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Should offline retailers expand online under consumer showrooming based on the effects of intershowrooming and intrashowrooming?

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C H R O N I C L E

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A B S T R A C T

This study aims to find a way to alleviate or eliminate the negative impact of showrooming on brick-and-mortar retailers. Therefore, under careful consideration of the effects of intershowrooming and intrashowrooming, this study explores whether retailers can effectively solve the negative impact of showrooming by opening online channels. Conduct a comparative study on the decision-making of dual/multi-channel supply chain members before and after the retailer opens an online channel and analyze the influence. In addition, we also explored the impact of factors such as the market scale expansion effect and internet market power structure. Research has found that regardless of the market scale expansion effect generated, it is effective for the retailer to increase profits by opening an online channel. The impact of market scale expansion is not entirely beneficial to the retailer. Under the intrashowrooming, the effect of market scale expansion may benefit the manufacturer. But what is more noteworthy is that for the manufacturer, the impact of intrashowrooming is not necessarily the greater, the better, and the manufacturer's profit may decrease as this effect increases.

1. Introduction

With the emergence and development of e-commerce, enterprises have developed their direct online channels to increase product exposure and expand their market coverage. Many manufacturers now are opening up electronic direct sales channels while retaining traditional retail channels(Tsay& Agrawal, 2004), such as electronics manufacturers (Apple, Sony, Gree, Lenovo, et al., (Jing et al., 2012) and clothing manufacturers (such as Coach, Nike, Adidas). In addition to cooperation with traditional brick-and-mortar retailers, these companies have also opened their own online websites, achieving a dual-channel structure. Offline retailers often stimulate consumers' willingness to buy through promotion and guide consumers' product demand to increase product sales to maximize their profits. For example, through product advertising, publicity, free trial, and other promotional efforts, consumers can experience or get the relevant information, functions of the product to a certain extent, and their willingness may be stimulated to purchase the product. However, not all consumers will buy products from offline retailers after generating purchase intention, and some consumers may switch to other channels to purchase products, which will lead to consumers' free-riding behavior caused by offline retailers' promotion efforts (Li et al., 2014; G. Xu et al., 2014), also known as “showrooming” because offline retailers are forced to become showrooms at this time. (Chai et al., 2021; Mehra, 2018).

In the showrooming, manufacturers do not provide promotion effort, but indirectly enjoy the increase in product sales by the offline retailers’ promotion effort and increase their profits to a certain extent. However, these may harm offline retailers' willingness to promote, level of promotion effort, and profits (Balakrishnan et al., 2014; Mehra, 2018). Suppose only offline retailers bear the cost of sales efforts, in that case, rational retailers will choose the level of promotion effort that is most

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beneficial to them, leading to the supply chain failing to achieve optimal system performance to some extent (Tang & Xing, 2001; Zhou et al., 2018).

Aiming at this phenomenon, some scholars have tried to coordinate the channels of offline retailers and manufacturers' network channels through different contracts (Gupta et al., 2009; Tsay & Agrawal, 2004). For example, some scholars have proposed contracts such as a cost-sharing contract (Pu et al., 2017), a revenue-sharing contract (Guo et al., 2022; S. Xu et al., 2022), price hike Mechanism (C. Liu et al., 2022), and a two-part tariff contract coordination model (Liang & Sun, 2022), etc. Manufacturers could use these contracts to de-escalate the channel conflict in dual channels and pursue better performances of members, to achieve Pareto improvement of the profits of manufacturers and retailers.

In addition, retailers have responded to showrooming in various ways, including (1) providing exclusive products for offline channels, such as Target designing a baby product for offline stores that is different from online channels (Zimmerman et al., 2012); (2) sparing no effort to increase the additional revenue from per customer visit(S. Zhang et al., 2021); (3) matching the price of online products and better convert in-store experiencers into customers (i.e., customers who know the online price adopt the same price as online, weakening the showrooming from the root of price comparison (Zeng & Hou, 2022); These measures are effective for retailers to counter showrooming and expand product market sales to a certain extent.

The above studies have focused on the showrooming's negative effects, while neglecting the positive effects. In fact, showrooming can be subdivided into intershowrooming and intrashowrooming. When customers check out products at a physical store and then purchase them through that retailer's online channel, this behavior is known as "intershowrooming" (Gu & Tayi, 2017a), whereas "intrashowrooming" occurs when customers check out products at a brick and mortar store and then pay for them online from the manufacturer online (Zhang et al., 2020).

Whether offline retailers can leverage the positive effect of intershowrooming to gain revenue by expanding online channels is worth further exploring. Some researchers have explored the possibility of offline retailers opening online channels. Zhang et al. discovered that when both the retailer's greater income from each visit and the expense of inconvenience (such as travel expenses, time costs, etc.) to the customer are matched, suppliers and retailers can profit from consumer showrooming. In addition, they found that opening online channels by retailers will exacerbate the competitive effect of showrooming, hence the omnichannel strategy may cause this "win-win" range to become smaller(Zhang et al., 2021).

In fact, offline retailers may expand the market to some extent by opening online channels (Pozzi, 2013). The introduction of electronic channels usually expands the market scale, and one of the great values of e-commerce lies in creating new market opportunities through the opening of online channels (Srivastava & Thompson, 2010). The development of online channels by retailers has raised the distribution intensity in the overall market, enhanced customer accessibility to company items, and consequently boosted the market share of enterprises from the perspective of the overall market (Geyskens et al., 2002). Combining online and offline channels gives retailers more opportunities to reach new customers and the potential for market expansion(Brynjolfsson et al., 2013; Gao, 2017).

In this scenario, how will an offline retailer opening an online channel affect himself, the manufacturer, and the supply chain? What impact will the market scale expansion effect and the internet power structure of the channel have on the decision-making of the main body and the supply chain system? Clarifying these issues is crucial for the scientific decision-making of supply chain members, as it can lay a theoretical foundation for offline retailers to weaken the negative impact of showrooming and leverage their positive impact.

This article builds a model based on this that has a manufacturer, a brick-and-mortar retailer, and multiple channels, considering the coexistence of intershowrooming and intrashowrooming, and attempts to analyze and clarify the following two issues:

(1) The impact of an offline retailer's online expansion on the decision-making, profits and performance of different channels is discussed. We analyze the equilibrium decisions in two typical scenarios (offline retailer does not open online channels, and offline retailer opens online channels). The applicability, advantages and disadvantages of retailers opening online channels are explored by comparing the decision-making and profit performance changes in two typical scenarios.
(2) The impact of market scale expansion and various internet channel power structures on the profits of supply chain members is further analyzed with the scenario of offline retailers opening online channels in mind. The differential impact mechanism of these two factors on the performance of different channels is clarified.

Compared with existing research, this article has the following improvements and innovations: (1) Some scholars only focus on intershowrooming or intrashowrooming and attempt to weaken the negative impact on retailers' promotion effort level through some contracts or coordination mechanisms based on the manufacturer's dominance. This article focuses on the coexistence of intershowrooming or intrashowrooming, and tries to analyze the possibility, scope of application, and advantages and disadvantages of opening online channels from the perspective of retailers. This will lay a theoretical foundation for retailers to seek ways to improve their performance. (2) Some scholars' research has focused on the negative

impact of showrooming on retailers. Thus, some measures are proposed to consolidate their sales volume further. This article attempts to play a positive role in retailers by opening online channels to find an innovative path to improve retailers' performance. In addition, by clarifying the market scale expansion effect and the differential influence mechanism of different internet channel power structures on different channels, theoretical suggestions are provided for the reasonable decision-making of multi-channel supply chain members.

The rest of the essay is divided into the following sections. In Section 2, the literature is reviewed. Two models and their underlying assumptions are discussed in Section 3. And Section 4 examines the strategies and profitability of various models to figure out the impact of the retailer's online channel. To comprehend the market scale expansion and the power of the internet channel, Section 5 compares earnings within models. In Section 6, conclusions are offered.

2. Background literature

The two key topics from earlier literature: showrooming and multi-channel retailing are built upon in this study. Below, we quickly examine two themes and where our research stands in relation to earlier studies.

2.1 Showrooming

Showrooming can be seen as a unique way of fusing free-riding with internet purchasing practices. It is a natural behavior that has emerged with multi-channel operations (Bachrach et al., 2016; Viejo-Fernandez et al., 2020). Nowadays, studies on showrooming have matured, but there is still no consensus among academics about it. Most studies have shown that the emergence of showrooming is detrimental to the profits of offline retailers(Basak et al., 2017; Mehra, 2018; S. Zhang et al., 2021). Based on the negative impact of showrooming, some scholars have proposed relevant strategies to mitigate its negative impacts (Bell et al., 2015; Bob & Ankosko, 2012; Ma et al., 2020). For example, Wang et al. designed consistent pricing and price-limiting strategies to eliminate showrooming (Wang Qian et al., 2021). Mehra et al. proposed short-term price matching and long-term brand strategies(Mehra, 2018). Gensler et al. suggested that physical retailers can alleviate showrooming by increasing sales personnel instead of training (Gensler et al., 2017). Basak et al. constructed a three-parameter contract to combat the adverse effects of showrooming, thereby achieving a win-win situation for manufacturers and physical retailers (Basak et al., 2020). Some scholars believe that it also has a positive side. Sit et al. (2018) argued that retailers could better utilize showrooming through the consumer experience. Kuksov and Liao (2018) indicated that the profitability of brick-and-mortar retailers might increase with showrooming when appropriate supply-sale contracts are established. According to Liu et al., widening market channels can boost supply chain earnings when showrooming is present (Liu et al., 2019). Li et al. (2020) divided the showroom feasibility into different levels based on the setup cost and the proportion of local consumers. They also classified consumer showrooming behavior into two types: intra-product showrooming and inter-product showrooming(Zhang et al., 2020). Gu and Tayi examined consumers' cross-channel search behavior of "pseudo-showrooming" (Gu & Tayi, 2017b), which is somewhat similar to the meaning of showrooming. Consumers experience products in the same retailer's physical store before purchasing through the same retailer's online channel. Zhang et al. (2021) analyzed two types of showrooming behavior: Consumers may engage in both intrashowrooming (in which they examine products in a retailer's physical shop before buying them at the supplier's online channel) and intershowrooming (in which they first encounter products in a retailer's physical store before purchasing them at the retailer's online channel).

2.2 Multi-channel retailing

Research on multi-channel retail literature mainly revolves around three questions (Neslin et al., 2006): Will multi-channel retailing grow retailers' sales? What is the role of expanding online channels? Should prices be the same across all channels, too? These questions continue to lack definitive solutions. Some scholars believe that a multi-channel strategy may harm the profits of supply chain members. As Zhang (2009) found, multi-channel retailing may not be the best strategy for all retailers. Karray and Sigue argued that based on the size of the online market and the level of price competition among retailers, adopting multi-channel retailing may not increase the first-mover profit of offline retailers (Karray & Sigue, 2021). Cao et al. analyzed a retailer with multiple distribution channels selling products to customers and developed an analytical framework to explore the impact of "online to offline" channels on the retailer's demand distribution and profits. They found that although this new channel can help retailers develop new customer groups and increase product demand, it may cannibalize existing channels and increase operating costs, thereby damaging retailers' profits (Cao et al., 2016). According to Shao, omnichannel retailing is not necessarily associated with decreased retail costs and improved consumer welfare(Shao, 2021). However, some scholars have different opinions. Compared to single-channel, multi-channel sales can increase consumer satisfaction and loyalty, thereby bringing better economic benefits to retailers (Melis et al., 2015; Neslin & Shankar, 2009; Rangaswamy & Bruggen, 2010). Yan et al. (2019) suggested that multiple channels composed of manufacturer and retailer are the most advantageous for retailers. Zhang et al. (2022) showed that multi-channel retailers could give customers a deeper understanding, thereby helping to increase customer value. Kim and Chun indicated that manufacturers would tend to use online or omni channels as competition intensifies. If consumers do not prefer different online channels, manufacturers will adopt an omnichannel strategy (Kim & Chun, 2018). Jeffers and Nault demonstrated several counter-intuitive results, discovering that a multi-channel strategy may lead to an increase in retail prices and industry profits (Jeffers & Nault, 2011).

In fact, with the rapid development of the online market, whether retailers are active or passive, consumer free-riding behavior is ultimately inevitable, and this behavior will become increasingly common in the future. Research on showrooming involves the selection of sales channels, and retail-oriented research is becoming the mainstream direction of studies.

This article, which is based on showrooming, examines how implementing multi-channel retailing has affected the decisions made by supply chain participants before and after the strategy of opening an online channel. The paper also examines how a retailer's promotion effort affects supply chain participants' choices.

3. Models

There exists a dominant manufacturer and a follower offline retailer in the market. Manufacturer's direct online channel (MDOC) refers to the manufacturer selling products directly to consumers online, while the manufacturer also sells products through offline retailers (i.e., retailer's offline channel, ROFC). These two channels compete with each other, and consumers can choose to purchase from a manufacturer or retailer. The retailer is currently faced with the choice of whether to open its own online channel (hereinafter referred to as pre-opening and after-opening). Fig. 1 and Fig. 2 depict the supply chain structure before and after the retailer opening online channels.

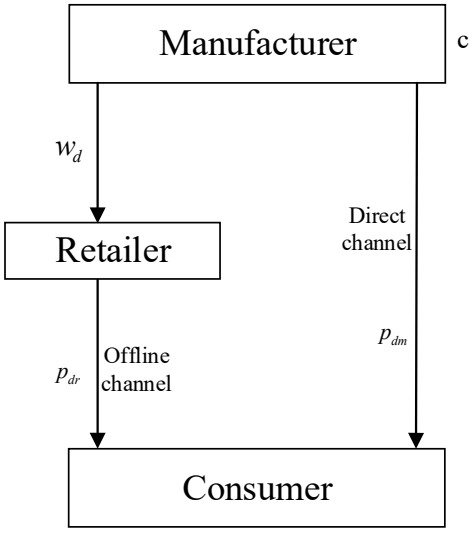

Fig. 1. Supply chain structure for unopened online channel

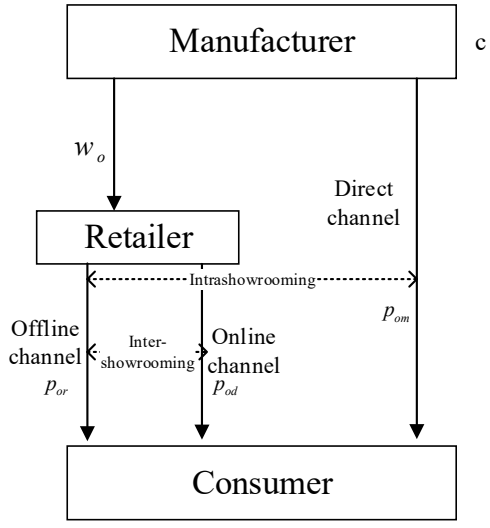

Fig. 2. Supply chain structure for opening online channel

We first outline the parameters that support our model. Table 1 contains a list of the variables used in the model.

Table 1
Description of parameters and symbols

Parameters	Description
c	Unit production cost
Q	Baseline demand
e	Cross-price sensitivity coefficient
θ	Proportion of MDOC to the total market
τ	Proportion of free-riding consumers entering the market
η	Cost coefficient of promotion effort
λ	Share of RONC in the entire online market
ρ	Market scale expansion effect caused by retailer opening online channel
m	Proportion of free riding consumer who choose MDOC, i.e., the effect of intrashowrooming
s	Promotion effort level of the retailer
w	Unit wholesale price
p_{dj}	$j = r, m$， Pre-opening ROFC's /MDOC's price
p_{oi}	$i = r, d, m$, After-opening ROFC's/RONC's/MDOC's price
D_{dj}	$j = r, m$， Pre-opening ROFC's /MDOC's demand
D_{oi}	$i = r, d, m$, After-opening ROFC's/RONC's/MDOC's demand
π_R	Profit of retailer
π_M	Profit of manufacturer

3.1. Model 1: Pre-opening

Manufacturer not only sells products through an offline retailer, but also establishes online direct channel. Particularly, the manufacturer determines the wholesale price w using the unit cost of c, and the MDOC's price p_{dm}. The retailer only sets the offline retail price p_{dr}. We assume that the demand functions are linear (Li et al., 2021; Liu et al., 2020; Zhang et al., 2010; Zheng et al., 2021). The following demand functions are adopted:

$$D_{dr} = a_{dr} - p_{dr} + e(p_{dm} - p_{dr}) + (1-\tau)s_d \tag{1}$$

$$D_{dm} = a_{dm} - p_{dm} + e(p_{dr} - p_{dm}) + \tau s_d \tag{2}$$

where $a_{dr} = (1-\theta)Q$, represents the basic consumer group occupied by the retailer; $a_{dm} = \theta Q\ (0<\theta<1)$, means the basic consumer group of the MDOC. The potential demand is expressed in parameter Q, and Q is positive. The price elasticity coefficient of demand from different channels is 1, and the cross-price sensitivities denoted by $e(0<e<1)$ are the same. We assume that when a retailer puts in a level of promotion effort s, the new consumer group attracted to enter the market is s with a subset of free-riding consumers. Therefore, the proportion of new consumers lost by promotion is $\tau s(0 \le \tau \le 1)$, τ is the proportion of free-riding consumers entering the market. The retailer's promotion effort cost function is $h(s) = \frac{\eta s^2}{2}$ with the cost coefficient of promotion effort $\eta(\eta > 0)$. Profits for the manufacturer (π_{dm}) and retailer (π_{dr}) are as follows:

$$\pi_{dm} = (w_d - c)D_{dr} + (p_{dm} - c)D_{dm} \tag{3}$$

$$\pi_{dr} = (p_{dr} - w_d)D_{dr} - \frac{\eta {s_d}^2}{2} \tag{4}$$

Lemma 1. *For the case of dual-channel with an unopened online channel, there exist equilibrium solutions, where*

$$s_d^* = \frac{(c - Q + Q\theta)(-1+\tau)}{-1+8\eta+8e\eta+2\tau-\tau^2} = \frac{(a_{dr}-c)(1-\tau)}{8\eta+8e\eta-(1-\tau)^2}$$

$$w_d^* = \frac{c+2ce+Q(1+e-\theta)+(1+e-\tau)s_d^*}{2+4e}$$

$$p_{dm}^* = \frac{c+2ce+Q(e+\theta)+(e+\tau)s_d^*}{2+4e}$$

$$p_{dr}^* = \frac{c(1+2e)^2+Q(3+2e(3+e-2\theta)-3\theta)+(3+2e(3+e-2\tau)-3\tau)s_d^*}{4(1+e)(1+2e)}$$

To ensure that the manufacturer's wholesale price is less than the price of MDOC, and the promotion level of the retailer is greater than 0, there are

$$\theta > A = \frac{8\eta(1+e)Q+Q(-1+\tau)\tau+c(1-\tau)(-1+2\tau)}{Q(16\eta(1+e)-(1-\tau))}$$

$$\eta > \frac{(1-\tau)^2}{8(1+e)}$$

For a dual-channel supply chain, the premise of equilibrium solutions is $\theta > 0.5$ (Karray & Sigue, 2018; Yan, 2011). When an online channel has a limited market share, the manufacturer's profit from using that channel does not compensate for the costs incurred. In other words, the manufacturer will only adopt a dual-channel model when the demand for online channels reaches a certain level. The proof can be found in Appendix A.1.

Next, we analyze the sensitivity of the promotion effort s_d and MDOC's price p_{dm} and ROFC's price p_{dr}, which is given in Proposition 1. The values of M_1 and M_2 are given in Appendix A.2.

Proposition 1. (1) $\partial p_{dr}^* / \partial s_d^* = M_1 > 0$; (2) $\partial p_{dm}^* / \partial s_d^* = M_2 > 0$

Both the ROFC's and the MDOC's price will increase as retailers' promotion effort. Proposition 1 states that when a retailer bears the full cost of promotion effort, it generally compensates for promotion costs by increasing the ROFC's price, and the

manufacturer also uses this to increase MDOC's price to gain more revenue

Proposition 2. (1) $\partial M_1 / \partial \tau < 0, \partial M_2 / \partial \tau > 0$; (2) For the price: $\begin{cases} M_1 > M_2, 0 < \tau < \dfrac{3+4e}{5+6e} \\ M_1 < M_2, \dfrac{3+4e}{5+6e} \le \tau < 1 \end{cases}$

Proposition 2: The increasing range in ROFC's prices will decrease as τ increases, while the increasing range in MDOC's prices will increase. When τ increases, the retailer will not significantly increase product prices to avoid greater loss of consumer groups, while the manufacturer will increase MDOC's price to enjoy the dividends of free-riding consumers and maximize their own profits. The proof can be found in Appendix A.3.

Proposition 3. *Analyzing the relationship between the percentage of free-riding consumers and the level of optimal promotion effort, optimal ROFC's price and MDOC's price.*

In the following paper, η^* is the threshold value given in Appendix A.4.

(1) $\partial s_d^* / \partial \tau < 0$; (2) $\partial p_{dr}^* / \partial \tau < 0$, when $\eta > \eta^*$, $\begin{cases} \partial p_{dm}^* / \partial \tau > 0, 0 < \tau < \tau_2 \\ \partial p_{dm}^* / \partial \tau < 0, \tau_2 < \tau < 1 \end{cases}$

Proposition 3.1: The level of promotion effort shows a decreasing trend as τ increases. Retail will choose to reduce the level of promotion effort to save costs because the promotion effort cannot bring higher profits. Objectively, it will also have a certain negative impact on the manufacturer's product sales and profits.

Proposition 3.2: When η is greater than η^* , the MDOC's price exhibits a tendency of initially rising and then falling as τ increases. When τ is small, the retailer will choose to raise the level of promotion effort, and the manufacturer may increase product price to maximize its own profits. However, as τ increases, the cost of promotion effort paid by the retailer may exceed the profit brought by product sales. Therefore, the retailer may so choose to reduce the level of promotion effort. Under this influence, MDOC may lower product prices.

3.2. Model 2: After-opening

According to this strategy, the manufacturer sells products directly online and through the retailer, while the retailer now offers the same item through both offline and online channels (i.e., retailer's online channel, RONC). At the same time, considering that the introduction of a RONC leads to a market scale expansion effect, multiple channels will improve consumers' access to enterprise's products, thereby increasing the market share of enterprises (Dan et al., 2016; Fu & Guo, 2021). Therefore, this section analyzes the impact of RONC's opening on members under the condition of market scale expansion.

The retailer determines the promotional effort level and retail price for each of his two channels while the manufacturer's decision-making variables stay unchanged. The product can then be purchased by customers either offline or online through one of three channels. Denote p_{or}, p_{od} and p_{om} the price of ROFC, RONC and MDOC. The new parameter $\lambda (0 < \lambda < 1)$ represents the share of RONC in the entire internet market. The $\rho (\rho > 0)$ is market scale expansion effect caused by opening RONC. The parameter m $(0 < m < 1)$ represents the proportion of free-riding consumers who choose MDOC, i.e., representing the intrashowrooming, and $1-m$ represents the intershowrooming. The three channels' demand functions are provided by:

$$D_{or} = a_{or} - p_{or} + e\left(p_{om} - p_{or}\right) + e\left(p_{od} - p_{or}\right) + \left(1-\tau\right) s_o \tag{5}$$

$$D_{od} = a_{od} - p_{od} + e\left(p_{or} - p_{od}\right) + e\left(p_{om} - p_{od}\right) + \left(1-m\right) \tau s_o \tag{6}$$

$$D_{om} = a_{om} - p_{om} + e\left(p_{or} - p_{om}\right) + e\left(p_{od} - p_{om}\right) + m\tau s_o \tag{7}$$

Among, $a_{or} = (1-\theta)Q$, $a_{od} = \lambda(\theta+\rho)Q$, $a_{om} = (1-\lambda)(\theta+\rho)Q$.

Profits for the manufacturer and retailer are now given by

$$\pi_{om} = \left(w_o - c\right)\left(D_{or} + D_{od}\right) + \left(p_{om} - c\right) D_{om} \tag{8}$$

$$\pi_{or} = \left(p_{or} - w_o\right) D_{or} + \left(p_{od} - w_o\right) D_{od} - \frac{\eta s_o^{\,2}}{2} \tag{9}$$

Lemma 2. *In the case of multi-channel with RONC, there exist equilibrium solutions, where*

$$w_o^* = \frac{2c + 6ce + (1+2e)a_{od} + 2ea_{om} + a_{or} + 2ea_{or} + (1+2e-m\tau)s_o^*}{4+12e}$$

$$p_{om}^* = \frac{c + 3ce + a_{om} + e(a_{od} + a_{om} + a_{or}) + (e+m\tau)s_o^*}{2+6e}$$

$$p_{or}^* = \frac{2c(1+e(5+6e)) + (1+e(7+4e))a_{od} + 4e(1+e)a_{om} + (5+e(11+4e))a_{or}}{8(1+e)(1+3e)} + \frac{(5+e(11+4e)-(4+4e+m+3em)\tau)s_o^*}{8(1+e)(1+3e)}$$

$$p_{od}^* = \frac{2c(1+e(5+6e)) + (5+e(11+4e))a_{od} + 4e(1+e)a_{om} + (1+e(7+4e))a_{or}}{8(1+e)(1+3e)} + \frac{(1+e(7+4e)+(4+4e-5m-7em)\tau)s_o^*}{8(1+e)(1+3e)}$$

$$s_o^* = \frac{2c(1+3e)(-1+m\tau) - (3+e+(-8+5m+e(-8+7m))\tau)a_{od} + (5+7e-8(1+e)\tau+(3+e)m\tau)a_{or}}{-5-7e+16\eta+64e\eta+48e^2\eta-2(-8+e(-8+m)+3m)\tau-(16(1+e)-16(1+e)m+(5+7e)m^2)\tau^2}$$

If and only if λ satisfies $\lambda < \frac{8Q(1-\theta)(1+e) - mQ(1-\theta)(3+e) - 2mc(1+3e)}{Q(8-5m+8e-7me)(\theta+\rho)}$ and c satisfies $c < \frac{5a_{or} + 7ea_{or} - 3a_{od} - ea_{od}}{2(1+3e)}$ to ensure that retailer's promotion effort level is not negative. (The proof can be found in Appendix A.5.)

Proposition 4. *Analyzing the relationship between retailer's promotion effort level and market scale expansion effect. The proof can be found in Appendix A.6.*

$$\frac{\partial s_o^*}{\partial \rho} = -\frac{Q\lambda(3+e+(-8+5m+e(-8+7m))\tau)}{-5-7e+16\eta+64e\eta+48e^2\eta-2(-8+e(-8+m)+3m)\tau-(16(1+e)-16(1+e)m+(5+7e)m^2)\tau^2}$$

Proposition 4 shows that when τ is less than $\hat{\tau}$, ρ can bring more product sales to the retailer, but the retailer will actually reduce the promotion effort level. From this, it can be seen that when market demand expands, and fewer consumers are lost (τ is small), the retailer has little incentive to ramp up sales efforts. When ρ continues to increase, as τ increases, the showrooming will be intensified, which will have a negative impact on retailer product sales. Therefore, the retailer tends to increase promotion effort to strengthen product sales. This indicates that the market scale expansion effect is not entirely beneficial to the retailer, and under the showrooming, which may benefit the manufacturer. The retailer should take measures, such as adopting differentiated promotion effort levels for different channels, striving to weaken the intrashowrooming strengthening the intershowrooming.

Proposition 5. *Analyzing the expression of* $p_{or}^*, p_{od}^*, p_{om}^*$.

(1) $\partial p_{or}^* / \partial s_o^* = G_1 > 0, \partial p_{od}^* / \partial s_o^* = G_2 > 0, \partial p_{om}^* / \partial s_o^* = G_3 > 0$;

(2) $\partial G_1 / \partial \tau = (-4-4e-m-3em)/(8(1+e)(1+3e)) < 0$, if $m < \hat{m} = (4(1+e))/(5+7e)$, then $\partial G_2 / \partial \tau > 0$, if $m > \hat{m} = (4(1+e))/(5+7e)$, then $\partial G_2 / \partial \tau < 0$, $\partial G_3 / \partial \tau = m/(2+6e) > 0$

(3) $\partial G_1 / \partial m < 0, \partial G_2 / \partial m < 0, \partial G_3 / \partial m > 0$ and $\partial G_3 / \partial m > \partial G_1 / \partial m > \partial G_2 / \partial m$

Proposition 5.1:

As s_o^* grows, prices from retailer's dual channels and MDOC will also increase. As retailer increases the level of promotional effort with the expansion of product demands, the manufacturer is inclined to increase MDOC's price to further maximize its own profits. Similar to the conclusion of Proposition 2, for ROFC's price, the increase slows down as the τ glows, while the MDOC's price is the opposite. It is worth noting that there is a critical point $\hat{m}$ for retailer to determine whether to raise or low the price of RONC. When the intrashowrooming m is small, the increase in RONC's price increases with τ. Conversely, the opposite is true.

Proposition 6. (1) $m < (4+4e)/(9+11e)$, $\begin{cases} G_1 > G_2 > G_3 & if\ 0 < \tau < \tau_0 \\ G_2 > G_1 > G_3 & if\ \tau_0 < \tau < \tau_1 \\ G_2 > G_3 > G_1 & if\ \tau_1 < \tau < 1 \end{cases}$,

$$(2)\ (4+4e)/(9+11e)<m<(3+8e)/(5+12e+7e^2),\begin{cases}G_1>G_2>G_3 & if\ 0<\tau<\tau_0\\ G_2>G_1>G_3 & if\ \tau_0<\tau<\tau_1\\ G_2>G_3>G_1 & if\ \tau_1<\tau<\tau\\ G_3>G_2>G_1 & if\ \tau_2<\tau<1\end{cases},$$

The proof can be found in Appendix A.7.

Proposition 6.1: When τ is small and the intrashowrooming m is less than a certain threshold, the price of ROFC will increase more sharply as the increase of retailer's promotion effort than the RONC and MDOC. With τ increasing, the retailer has the largest increase in RONC's prices.

Proposition 6.1 states that price changes in multiple channels are influenced by showrooming. The prices in all three channels increase with the retailer's promotion effort. However, when faced with an offline route is being squeezed by an online channel, the price increase of ROFC has to be lower than the other two channels.

Proposition 6.2: When the intrashowrooming m exceeds a certain threshold, multi-channel product pricing is more susceptible to the influence of τ. When τ is greater than τ_2, the price fluctuation of the MDOC is most affected by the level of the retailer's promotion effort.

Proposition 6.2 indicates that for the manufacturer, as impact of the intrashowrooming increases, the optimal price of MDOC correspondingly increases. It is worth noting that when τ is small, even with the intensification of the intrashowrooming, the manufacturer may not necessarily benefit from it. Only when τ is high, the manufacturer can earn more by increasing the price of MDOC.

4. Comparative analysis

Due to the complexity of the pricing, promotion effort, product demands, and profits expressions of the subjects in a multi-channel supply chain system, numerical examples are used to compare and analyze the impact of opening an RONC on various decision variables, channel product demands, and main body profits. The numerical values taken are based on the research of Ji et al. (2017) and have been repeatedly validated and meet the parameter selection range, such as satisfying the conditions of retail product price greater than the wholesale price, non-negative sales of each channel, and promotion effort level greater than 0. The initial values of the parameters are shown in Table 1. Furthermore, in order to observe the impact of intrashowrooming on the decision variables of the supply chain system entities, this article selects $m=0.1, 0.4, 0.7, 1$ to represent different degrees of intrashowrooming.

Table 2
The initial values of the parameters

Parameters	Q	θ	c	e	η	ρ	λ
Values	400	0.5	30	0.4	4	0.4	0.4

4.1 On retailer's level of promotion efforts

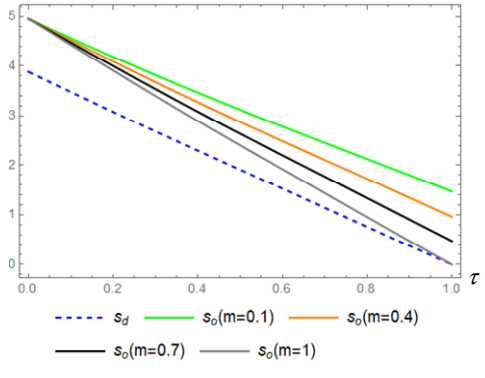

Fig. 3. The level of promotion efforts by retailer under different τ

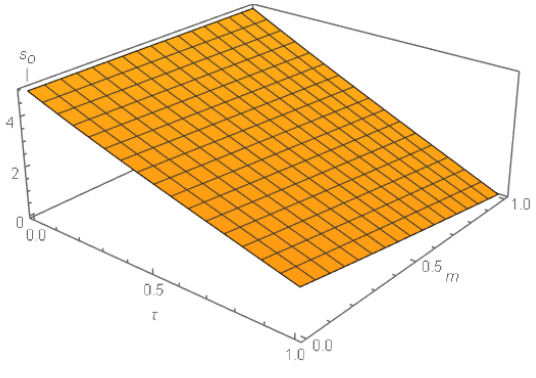

Fig. 4. The impact of promotion efforts on τ and m

When compared to the retailer's pre-opening, one who does put in more promotion effort. The retailer's level of promotion

effort tends to decrease as τ rises (see Fig. 3). Retailer's promotion effort is influenced by both the proportion of free-riding consumers τ and the intrashowrooming m, but the effect of τ is higher than that of m. As τ increases and the degree of m intensifies, the level of promotion shows a downward trend (see Fig. 4). As shown in the figure, as τ increases, the intrashowrooming and intershowrooming intensify. In this scenario, the retailer tends to reduce promotion efforts after weighing the relationship between profit and cost. Even if all free-riding consumers shift to RONC to purchase products, the retailer still tends to reduce promotional effort level.

4.2 On channel prices

The retailer who opens an online channel has a lower price for an offline channel than an unopened one. With the τ increasing, the ROFC's price shows a downward trend (see Fig. 5). The impact of whether the retailer establishes RONC on MDOC's price is not significant. As τ increases, MDOC's price generally exhibits a trend of first rising and then falling (see Fig. 6). The MDOC (RONC) only occasionally benefits when m is small (large). As τ rises, the product prices for the MDOC and RONC will rise and fall (see Figs. 8-9). With the increase of τ, the prices of retailer's dual channels and MDOC's and wholesale price of manufacturer, all show a downward trend. Compared to ROFC's price and wholesale price of the manufacturer, the price of MDOC and RONC are more affected by the m (see Figs. 7-10).

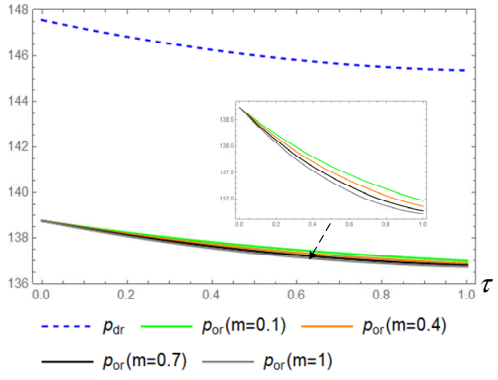

Fig. 5. ROFC's price for different τ

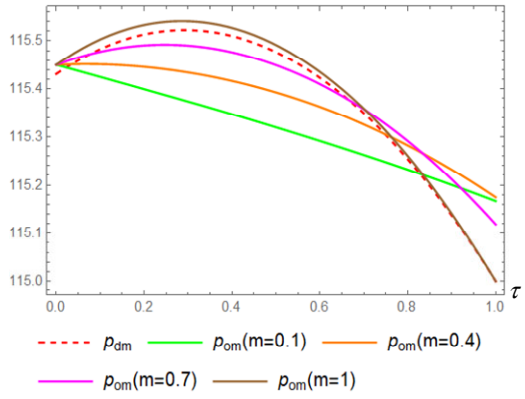

Fig. 6. MDOC's price for different τ

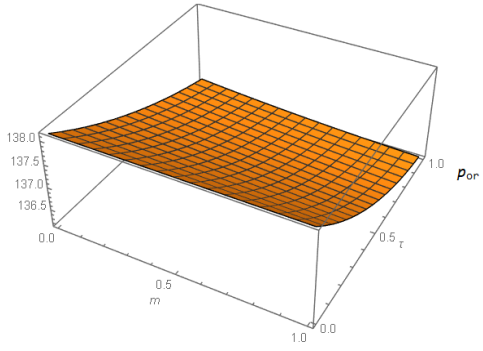

Fig. 7. The impact of τ and $m$on ROFC's price

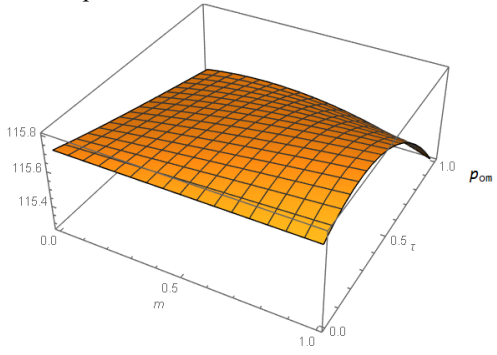

Fig. 8. The impact of τ and $m$on MDOC's price

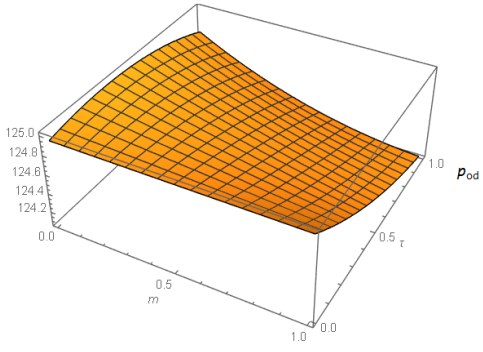

Fig. 9. The impact of τ and $m$on RONC's price

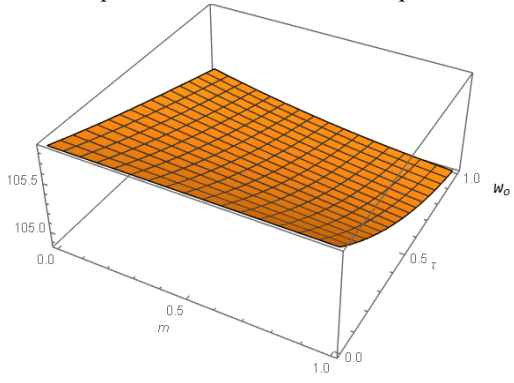

Fig. 10. The impact of τ and m on manufacturer's wholesale price

4.3 On channel demands

Due to the market scale expansion effect, when a brick-and-mortar retailer opens an online channel, the demands of ROFC and MDOC are larger than when the retailer does not open (see Fig. 11 and Fig. 12). As τ increases, the ROFC's demands show a downward trend, while MDOC's demands exhibit a tendency of initial increasing and then a decline. With the intensification of m, the demands of MDOC are higher when τ is small, and lower when τ is large. The market share of scales through MDOC tends decline if the retailer opens an online channel. In other words, MDOC could lose some of its competitive advantage with the opening of RONC.

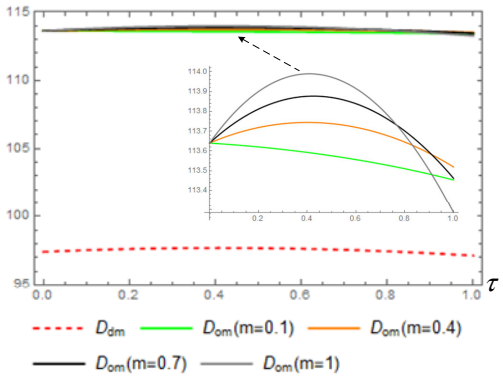

Fig. 11. Demands of MDOC under varying τ

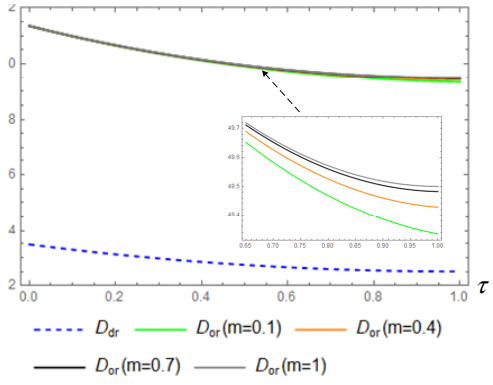

Fig. 12. Demands of ROFC under varying τ

4.4 On channel profits

As τ increases, both ROFC's profits and MDOC's profits show a downward trend, while RONC's profits show an upward trend. However, contrary to our traditional understanding, the higher m, the lower the profits of RONC, while the profits of ROFC are higher. Due to τ and m, both will reduce retailer's promotion effort, making them lose the willingness to promote. Therefore, with the higher m, the retailer may reduce promotion efforts, thereby saving the cost. At this time, the profits of ROFC will be higher. From this, it can be seen that there is a mutually dependent and influencing relationship between diverse channels. When m has a significant impact, the manufacturer's profits decrease, so for the manufacturer, it is not that the greater m, the more profitable it is.

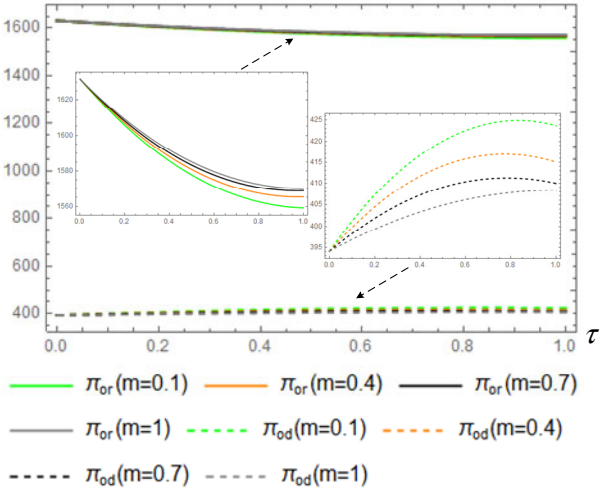

Fig. 13. The ROFC's/RONC's profit under different m

5. Market scale expansion and online power structures

5.1 Market scale expansion

In the context of the retailer opening an online channel, this section analyzes the impact of market scale expansion on the equilibrium states. Similar to the parameter settings in the previous section, we consider three scenarios for the proportion of free-riding consumers: low, medium, and high, respectively set $\tau_L = 0.1$, $\tau_M = 0.5$, $\tau_H = 0.9$, $m = 0.5$.

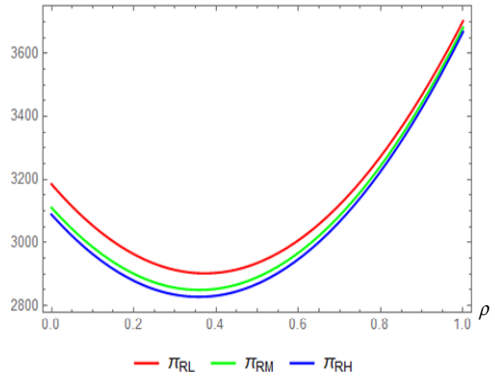

Fig. 14. The impact of market scale expansion on the profit of retailer

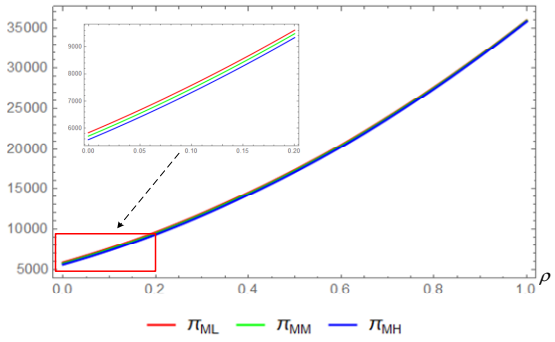

Fig. 15. Changes in Manufacturer Profit Across three situations

Upon opening online channels, manufacturers' profits show an upward trend, whereas the retailer observes a tendency of first falling and then growing with the rise of market scale. In the early stage, although market scale expands, the manufacturer takes the opportunity to raise wholesale prices, resulting in a significant increase in purchasing costs for the retailer. Consequently, the retailer's profit shows a certain downward trend. In the later stage, the retailer increases selling price, and the retailer's profits show an upward trend. For the retailer, market scale expansion is only partially beneficial. Opening an online channel may lead to a shrink in offline product sales. Further, the manufacturer may use the situation to raise wholesale prices and pursue high profits. If the retailer does not take proactive measures, profits may show a downward trend for a certain period.

5.2 Internet power structures

This section considers the impact of power structures in different internet channels on equilibrium decision-making. A member within a channel is more powerful when it occupies a grander market scale than other channel partners. Therefore, by analyzing the relationship between the share of RONC in the internet market, we attempt to clarify the influence of channel power structures on member performance.

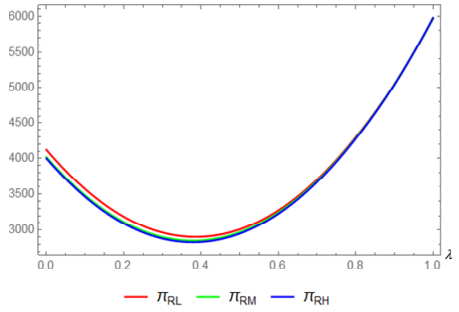

Fig. 16. The relationship between the market share of RONC in the internet market and retailer's profits

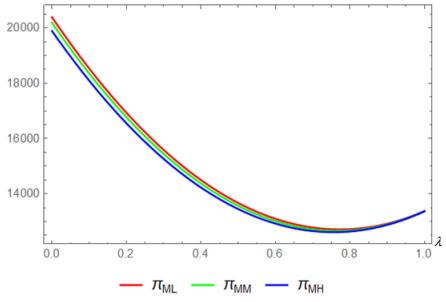

Fig. 17. The relationship between the market share of RONC in the internet market and manufacturer's profits

According to our research, the earnings of both the manufacturer and the retailer display a tendency of first declining and then growing as the RONC's market share rises. We have analyzed the trend of changes in retailer profits in Chapter 5.1. The manufacturer's profit will trend downward as the RONC overtakes his direct online sales. However, it is noteworthy that in extreme cases, where RONC occupies a vast majority of the internet market share, the manufacturer's profits will increase compared to the previous situation. This phenomenon reflects the "starving dog" business type in the Boston matrix. If MDOC has a low market share, the manufacturer's wholesale quantities will rise along with the retailer's dual-channel demands. Therefore, the manufacturer's main source of profit comes from selling products to the retailer.

6. Conclusion

With the continuous growth of the market scale of online channels, showrooming has become a common phenomenon. This phenomenon may hurt the retailer's promotional willingness. Therefore, this article takes the retailer's opening an online channel as a way to alleviate or eliminate the negative impact of showrooming. Under the comprehensive consideration of intrashowrooming and intershowrooming, the article explores the impact of opening a retailers' online channel on promotional efforts, channel prices, product sales, and member profits. In addition, the effects of market scale expansion effect and online

market power structures on the supply chain system are also explored. Draw some conclusions as follows:

Considering the market expansion effect brought by opening online channels, our research found that it is effective for retailers to increase profits. Traditional researchers have suggested that opening online channels for retailers will compete with manufacturers' direct online channels, thereby worsening supply chain profits. Furthermore, this study found that compared to dual channels, the profit of supply chain members has significantly increased regardless of the scale of the market expansion effect generated by opening online channels. Retailers' addition of online channels has promoted the demand for original channels. Supply chain members can earn more profits from multiple channels than a single channel due to reduced consumer purchase costs and marketing exposure.

In dual and multi-channel channels, the motivation and enthusiasm for retailer promotions will decrease as the proportion of free-riding consumers increases. Regardless of the channel chosen by free-riding consumers for purchasing, even if all free-riding consumers shift to the retailer's online channel to purchase products, the retailer is not inclined to increase promotional efforts. Secondly, both the manufacturer's direct online channel prices and the retailer's online channel prices increase with the retailer's promotional effort. However, they are also influenced by the proportion of free-riding consumers and the showrooming. However, whether a retailer opens online channels has little impact on the prices of the manufacturer's direct online channel.

There exists a mutually dependent and influential relationship among diverse sales channels. When the intrashowrooming is small (large), it is only sometimes advantageous for the retailer's online channel (manufacturer's direct online channel). The retailer’s online channel will earn less money the more intrashowrooming there is. While the profit of the retailer's offline channel is higher, and optimal pricing of the manufacturer's direct online channel will also increase accordingly. It is worth noting that when the proportion of free-riding consumers is low, even with the intensification of the intrashowrooming, manufacturers may not necessarily benefit from it. Only when the proportion of free-riding consumers is high can manufacturers gain more profits by raising the prices in direct online channels. Meanwhile, when the intrashowrooming has a significant impact, the manufacturer's profits will decrease. For manufacturers, it is not that the greater the intrashowrooming, the more profitable it is.

The market scale expansion is only partially beneficial for retailers. Opening online channels may lead to declining sales of the retailer's offline channel. In addition, manufacturers may take the opportunity to increase wholesale prices in pursuit of high profits. If the retailer does not take active measures, its profits may fluctuate. This indicates that the market scale expansion effect is not entirely beneficial to the retailer, and under the showrooming, the market scale expansion effect may benefit the manufacturer. Retailers should take measures, such as adopting differentiated promotion efforts for different channels, to weaken the intrashowrooming and strengthen the intershowrooming.

Acknowledgments

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Appendices. A.1.

Proof of Lemma 1

In order to obtain the Stackelberg equilibrium, the best response of the follower in the second stage should be determined at first. The leader’s decision problem is solved based on the follower’s response. We can get H to be a Hessian of π_{dm},

$$H=\begin{pmatrix} -1-e & e \\ e & -(2+4e+e^2)/(1+e) \end{pmatrix},$$

H is a negative definite because $H_{11}<0$, and $\det(H)=2+4e>0$. Hence, π_{dm} is concave in p_{dm} and w_d. Let $\partial\pi_{dm}/\partial p_{dm}=0$ and $\partial\pi_{dm}/\partial w_d=0$, then we get $s_d^*, w_d^*, p_{dm}^*, p_{dr}^*$.

A.2. Proof of Proposition 1

$$\frac{\partial p_{dr}^*}{\partial s_d^*}=M_1=\frac{3+2e(3+e-2\tau)-3\tau}{4(1-e)(1+2e)}=\frac{3(1-\tau)+2e(3+e-2\tau)}{4(1-e)(1+2e)}>0$$

$$\frac{\partial p_{dm}^*}{\partial s_d^*}=M_2=\frac{e+\tau}{2+4e}>0$$

A.3. Proof of Proposition 2

Comparing the size relationship between M_1 and M_2.

$$\frac{\partial M_1}{\partial \tau}=\frac{-3-4e}{4(1-e)(1+2e)}<0,\frac{\partial M_2}{\partial \tau}=\frac{1}{2(1+2e)}>0,$$

$M_1-M_2=\frac{3+4e-5\tau-6e\tau}{4(1+3e+2e^2)}$, when $0<\tau<\frac{3+4e}{5+6e}$, there is $M_1>M_2$; When $\frac{3+4e}{5+6e}\le\tau<1$, there is $M_1<M_2$.

A.4. Proof of Proposition 3

$$\frac{\partial s_d^{\ *}}{\partial \tau}=\frac{\left(8(1+e)\eta+(-1+\tau)^2\right)(c-a_{dr})}{\left(-8(1+e)\eta+(-1+\tau)^2\right)^2}<0$$

Proof of Proposition 3.2

$$(1)\frac{\partial p_{dr}^*}{\partial \tau}=-\frac{(a_{dr}-c)F}{2(1+2e)\left(-8(1+e)\eta+(-1+\tau)^2\right)^2}$$

$$F=e+24\eta+8\eta e(5+e)-2\left(e+4(3+4e)\eta\right)\tau+e\tau^2$$

$$\frac{\partial F}{\partial \tau}=-2\left(e+4(3+4e)\eta\right)+2e\tau=2(\tau e-e-4\eta(3+4e))<0$$

$$MaxF(\tau=0)=e+24\eta+8\eta e(5+e)$$

$$MinF(\tau=1)=e+24\eta+8\eta e(5+e)-2\left(e+4(3+4e)\eta\right)\tau+e\tau^2=8e(1+e)\eta>0$$

$$F>0\Rightarrow\frac{\partial p_{dr}^*}{\partial \tau}=-\frac{(a_{dr}-c)F}{2(1+2e)\left(-8(1+e)\eta+(-1+\tau)^2\right)^2}<0$$

$$(2)\frac{\partial p_{dm}^*}{\partial \tau}=\frac{(1+e)(c-a_{dr})G}{2(1+2e)\left(-8(1+e)\eta+(-1+\tau)^2\right)^2}$$

$$G=(-1+\tau)^2+8\eta(-1+e+2\tau)=0\Rightarrow 1+8\eta(-1+e)<0\Rightarrow\eta>\eta^*=\frac{1}{8(1-e)}$$

$$\tau_1=1-8\eta-2\sqrt{2}\sqrt{-\eta-e\eta+8\eta^2}<0,\tau_2=1-8\eta+2\sqrt{2}\sqrt{-\eta-e\eta+8\eta^2}>0$$

When $0<\tau<\tau_2=1-8\eta+2\sqrt{2}\sqrt{-\eta-e\eta+8\eta^2}$, $G<0\Rightarrow\frac{\partial p_{dm}^*}{\partial \tau}>0$, and $\tau_2<\tau<1\Rightarrow G>0\Rightarrow\frac{\partial p_{dm}^*}{\partial \tau}<0$.

A.5. Proof of Lemma 2

The Model 2 solution method is similar to Appendix 1 and is not demonstrated here. Only the size of s_o^* is analyzed.

$$s_o^*=\frac{\Omega_1}{\Omega_2}$$

$$(1)\Omega_1=a_1+k_1\tau$$

$$a_1=-2c(1+3e)+5Q(1-\theta)+7eQ(1-\theta)-3Q\lambda(\theta+\rho)-eQ\lambda(\theta+\rho)$$

$$k_1=2mc(1+3e)-8Q(1-\theta)(1+e)+mQ(1-\theta)(3+e)+(8-5m+8e-7me)Q\lambda(\theta+\rho)$$

When $\lambda<\frac{8Q(1-\theta)(1+e)-mQ(1-\theta)(3+e)-2mc(1+3e)}{Q(8-5m+8e-7me)(\theta+\rho)}$, there is $k_1<0$.

Ω_1 decreases with the increase of τ.

$$\max\Omega_1(\tau=0)=-2c(1+3e)+(5+7e)a_{or}-(3+e)a_{od}\qquad\min\Omega_1(\tau=1)=(1-m)\left(-2c(1+3e)+(5+7e)a_{od}-(3+e)a_{or}\right)$$

When $c < \frac{(5+7e)a_{od} - (3+e)a_{or}}{2(1+3e)}$, $Min\Omega_1 > 0, \Rightarrow \Omega_1 > 0$.

$(2)\Omega_2 = a_1\tau^2 + b_1\tau + c_1\tau$

$a_2 = -\left(16(1+e) - 16(1+e)m + (5+7e)m^2\right)$, $b_1 = -2\left(-8 + e(-8+m) + 3m\right)(*b_1 > 0*)$

$c_1 = -5 - 7e + 16\eta + 64e\eta + 48e^2\eta$, $\Delta_1 = b_1^2 - 4a_2c_1 > b_1^2 > 0$

$\tau_{o1} = \frac{-b_1 + \sqrt{\Delta_1}}{2a_2} < 0, \tau_{o2} = \frac{-b_1 - \sqrt{\Delta_1}}{2a_1} > 0$, $\tau_{o2} = \frac{-b_1 - \sqrt{\Delta_1}}{2a_2} > \frac{-b_1}{a_2} > 1$

Because Ω_2 is a quadratic function of τ with a downward opening and one root less than 0 and another greater than 1. Therefore, for any $\tau \in (0,1)$, there is $\Omega_2 > 0$.

A.6. Proof of Proposition 4

$$\frac{\partial s_o^*}{\partial \rho} = -\frac{Q\lambda\left(3 + e + \left(-8 + 5m + e(-8+7m)\right)\tau\right)}{-5 - 7e + 16\eta + 64e\eta + 48e^2\eta - 2\left(-8 + e(-8+m) + 3m\right)\tau - \left(16(1+e) - 16(1+e)m + (5+7e)m^2\right)\tau^2}$$

When $\tau < \hat{\tau} = \frac{3+e}{8 - 5m + e(8-7m)} < 1$, there is $\frac{\partial s_o^*}{\partial \rho} < 0$, Otherwise, $\frac{\partial s_o^*}{\partial \rho} > 0$

A.7. Proof of Proposition 6

Proof of Proposition 6.1

When $m < \frac{4+4e}{9+11e}$, there are three points:

$\tau_0 = \frac{1}{2-m}, \tau_1 = \frac{5+7e}{4+5m+4e+7me}, \tau_2 = \frac{-1-3e}{4+4e-9m-11em}$

$$\begin{cases} 0 < \tau < \tau_0, G_1 - G_2 > 0 \,\&\, G_1 - G_3 > 0 \,\&\, G_2 - G_3 > 0 \Rightarrow G_1 > G_2 > G_3 \\ \tau_0 < \tau < \tau_1, G_2 - G_1 > 0 \,\&\, G_1 - G_3 \,\&\, 0, G_2 - G_3 \,\&\, 0 \Rightarrow G_2 > G_1 > G_3 \\ \tau_1 < \tau < 1, G_2 - G_1 > 0 \,\&\, G_3 - G_1 > 0 \,\&\, G_2 - G_3 > 0 \Rightarrow G_2 > G_3 > G_1 \end{cases},$$

Proof of Proposition 6.2

When $\frac{4+4e}{9+11e} < m < \frac{3+8e}{5+12e+7e^2}$, the relationships between G_1, G_2 and G_3 are as follows:

$$\begin{cases} 0 < \tau < \tau_0, G_1 - G_2 > 0 \,\&\, G_1 - G_3 > 0 \,\&\, G_2 - G_3 > 0 \Rightarrow G_1 > G_2 > G_3 \\ \tau_0 < \tau < \tau_1, G_2 - G_1 > 0 \,\&\, G_1 - G_3 > 0 \,\&\, G_2 - G_3 > 0 \Rightarrow G_2 > G_1 > G_3 \\ \tau_1 < \tau < \tau_2, G_2 - G_1 > 0 \,\&\, G_3 - G_1 > 0 \,\&\, G_2 - G_3 > 0 \Rightarrow G_2 > G_3 > G_1 \\ \tau_2 < \tau < 1, G_2 - G_1 > 0 \,\&\, G_3 - G_1 > 0 \,\&\, G_3 - G_2 > 0 \Rightarrow G_3 > G_2 > G_1 \end{cases}$$

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