commerce platform sales model and blockchain anti-counterfeit traceability service strategy. *IEEE Access* **2021**, *9*, 138082–138105. [\[CrossRef\]](#)
44. Hao, C.; Yang, L. Resale or agency sale? Equilibrium analysis on the role of live streaming selling. *Eur. J. Oper. Res.* **2022**; *in press*. [\[CrossRef\]](#)
45. Wang, Q.; Zhao, N.; Ji, X. Reselling or agency selling? The strategic role of live streaming commerce in distribution contract selection. *Electron. Commer. Res.* **2022**. [\[CrossRef\]](#)
46. Hu, H.; Zheng, Q.; Pan, X.A. Agency or Wholesale? The Role of Retail Pass-Through. *Manage. Sci.* **2022**, *68*, 7065–7791. [\[CrossRef\]](#)
47. Shi, G.; Jiang, L.; Wang, Y. Interaction between the introduction strategy of the third-party online channel and the choice of online sales format. *Int. Trans. Oper. Res.* **2022**, *29*, 2448–2493. [\[CrossRef\]](#)
48. Zhang, Y.; Li, B.; Zhao, R. Resale or agency: Pricing strategy for advance selling in a supply chain considering consumers’ loss aversion. *IMA J. Manag. Math.* **2022**, *33*, 229–254. [\[CrossRef\]](#)
49. Chen, L.; Nan, G.; Liu, Q.; Peng, J.; Ming, J. How Do Consumer Fairness Concerns Affect an E-Commerce Platform’s Choice of Selling Scheme? *J. Theor. Appl. Electron. Commer. Res.* **2022**, *17*, 1075–1106. [\[CrossRef\]](#)
50. Kurata, H.; Yao, D.Q.; Liu, J.J. Pricing policies under direct vs. indirect channel competition and national vs. store brand competition. *Eur. J. Oper. Res.* **2007**, *180*, 262–281. [\[CrossRef\]](#)
51. Dan, B.; Xu, G.; Liu, C. Pricing policies in a dual-channel supply chain with retail services. *Int. J. Prod. Econ.* **2012**, *139*, 312–320. [\[CrossRef\]](#)
52. Wang, R.; Nan, G.; Chen, L.; Li, M. Channel integration choices and pricing strategies for competing dual-channel retailers. *IEEE Trans. Eng. Manag.* **2022**, *69*, 2260–2274. [\[CrossRef\]](#)
53. Valeri, M. *Organizational Studies*; Springer International Publishing: Cham, Switzerland, 2021; ISBN 978-3-030-87147-5.