

Decision and Coordination of an O2O Supply Chain With Market Segmentation and Showrooming Effect

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ABSTRACT

This paper investigates the impacts of market segmentation and showrooming effect on the decision making of an O2O supply chain and puts forwards a contract to coordinate the O2O supply chain. Results show that the showrooming effect is beneficial to the manufacturer, retailer, and the supply chain, and the retailer will offer offline showrooming service. Under the influence of market segmentation, O2O supply chain structure is not necessarily better than single-channel supply chain structure. But adopting advertising and other means to improve consumers' online channel acceptance, it can realize the successful transformation from single-channel structure to O2O structure. The benefits of showrooming effect can eliminate the disadvantage of market segmentation. Moreover, a service cost sharing contract is put forward, which can perfectly coordinate the O2O supply chain with market segmentation and showrooming effect. These research findings help supply chain managers to understand which channel structure is optimal by considering market segmentation and showrooming effect and identify possible pathways for them to perfectly cooperate.

KEYWORDS

Coordination, Market Segmentation, O2O Supply Chain, Showrooming Effect

1. INTRODUCTION

With the rapid development of mobile internet and e-commerce, online shopping is the main mode of consumer shopping (Gajewska et al., 2020). Manufacturers have opened up online channels and formed dual channels on the basis of the original offline channels, such as Nike, Apple, and Cisco Systems (Matsui, 2016). The emergence of online channels poses immense challenges for the traditional retailers. In order to deal with the threat of manufacturers' online channels, retailers use

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their offline channels to provide offline services for consumers to promote market sales (Li et al., 2019; Bell et al., 2018). In order to alleviate the conflict between the two channels and encourage retailers to provide offline services, more and more manufacturers entrust online channels to retailers to realize the integration of online and offline channels, namely O2O mode (Wu et al., 2021). In the O2O supply chain, some consumers may transfer to online channels through online price comparison after receiving services in offline stores, which is called showrooming effect (Li et al., 2020). The showrooming effect not only affects the overall demand in the market (Basak et al., 2020), but also increases retailers' offline service cost. Hence, retailers need to weigh costs and benefits to decide whether to provide offline showrooming service by considering showrooming effect in different supply chain structures.

For heterogeneous consumers, market segmentation strategy is a reasonable and accurate adjustment of products and marketing efforts to meet different customer needs and bring benefits to enterprises (Lin et al., 2020). Market segmentation is widely used as a means of enterprise competition (Liu et al., 2019). But, consumers belonging to different segments have different preferences, and thus have different substitution behaviors (Lee and Eun, 2020), which is called consumer choice behavior (Khan and Mohsin, 2017). Consumer choice behavior under market segmentation strategy has been investigated from many perspectives (Wang and Wang, 2017; Zhang et al., 2017; Yang et al., 2019; Hwang and Park, 2016; Aviv et al., 2019), such as supply chain decisions and coordination (Buell and Kalkanci, 2021; Kabul and Parlaktürk, 2019; Wang et al., 2020; Farshbaf-Geranmayeh and Zaccour, 2021). They found that, because of consumer choice behavior, dual-channel supply chain structure is not always better than single-channel supply chain structure (Zhang et al., 2017). In this paper, the applicable conditions of different supply chain channel structure modes by considering both market segmentation and showrooming effect will be investigated.

In practice, supply chain members are often in a decentralized decision-making state. In a decentralized supply chain, members of the supply chain make decisions to maximize their own benefits, so they can not optimize the whole supply chain, thus forming double marginal benefits (Yan et al., 2020; Zhang et al., 2021). To coordinate the supply chain, revenue-sharing, cost-sharing and price discount contracts are designed (Zhao et al., 2020; Xu et al., 2020; Hosseini-Motlagh et al., 2020). But considering market segmentation and showrooming effect, coordination contract needs to be redesigned. A three-parameter contract in a multi-channel environment affected by showrooming effect is designed, which can coordinate the manufacturer and the retailer (Basak et al., 2017). Considering the market segmentation, mathematical models for single channel coordination that integrate price differentiation and demand leakage aspects for green and regular products are proposed (Raza and Govindaluri, 2019). However, coordination contracts considering showrooming effect and market segmentation in an O2O supply chain is still not investigated. In this study, we will put forward a contract to coordinate an O2O supply chain with market segmentation and showrooming effect.

More specifically, we incorporate market segmentation and showrooming effect into supply chains with different structure consisting of a manufacturer and a retailer. Five scenarios are examined: (1) the decentralized case in a single-channel supply chain with showrooming service (Model O), (2) the decentralized case in an O2O supply chain without showrooming service (Model W), (3) the decentralized case in an O2O supply chain with showrooming service (Model D), (4) the centralized case in an O2O supply chain with showrooming service (Model I), and (5) the cooperation case in an O2O supply chain with showrooming service (Model C). The comparison of the optimal results of single-channel and dual-channel supply chains is used to analyze the impact of market segmentation on performance of supply chains. In the O2O supply chain, the comparison of optimal results with and without showrooming service is used to analyze the influence of showrooming effect. The comparison of the optimal results under centralized and decentralized cases is used to propose the coordination contract.

This research attempts to address the following four questions: (1) How to derive the optimal pricing and service level decisions, demands and profits in the five models O , W , D , I and C

by considering the impact of market segmentation and showrooming effect? (2) How the market segmentation and showrooming effect affect performance of the O2O supply chain? (3) Which is the optimal channel structure and what the conditions of using single-channel or dual-channel supply chain with market segmentation and showrooming effect? (4) How can the O2O supply chain with market segmentation and showrooming effect be coordinated?

The remainder of this paper is organized as follows. Section 2 reviews the relevant literatures. Section 3 states the Problem description and model hypothesis. The games of single-channel and O2O supply chains with market segmentation and showrooming effect are investigated in Section 4. Section 5 analyzes the centralized scenario and puts forwards a contract to coordinate the O2O supply chain with showrooming effect. Numerical analysis is illustrated in Section 6. Section 7 concludes this research.

2. LITERATURE REVIEW

Our research is closely related to four streams of literature: e-commerce and customer behavior, the application of market segmentation, supply chain with showrooming effect, and dual-channel Supply chain coordination.

2.1 E-Commerce and Customer Behavior

Under the environment of E-commerce, consumers' purchasing behavior has changed (Lysenko-Ryba and Zimon, 2021; Gupta et al., 2021; Zimon et al. 2020; Zhang and You, 2020). Busalim et al. (2021) proposed a new model for social commerce customer engagement. Kang et al. (2021) developed a research model using real-time data to investigate the dynamic effect of interactivity on customer engagement behavior through tie strength in live streaming commerce. Saruchera and Asante-Darko (2021) provided evidence on how reverse logistic and organizational culture provide benefits specifically to the operational performance of an organization. Kumar and Ayodeji (2021) investigated the five factors that influence the online customers repeat purchase intention on the basis of the means end chain theory and prospect theory. Ballestar et al. (2018) showed how the customer's role within the cashback website's social network determines the customer's behavior commercial activity on the website. Zimon et al. (2020) showed standardized management systems are useful in supply chain management regardless of the role that the organization plays in the supply chain. Liu et al. (2020) drew on the cross-network effect theory to explore whether and how a B2B e-commerce platform firm's congruent customer orientation strategic initiatives toward sellers or buyers affect the firms' performance. Enterprises need to consider consumer behavior when making decisions.

2.2 The Application of Market Segmentation

More and more scholars began to pay attention to the application of market segmentation theory (Liu et al., 2019; Arias-Oliva et al., 2020; Song et al., 2019). Most of the existing studies put forward the method of market segmentation (Kieu et al., 2018) and use market segmentation as a means of marketing to participate in competition (Kim and Park, 2020). For instance, Zhou et al. (2020) proposed a methodology integrating RFM with the sparse K-means clustering algorithm, which is suitable for handling large, high-dimensional and sparse consumer data. Murray et al. (2017) solved customer market segmentation problem by applying data mining methods to identify behavior patterns in historical noisy delivery data. Wong (2020) constructed a fuzzy goal programming model focusing on the importance of a supplier portfolio and order allocation under green market segmentation. Zhou et al. (2020) proposed a model-based market segmentation approach to identify and investigated existing and potential aviation markets. Qin et al. (2020) and Que et al. (2018) explored the impacts of market segmentation on environmental efficiency. Liu et al. (2019) proposed a new multiply criteria decision aiding approach for market segmentation that integrates preference analysis and segmentation decision within a unified framework. The above research gives the methods and benefits

of market segmentation. However, market segmentation in the supply chain will lead to consumer's self-selection behavior, which will affect the decision-making of supply chain members (Zhang et al., 2017; Zhang et al., 2015). Limited research focused on the negative effects of market segmentation. Xia et al. (2015) constructed a theoretical model to study the competition and market segmentation of call centers in the call center service supply chain. Agi and Yan (2020) investigated product line expansion based on the consumers' willingness to pay for the green feature of the product. Zhang et al. (2020) investigated market targeting and information sharing problem with social influences in a luxury supply chain. The above research indicates that market segmentation has significant impact on decisions of supply chain members. But the joint influence of market segmentation and showrooming effect is less considered.

2.3 Supply Chain with Showrooming Effect

The influence of offline showrooms on the online and offline demands of consumers and the decision-making of supply chain members had been paid attention (Moorthy et al., 2018; Zhang and Wang, 2019). Fernández et al. (2018) found that webroomers emerge as individuals who engage in a prolonged purchasing process over time. In omnichannel retail, Bell et al. (2018) demonstrated that online-first retailers can realize demand and operational efficiency benefits from opening showrooms. Liu et al. (2020) showed that regardless of the kind of channel structure, a display showroom can generate benefits for the manufacturer, the retailer and the whole omni-channel supply chain. Li et al. (2020) investigated the impacts of the demonstration informativeness on online and offline retail pricing decisions under showrooming behavior. Konur (2021) investigate the equilibrium prices and discuss the implications of different showroom configurations on the prices, demands, and profits of the brands. Basak et al. (2017) analyzed multichannel retailing under showrooming and determined the veracity of the popularly held belief. In supply chain environment, Xia et al. (2019) examined service-level and distribution channel decisions for two competing supply chains with a focus on how service competition affects the channel structure. Li et al. (2019) investigated the influence of the showrooming effect on firms' pricing and service effort in a dual-channel supply chain. Basak et al. (2020) analyzed the effect of wholesale prices set by the manufacturer on the retail prices of the products in a multi-channel environment affected by showrooming. It is worth noting that the showrooming effect has a significant impact on supply chain members' decisions about pricing, service level and channel structure. This motivates us to consider the showrooming effect in O2O supply chain.

2.4 Dual-Channel Supply Chain Coordination

In dual-channel supply chain, in order to alleviate the channel conflict and double marginal effect, scholars have designed a large number of coordination contracts, including two-part tariff contract, revenue sharing and so on (Zhang et al., 2020; Aslani and Heydari, 2019; Wang et al., 2016; Zhang et al., 2021; Liu et al., 2019; Wang et al., 2021). Jabarzadeh and Rasti-Barzoki (2020) analyzed how different game structures affect the optimal pricing and quality decisions as well as supply chain members' profit and designed profit-sharing contract. Zhang and Wang (2018) put forward a two-part tariff contract to coordinate the dual-channel supply chain and analyzed the influence of service value on the decisions. Considering consumer behavior, Feng et al. (2017) and Wang et al. (2020) proposed two complementary contracts: a two-part tariff contract and a profit-sharing contract, which succeed in coordinating the reverse supply chain system. Li et al. (2016) put forward an improved risk-sharing contract to ensure that both supply chain members achieve a win-win outcome. Zhu et al. (2020) verified that the joint contracts of revenue sharing contract and buyback contract can coordinate a dual-channel supply chain under uncertainties of yield and demand. Considering service level and sales effort, Wu et al. (2020) designed a revenue sharing contract between the recycling center and third-party recycler to coordinate the dual channel reverse supply chain considering service level. Ranjan and Jha (2019) investigated the pricing strategies and coordination mechanism between the

members by considering green quality and sales effort. Xie et al. (2017) developed a revenue-sharing mechanism under O2O's closed-loop supply chain. These aforementioned papers all highlighted that coordination mechanisms play a significant role in dual-channel supply chain, but less attention is paid to the coordination mechanism with market segmentation and showrooming effect, especially in O2O supply chain. Therefore, our study will investigate the effect of market segmentation and showrooming effect on decisions of O2O supply chain members, and design a coordination contract to improve supply chain members' profits. The main contributions of this paper are as follows:

1. Exploring whether the manufacturer adopts the O2O supply chain and the retailer provides the offline showroom service, and the decision-making of the supply chain is investigated by considering market segmentation and showrooming effect.
2. Structuring five dynamic game models under the restriction of consumer behavior to analyze the effect of market segmentation and showrooming effect on the decisions of supply chain, and an optimal channel structure and its application conditions are put forwards.
3. Putting forward a contract to coordinate the O2O supply chain by considering both market segmentation and showrooming effect, which can achieve a win-win situation.

3. PROBLEM DESCRIPTION AND MODEL HYPOTHESIS

We consider a supply chain consisting a manufacturer and a retailer. Firstly, the manufacturer produces one kind of products and sells products to the retailer. Secondly, the retailer sells products to customers via offline channel, or sells products to customer via both offline and online channels, respectively. We denote these two supply chain structures as single-channel and O2O supply chains.

Based on the problem description, we employ the symbols and notation given in Table 1. To make the analysis tractable, the following assumptions are made:

Assumption 1 Customers make their purchase options by aiming to maximize their utilities. Customers' willingness-to-pay for a product via online channel is assumed to be a fraction μ ($0 \leq \mu \leq 1$) of that for products via offline channel, and the service level offered by the retailer also affects customers' utilities (Maher, 2020; Örsdemir et al., 2014).

Based on Assumption 1, a customer's utility of buying products via online or offline channel is $U_d = \mu v - p_d + \alpha s$ or $U_r = v - p_r + s$ (Li et al., 2019), which will be used to describe the market segmentation and customer self-selection behavior.

Assumption 2 In O2O supply chain, rational customers will buy products only when the utility is greater than zero ($U_{dd} \geq 0$ and $U_{rr} \geq 0$), and they will buy products through the channel that makes their utilities the greatest ($U_{dd} \geq U_{dr}$ and $U_{rr} \geq U_{rd}$) (Zhang et al., 2017; Hua et al., 2011).

Assumption 3 The market demand in each channel is assumed to be $D_r = \lambda M + s$ and $D_d = (1 - \lambda)M + \alpha s$ (Zhang et al., 2017; Li et al., 2019).

Assumption 4 Following Xia et al. (2018) and Liu et al. (2016), the service cost is represented as $C(s) = \frac{ks^2}{2}$, $k > 0$, which satisfies that $C(0) = 0$, $\frac{dC(s)}{ds} > 0$, and $\frac{d^2C(s)}{ds^2} > 0$.

Assumption 5 The market demand M and the service cost coefficient k are sufficiently large and are significantly greater than the other parameters of the model (Xia et al., 2018).

Table 1. Symbols and notations

Symbol	Definition
M	Basic market demand
$\lambda / 1 - \lambda$	Demand proposition of the offline/online channel
c	Production cost per unit of products
k	Service cost coefficient
μ	Channel acceptance coefficient
α	Showrooming effect coefficient
w	Wholesale price per unit of products
s	Service level offered by the retailer
p	Retail price per unit of products
$C(s)$	Service cost
D_f	Market demand of products in channel f , $f \in \{d, r\}$
U_{fh}	Utility of consumers in channel f buying products via channel h , $f, h \in \{d, r\}$
π_j^i	Profit of supply chain member j in model i , $j \in \{m, r\}$, $i \in \{O, W, D, I, C\}$

4. EQUILIBRIUM ANALYSIS

In this section, we derive the equilibrium results for the three models, O , W and D . The models O and W are set as benchmark models, which are compared with the model D to respectively highlight the effect of market segmentation and showrooming effect.

4.1. Single-Channel Supply Chain with Showrooming Service (Model O)

In the model O , the manufacturer firstly decides the wholesale price w^O , and then the retailer decides the price p^O and service level s^O . They play the manufacturer-dominant Stackelberg game. In this case, it does not exist customer self-selection behavior, and only the individual rational constraint ($U_{rr} \geq 0$) needs to be satisfied. The optimization model is described as:

$$\begin{aligned}
 \max_{w^O} \pi_m^O &= (w^O - c)(\lambda M + s^O) \\
 \max_{p^O, s^O} \pi_r^O &= (p^O - w^O)(\lambda M + s^O) - ks^{O2}/2 \\
 s.t. \quad v - p^O + s^O &\geq 0
 \end{aligned} \tag{1}$$

By using the reverse induction, we obtain the optimal results: $s^{O*} = \frac{(3-k)\lambda M + v - c}{2(k-2)}$, $w^{O*} = \frac{(k-1)\lambda M + v + c}{2}$, $p^{O*} = v + s^{O*}$

Proof. See Appendix A.

$$\begin{aligned} \text{Therefore, the demand and profits are given as } D^{O*} &= \lambda M + \frac{(3-k)\lambda M + v - c}{2(k-2)}, \\ \pi_m^{O*} &= \frac{[(k-1)\lambda M + v - c]^2}{4(k-2)} \\ \pi_r^{O*} &= \frac{[(1+2k-k^2)\lambda M + (k-1)(v-c)][(k-1)\lambda M + (v-c)]}{4(k-2)^2} - \frac{k[(3-k)\lambda M + (v-c)]^2}{8(k-2)^2} \\ \pi^{O*} &= \frac{2[(3-k)\lambda M + (2k-3)(v-c)][(k-1)\lambda M + (v-c)] - k[(3-k)\lambda M + v - c]^2}{8(k-2)^2} \end{aligned}$$

4.2. O2O Supply Chain without Showrooming Service (Model W)

In the model W , the manufacturer firstly decides the wholesale price w^W , and then the retailer decides the prices p_r^W and p_d^W . They play the manufacturer-dominant Stackelberg game. In this case, individual rational ($U_{dd} \geq 0$ and $U_{rr} \geq 0$) and incentive compatible ($U_{dd} \geq U_{dr}$ and $U_{rr} \geq U_{rd}$) constraints need to be satisfied. The optimization model is described as:

$$\begin{aligned} \max_{w^W} \pi_m^W &= (w^W - c)M \\ \max_{p_d^W, p_r^W} \pi_r^W &= (p_d^W - w^W)(1-\lambda)M + (p_r^W - w^W)\lambda M \\ \text{s.t. } \mu v - p_d^W &\geq 0 \\ v - p_r^W &\geq 0 \\ \mu v - p_d^W &\geq v - p_r^W \\ v - p_r^W &\geq \mu v - p_d^W \end{aligned} \quad (2)$$

Using the reverse induction to solve the model (2) gives the optimal results as $p_d^{W*} = \mu v$, $p_r^{W*} = v$, $w^{W*} = \mu v$.

Proof. See Appendix B.

Therefore, the demands and profits are given as $D_d^{W*} = (1-\lambda)M$, $D_r^{W*} = \lambda M$, $D^{W*} = M$,

$$\pi_m^{W*} = (\mu v - c)M, \pi_r^{W*} = (v - \mu v)\lambda M, \pi^{W*} = (\mu v - c)(1-\lambda)M + (v - c)\lambda M.$$

4.3. O2O Supply Chain with Showrooming Service (Model D)

In the model D , the manufacturer firstly decides the wholesale price w^D , and then the retailer decides the prices p_r^D , p_d^D and the service level s^D . They play the manufacturer-dominant Stackelberg game. In this case, individual rational ($U_{dd} \geq 0$ and $U_{rr} \geq 0$) and incentive compatible ($U_{dd} \geq U_{dr}$ and $U_{rr} \geq U_{rd}$) constraints need to be satisfied. The optimization model is described as:

$$\begin{aligned}
 \max_{w^D} \pi_m^D &= (w^D - c)(M + (1 + \alpha)s^D) \\
 \max_{p_r^D, p_d^D, s^D} \pi_r^D &= (p_d^D - w^D)((1 - \lambda)M + \alpha s^D) + (p_r^D - w^D)(\lambda M + s^D) - ks^{D^2}/2 \\
 s.t. \quad \mu v - p_d^D + \alpha s^D &\geq 0 \\
 v - p_r^D + s^D &\geq 0 \\
 \mu v - p_d^D + \alpha s^D &\geq v - p_r^D + \alpha s^D \\
 v - p_r^D + s^D &\geq \mu v - p_d^D + s^D
 \end{aligned} \tag{3}$$

Using the reverse induction to solve the model (2) gives the optimal results as
 $w^{D*} = \frac{(k - \alpha - \alpha^2)M + (1 + \alpha)(\alpha\mu + 1)v + (1 + \alpha)^2c}{2(1 + \alpha)^2}$, $s^{D*} = \frac{(3(1 + \alpha)\alpha - k)M + (1 + \alpha)(\alpha\mu + 1)v - (1 + \alpha)^2c}{2(1 + \alpha)(k - 2\alpha(1 + \alpha))}$,
 $p_d^{D*} = \mu v + \alpha s^{D*}$, $p_r^{D*} = v + \alpha s^{D*}$.

Proof. See Appendix C.

Therefore, the demands and profits are given as:

$$\begin{aligned}
 D_d^{D*} &= (1 - \lambda)M + \alpha s^{D*}, \quad D_r^{D*} = \lambda M + s^{D*}, \quad D^{D*} = M + (1 + \alpha)s^{D*}, \\
 \pi_m^{D*} &= (w^{D*} - c)(M + (1 + \alpha)s^{D*}), \\
 \pi_r^{D*} &= (\mu v + \alpha s^{D*} - w^{D*})((1 - \lambda)M + \alpha s^{D*}) + (v + \alpha s^{D*} - w^{D*})(\lambda M + s^{D*}) - \frac{ks^{D*2}}{2}, \\
 \pi^{D*} &= (\mu v + \alpha s^{D*} - c)((1 - \lambda)M + \alpha s^{D*}) + (v + \alpha s^{D*} - c)(\lambda M + s^{D*}) - \frac{ks^{D*2}}{2}.
 \end{aligned}$$

4.4. Comparing Analysis of Equilibrium Results

In the model D , by analyzing the effects of channel acceptance and showrooming effect coefficients on the optimal service level, retail prices and wholesale price, we have the following Proposition 1:

Proposition 1: (1) $\frac{\partial s^{D*}}{\partial \alpha} > 0$, $\frac{\partial s^{D*}}{\partial \mu} > 0$; (2) $\frac{\partial p_d^{D*}}{\partial \alpha} > 0$, $\frac{\partial p_r^{D*}}{\partial \alpha} > 0$, $\frac{\partial p_d^{D*}}{\partial \mu} > 0$, $\frac{\partial p_r^{D*}}{\partial \mu} > 0$; (3)
 $\frac{\partial w^{D*}}{\partial \alpha} < 0$, $\frac{\partial w^{D*}}{\partial \mu} > 0$.

Proof. See Appendix D.

From Proposition 1, we can find that, in the model D , with the increase of consumer channel acceptance coefficient μ and showrooming effect coefficient α , the retailer will increase the service level and retail prices of online and offline channels. The manufacturer will decrease the wholesale price with showrooming effect coefficient increases, but it will increase the wholesale price with consumer channel acceptance coefficient increases. With the enhancement of consumer channel acceptance and showrooming effect, the retailer can improve its offline service level, increases retail prices of online and offline channels and obtain more profits. Showrooming effect can make the manufacturer decrease wholesale price to motive the retailer to increase offline service level.

By comparing the optimal service levels in the models D and O , we have the following Proposition 2.

Proposition 2: If $\mu \geq \hat{\mu}_1$, then $s^{D*} \geq s^{O*}$,

$$\text{where, } \hat{\mu}_1 = \frac{[(3-k)\lambda M + v - c](k - 2\alpha(1 + \alpha))}{(k - 2)\alpha v} + \frac{(1 + \alpha)^2 c - (3(1 + \alpha)\alpha - k)M - (1 + \alpha)v}{(1 + \alpha)\alpha v}.$$

Proof. See Appendix E.

Proposition 2 shows that only when the consumer channel acceptance coefficient μ is higher than the threshold $\hat{\mu}_1$, the optimal service level in the model D is higher than that in the model O . Although the showrooming effect can increase the demand of online channel, due to the investment cost of offline showrooming service, only when the consumer channel acceptance coefficient is large enough, the retailer will provide higher offline showrooming service in O2O supply chain comparing the case in single-channel supply chain. In order to motivate the retailer to improve offline showrooming service, supply chain members should improve the consumer channel acceptance through advertising and other means.

By comparing the optimal retail prices in the model D with the models W and O , we have the following Proposition 3.

Proposition 3: (1) $p_d^{D*} \geq p_d^{W*}$, $p_r^{D*} \geq p_r^{W*}$, and if $\mu \geq \hat{\mu}_2$, then $p_r^{D*} > p_r^{O*}$; (2) if $\mu \geq \hat{\mu}_3$, then $w^{D*} \leq w^{W*}$, and if $\mu \geq \hat{\mu}_4$, then $w^{D*} \geq w^{O*}$,

$$\text{where } \hat{\mu}_2 = \frac{[(3-k)\lambda M + v - c](k - 2\alpha(1 + \alpha))}{(k - 2)\alpha^2 v} + \frac{(1 + \alpha)^2 c - (3(1 + \alpha)\alpha - k)M - (1 + \alpha)v}{(1 + \alpha)\alpha v},$$

$$\hat{\mu}_3 = \frac{(k - \alpha - \alpha^2)M + (1 + \alpha)^2 c + (1 + \alpha)v}{(2 + \alpha)(1 + \alpha)v}, \quad \hat{\mu}_4 = 1 - \frac{[k - \alpha - \alpha^2 - (k - 1)(1 + \alpha)^2 \lambda]M}{\alpha(1 + \alpha)v}.$$

Proof. See Appendix F.

Proposition 3 (1) indicates that the retail prices of offline and online channels in the model D are all higher than these in the model W . That is to say, the retailer will increase the retail prices of online and offline channels when it provides offline showrooming service. Comparing the case in the single-channel supply chain, affected by market segmentation, when the consumer acceptance coefficient μ is higher than the threshold $\hat{\mu}_2$, the retailer will increase the retail price of offline channel in O2O supply chain. Proposition 3 (2) shows that when the consumer acceptance coefficient μ is higher than the threshold $\hat{\mu}_3$, comparing the case without showrooming service, the manufacturer will decrease the wholesale price in O2O supply chain because of showrooming effect. While when the consumer acceptance coefficient μ is higher than the threshold $\hat{\mu}_4$, comparing the case in single-channel supply chain, the manufacturer will increase the wholesale price in O2O supply chain affected by market segmentation.

By comparing the optimal demands in the model D with the models W and O , we have the following Proposition 4.

Proposition 4: (1) $D_d^{D*} \geq D_d^{W*}$, $D_r^{D*} > D_r^{W*}$, and $D^{D*} > D^{W*}$; (2) $D^{D*} > D^{O*}$, and if $\mu \geq \hat{\mu}_1$, then $D_r^{D*} \geq D^{O*}$, where $\hat{\mu}_1 = \frac{[(3-k)\lambda M + v - c](k - 2\alpha(1 + \alpha))}{(k - 2)\alpha v} + \frac{(1 + \alpha)^2 c - (3(1 + \alpha)\alpha - k)M - (1 + \alpha)v}{(1 + \alpha)\alpha v}$.

Proof. See Appendix G.

From Proposition 4, we can find that, comparing the case without offline showrooming service, the offline showrooming service provided by the retailer can increase the demands of offline channel, online channel and supply chain. On the contrary, the retail prices of online and offline channels raised by the retailer increase the demands of offline and online channel because of showrooming effect. Comparing the case in single-channel supply chain, the supply chain demand is increased in O2O supply chain. That is to say, the benefits of showrooming effect can eliminate the adverse impact of market segmentation on consumer self-selection behavior. While only when the consumer channel acceptance coefficient μ is higher than the threshold $\hat{\mu}_1$, the offline demand can be increased in O2O supply chain comparing the case in single-channel supply chain. Therefore, opening up online and offline channels and providing offline showrooming service are beneficial to improve consumer demand.

5. COOPERATIVE CONTRACT DESIGN

Showrooming effect increases the demands of offline and online channels, but it also increases the investment cost for the retailer, therefore, the manufacturer should provide incentive contract to motivate the retailer to invest the offline showrooming service. In this part, the centralized scenario of the O2O supply chain with showrooming effect is firstly analyzed to be as the goal of the cooperation model, and then a service cost sharing contract is designed to coordination the O2O supply chain with showrooming effect.

5.1. Centralized Scenario With Showrooming Service (Model I)

In the model I, the manufacturer and the retailer as a whole to decide the prices p_r^I , p_d^I and the service level s^I to maximize the supply chain profit under the individual rational ($U_{dd} \geq 0$ and $U_{rr} \geq 0$) and incentive compatible ($U_{dd} \geq U_{dr}$ and $U_{rr} \geq U_{rd}$) constraints. The optimization model is described as:

$$\begin{aligned} \max_{p_d^I, p_r^I, s^I} \pi^I &= (p_d^I - c)((1 - \lambda)M + \alpha s^I) + (p_r^I - c)(\lambda M + s^I) - ks^{I^2}/2 \\ \text{s.t.} \quad &\mu v - p_d^I + \alpha s^I \geq 0 \\ &v - p_r^I + s^I \geq 0 \\ &\mu v - p_d^I + \alpha s^I \geq v - p_r^I + \alpha s^I \\ &v - p_r^I + s^I \geq \mu v - p_d^I + s^I \end{aligned} \quad (4)$$

Solving optimization problem (4) gives the optimal results as $s^{I*} = \frac{\alpha M + \alpha(\mu v - c) + v - c}{k - 2\alpha(1 + \alpha)}$, $p_d^{I*} = \mu v + \alpha s^{I*}$, $p_r^{I*} = v + \alpha s^{I*}$.

Proof. See Appendix H.

Therefore, the demands and profit are given as:

$$D_d^{I*} = (1 - \lambda)M + \alpha s^{I*}, D_r^{I*} = \lambda M + s^{I*}$$

$$\pi^{I*} = (\mu v + \alpha s^{I*} - c)((1 - \lambda)M + \alpha s^{I*}) + (v + \alpha s^{I*} - c)(\lambda M + s^{I*}) - \frac{ks^{I*2}}{2}$$

By comparing the optimal results between model I and D , we have the following Proposition 5.

Proposition 5: $s^{I*} > s^{D*}$, $p_d^{I*} \geq p_d^{D*}$, $p_r^{I*} \geq p_r^{D*}$; $D_d^{I*} \geq D_d^{D*}$, $D_r^{I*} \geq D_r^{D*}$, $\pi^{I*} > \pi^{D*}$.

Proof. See Appendix I.

From Proposition 5, we can find that comparing the decentralized scenario (model D), under the centralized scenario (model I), the retailer increases the service level and retail prices of online and offline channels. But demands of online and offline channel are all increased. Thus, the supply chain profit is increased. The centralized game can bring more higher operational efficiency of the O2O supply chain. To improve the O2O supply chain operational efficiency with showrooming effect, a coordination contract should be designed.

5.2. Cooperative Game of O2O Supply Chain (Model C)

In this model C , a service cost sharing contract is designed encourage the retailer to improve the service level, the manufacturer shares γ proposition of service cost, and the retailer shares $1 - \gamma$ proposition of service cost. The manufacturer firstly gives the wholesale price w^C , and then the retailer decides the prices p_r^C , p_d^C and the service level s^C . They play the manufacturer-dominant Stackelberg game and make their decisions to maximize their respective profits. The optimization model is described as:

$$\begin{aligned} \max_{w^C} \pi_m^C &= (w^C - c)(M + (1 + \alpha)s^C) - \gamma ks^{C2}/2 \\ \max_{p_r^C, p_d^C, s^C} \pi_r^C &= (p_d^C - w^C)((1 - \lambda)M + \alpha s^C) + (p_r^C - w^C)(\lambda M + s^C) - (1 - \gamma)ks^{C2}/2 \\ s.t. \quad &\mu v - p_d^C + \alpha s^C \geq 0 \\ &v - p_r^C + s^C \geq 0 \\ &\mu v - p_d^C + \alpha s^C \geq v - p_r^C + \alpha s^C \\ &v - p_r^C + s^C \geq \mu v - p_d^C + s^C \end{aligned} \quad (5)$$

Solving optimization problem (5) gives the optimal results as $s^{C*} = \frac{\alpha M + (\alpha\mu + 1)v - (1 + \alpha)w^{C*}}{(1 - \gamma)k - 2\alpha(1 + \alpha)}$,

$$w^{C*} = \frac{\gamma k \alpha M + \gamma k (\alpha\mu + 1)v - (1 + \alpha)[(1 - \gamma)k - 2\alpha - 2\alpha^2]c}{(k - 2\alpha(1 + \alpha))(1 + \alpha)}, p_d^{C*} = \mu v + \alpha s^{C*}, p_r^{C*} = v + \alpha s^{C*}.$$

Proof. See Appendix J.

Therefore, the demands and profit are given as

$$D_d^{C*} = (1 - \lambda)M + \alpha s^{C*}, D_r^{C*} = \lambda M + s^{C*}, \pi_m^{C*} = (w^{C*} - c)(M + (1 + \alpha)s^{C*}) - \frac{\gamma ks^{C*2}}{2}$$

$$\pi_r^{C^*} = (\mu v + \alpha s^{C^*} - w^{C^*})((1-\lambda)M + \alpha s^{C^*}) + (v + \alpha s^{C^*} - w^{C^*})(\lambda M + s^{C^*}) - (1-\gamma) \frac{ks^{C^*2}}{2}$$

$$\pi^{C^*} = (\mu v + \alpha s^{C^*} - c)((1-\lambda)M + \alpha s^{C^*}) + (v + \alpha s^{C^*} - c)(\lambda M + s^{C^*}) - \frac{ks^{C^*2}}{2}$$

Since $s^{I^*} = s^{C^*}$, we have $p_d^{C^*} = p_d^{I^*}$, $p_r^{C^*} = p_r^{I^*}$, $\pi_m^{C^*} + \pi_r^{C^*} = \pi^{C^*} = \pi^{I^*}$. Therefore, the service cost sharing contract can perfectly coordinate the O2O supply chain with showrooming effect. The service cost sharing contract should bring Pareto improvement after cooperation, and the value range of cost sharing coefficient is described as the following Theorem 1.

Theorem 1: If the cost sharing coefficient γ satisfies $1 - \frac{2(A+B)}{ks^{C^*2}} - \frac{s^{D^*2}}{s^{C^*2}} \leq \gamma \leq \frac{2E}{ks^{C^*2}} + \frac{s^{D^*2}}{s^{C^*2}}$, then $\pi_m^{C^*} \geq \pi_m^{D^*}$, $\pi_r^{C^*} \geq \pi_r^{D^*}$, $\pi_m^{C^*} + \pi_r^{C^*} = \pi^{C^*} = \pi^{I^*}$ where:

$$A = (v + \alpha s^{C^*} - w^{C^*})(\lambda M + s^{C^*}) - (v + \alpha s^{D^*} - w^{D^*})(\lambda M + s^{D^*})$$

$$B = (\mu v + \alpha s^{C^*} - w^{C^*})((1-\lambda)M + \alpha s^{C^*}) - (\mu v + \alpha s^{D^*} - w^{D^*})((1-\lambda)M + \alpha s^{D^*})$$

$$E = (w^{C^*} - c)(M + (1+\alpha)s^{C^*}) - (w^{D^*} - c)(M + (1+\alpha)s^{D^*})$$

Proof. See Appendix K.

Theorem 1 indicates that, when the cost sharing coefficient γ satisfies certain conditions, the service cost sharing contract can perfectly coordinate the O2O supply chain with showrooming effect, and improve the operational efficiency of the O2O supply chain. Under the service cost sharing contract, the profits of the manufacturer and retailer can be heightened. The specific value of cost sharing coefficient γ should be determined according to the power relationship between the manufacturer and retailer.

6. NUMERICAL ANALYSIS

In order to more intuitively describe the influence of consumer channel preference and showrooming effect on the decisions, and analyze the coordination effect of the service cost sharing contract on O2O supply chain with showrooming effect and market segmentation, numerical simulation analysis is carried out. According to the parameter relations in above part, the parameters are set as $k = 30$, $\lambda = 0.4$, $M = 30$, $v = 2000$, and $c = 0.1$. The effects of consumer channel acceptance coefficient μ on service level, price, demand and profit are firstly analyzed, and then the impacts of showrooming effect coefficient α on these supply chain performances are illustrated. At the end, the coordination effect of the service cost sharing contract is presented.

6.1. Effect of Consumer Channel Acceptance Coefficient μ on Supply Chain Performance

In this part, we set $\alpha = 0.4$ and $\mu \in [0, 1]$, then we have $\hat{\mu}_1 = 0.4195$, $\hat{\mu}_2 = 3.6605$, $\hat{\mu}_3 = 0.5481$ and $\hat{\mu}_4 = 0.8204$, the effects of μ on service level, price, demand and profit are shown in the following Figures 1-4.

Figure 1. The effect of consumer channel acceptance coefficient μ on service level

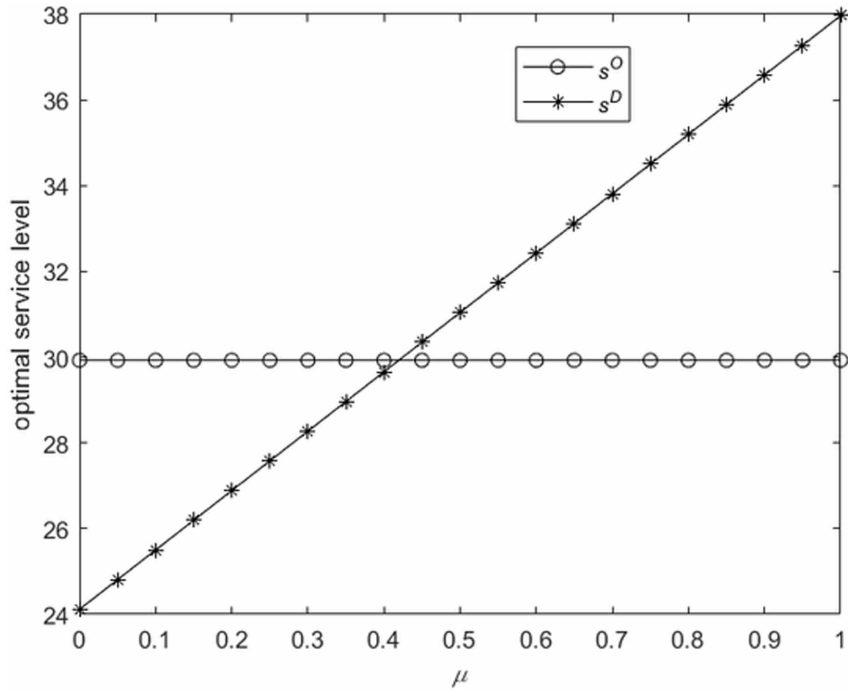


Figure 2a. The effect of consumer channel acceptance coefficient μ on price

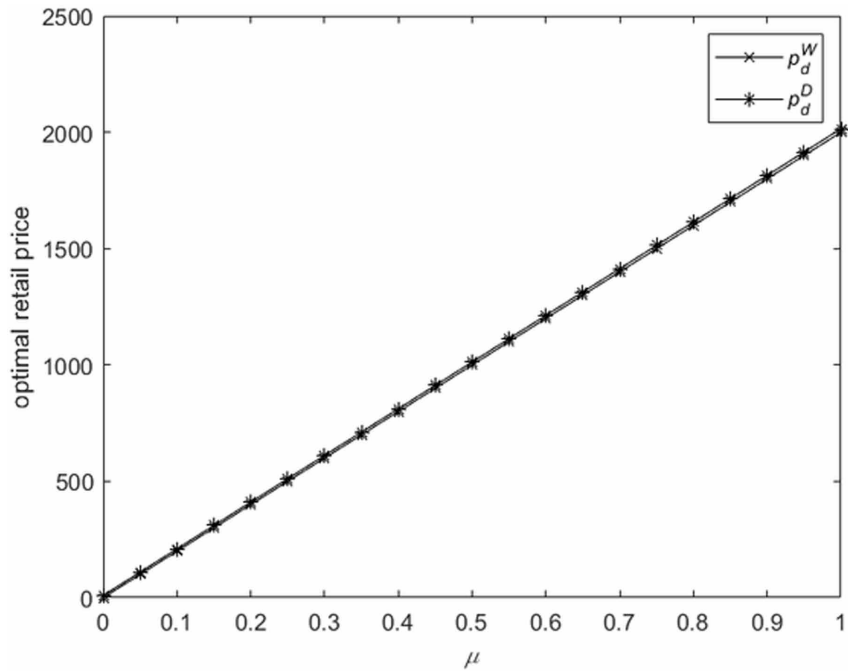


Figure 2b. The effect of consumer channel acceptance coefficient μ on price

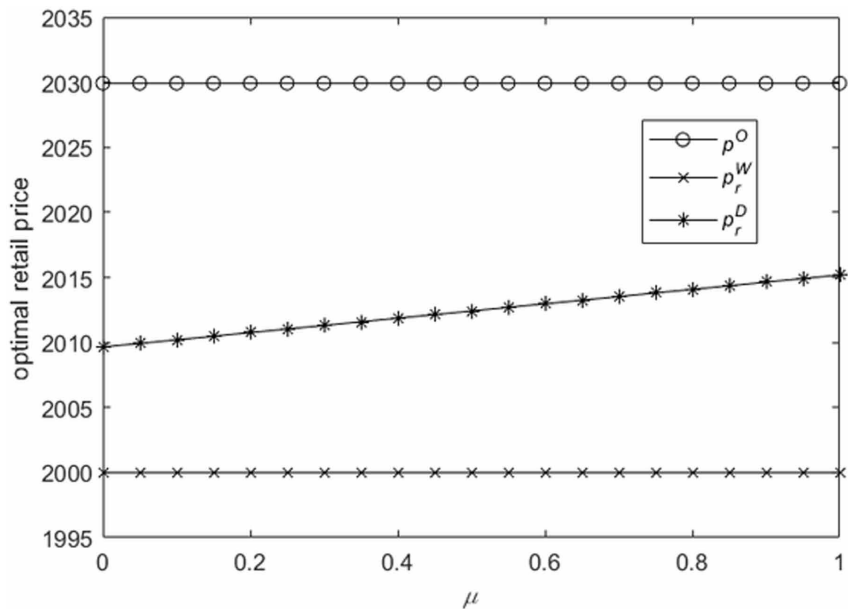


Figure 2c. The effect of consumer channel acceptance coefficient μ on price

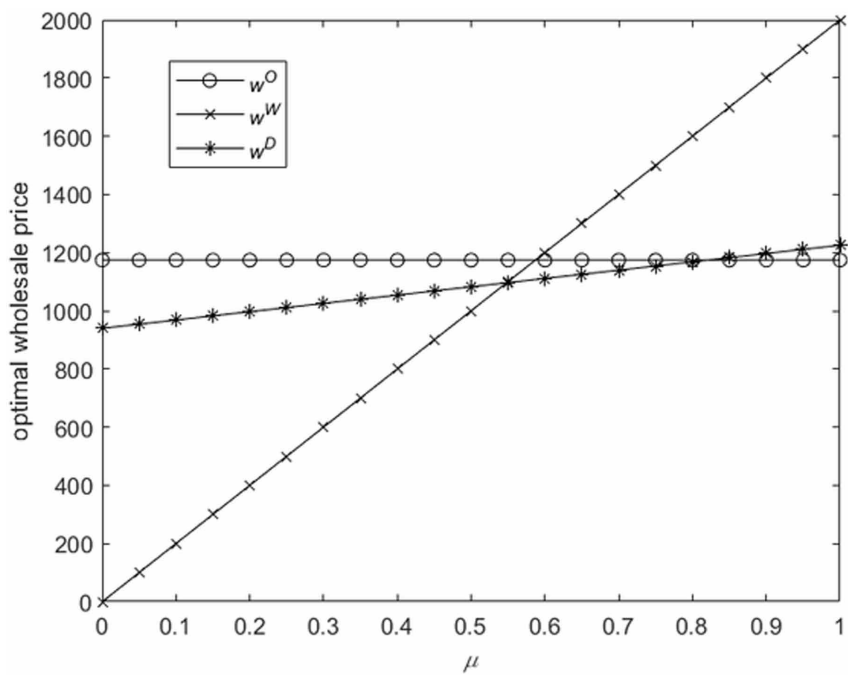


Figure 3a. The effect of consumer channel acceptance coefficient μ on demand

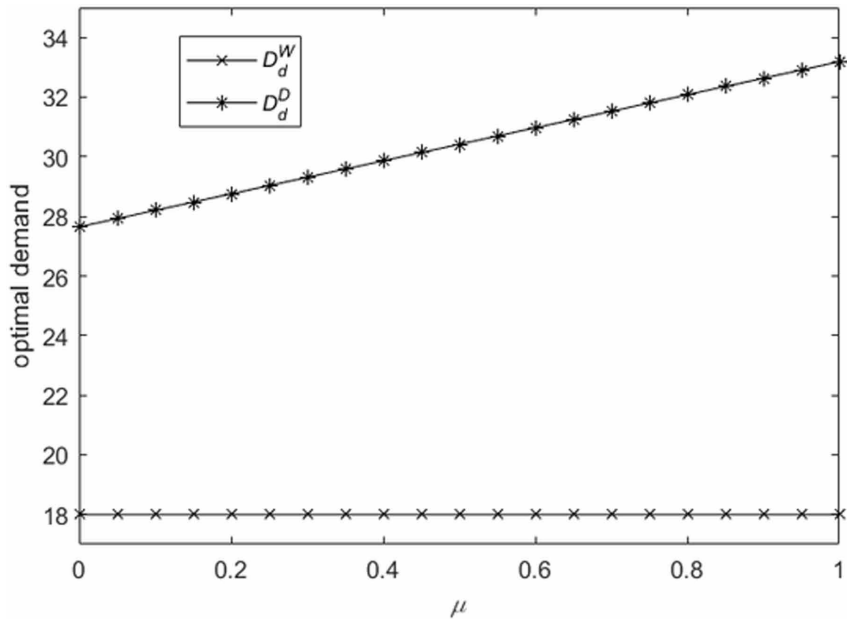


Figure 3b. The effect of consumer channel acceptance coefficient μ on demand

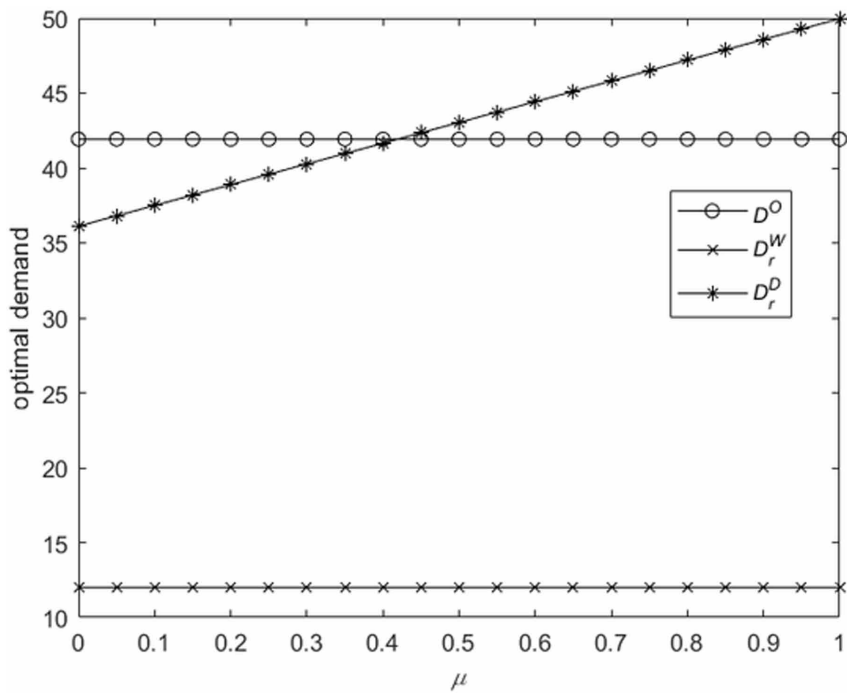


Figure 3c. The effect of consumer channel acceptance coefficient μ on demand

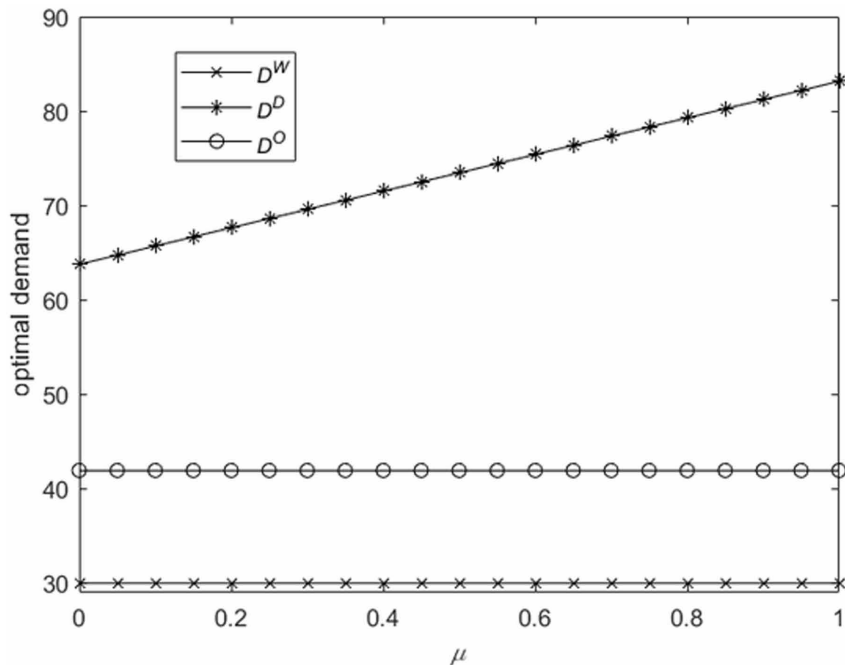


Figure 4a. The effect of consumer channel acceptance coefficient μ on profit

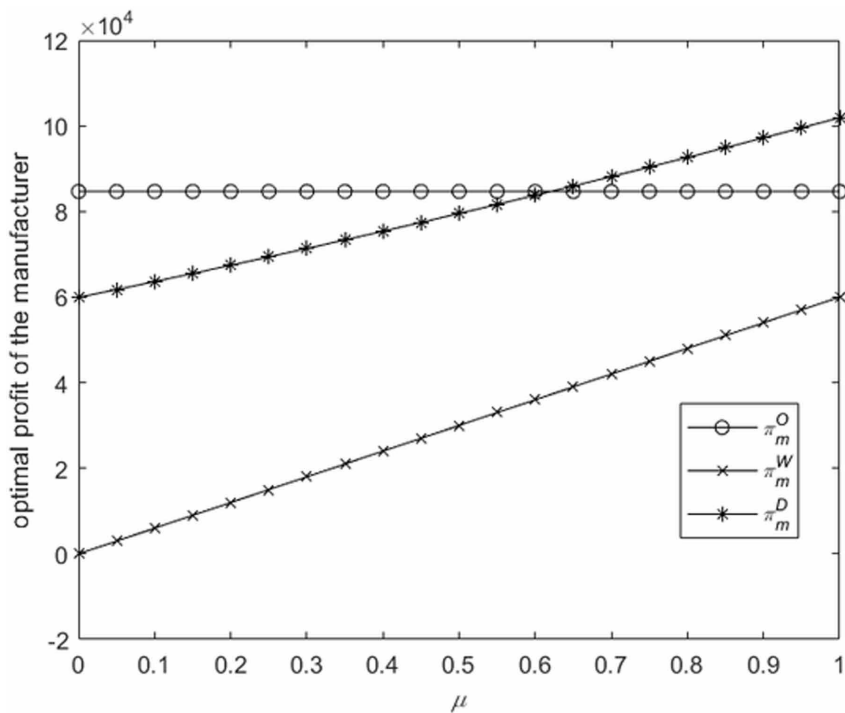


Figure 4b. The effect of consumer channel acceptance coefficient μ on profit

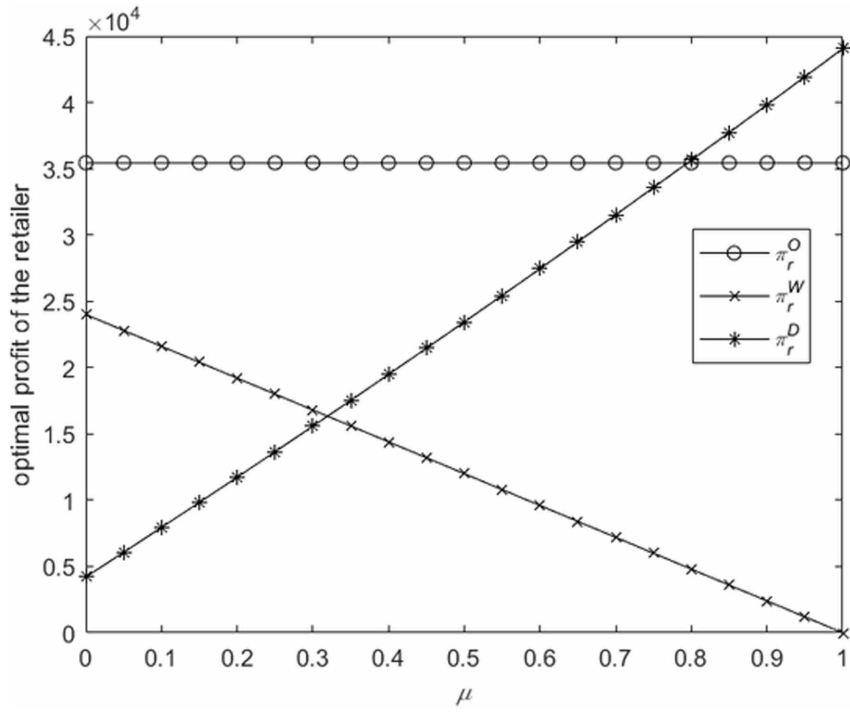
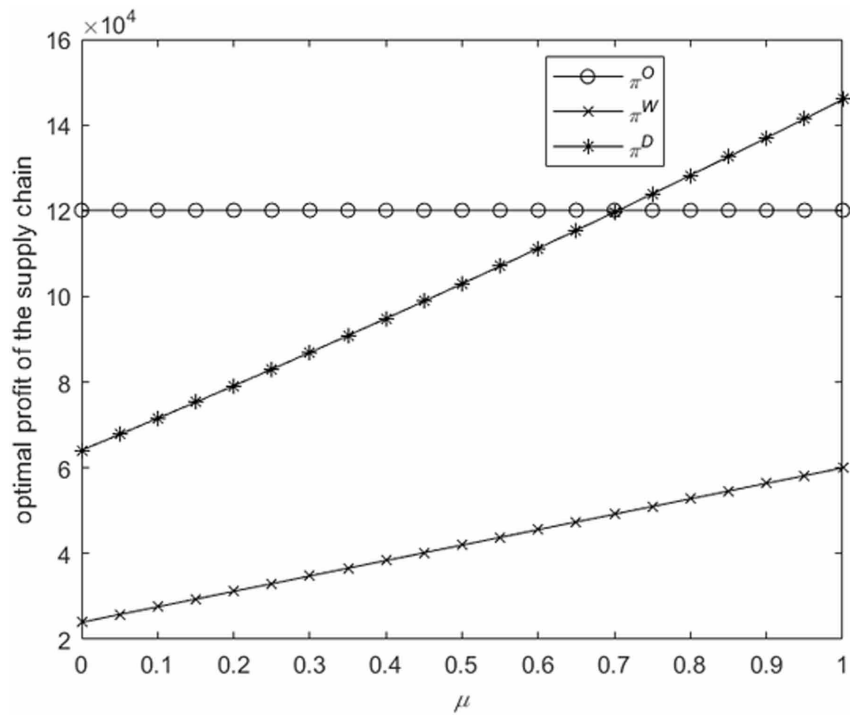


Figure 4c. The effect of consumer channel acceptance coefficient μ on profit



From Figure 1 we can find that, with the increase of consumer channel acceptance coefficient μ , the retailer increases the service level in O2O supply chain. And when the consumer channel acceptance coefficient μ is small ($0 < \mu \leq 0.4195$), comparing the case in single-channel supply chain, the retailer decreases the service level in O2O supply chain. While when the consumer channel acceptance coefficient μ is high ($0.4195 < \mu < 1$), the retailer increases the service level in O2O supply chain. Since in O2O supply chain, it exists market segmentation, when the retailer decides the service level and retail prices, he needs to consider consumers' choice behavior in two channels and the channel competition. Only when the consumer channel acceptance coefficient is very high, the retailer will increase the service level.

Figure 2 indicates that, comparing the case without offline showrooming service, the retailer will increase the retail prices of online and offline channels under most conditions. Because of the showrooming effect, the offline service provided by the retailer can improve the channel recognition of consumers in O2O supply chain, so that the retailer can set higher retail prices to obtain higher profit without reducing consumer utility. Since $\mu < \hat{\mu}_2 = 3.6605$, comparing the case in single-channel supply chain, the retailer decreases the retail price of offline channel in O2O supply chain. Moreover, when $\mu \geq \hat{\mu}_3 = 0.5481$, comparing the case without offline showrooming effect, the manufacturer decreases the wholesale price in O2O supply chain. And when $\mu \geq \hat{\mu}_4 = 0.8204$, the manufacturer increases the wholesale price in O2O supply chain. While comparing the case in the model O , the manufacturer always sets lower wholesale price when the consumer channel acceptance is small by considering the effect of market segmentation, only when the consumer channel acceptance is very higher, the manufacturer can set higher wholesale price to obtain higher profit.

From Figure 3 we can find that, with the increase of consumer channel acceptance coefficient μ , the demands of two channels in the model D are all increasing. Because when the consumer channel acceptance increases, the retailer will provide higher service level, and then the demands increases. The demands of online and offline channels in the model D is always higher than these in the model W . Since the showrooming effect can increase the consumer utility and demand. Comparing the case in the model O , the demand of offline channel in the model D is higher only when the consumer channel acceptance is very high ($\mu \geq \hat{\mu}_1 = 0.4195$), because the retailer provides higher offline service level. But the whole demand in the model D is always higher than that in the model O or W . That is to say, the retailer should open up online and offline channels and provide offline showrooming service are beneficial to improve the consumer demand.

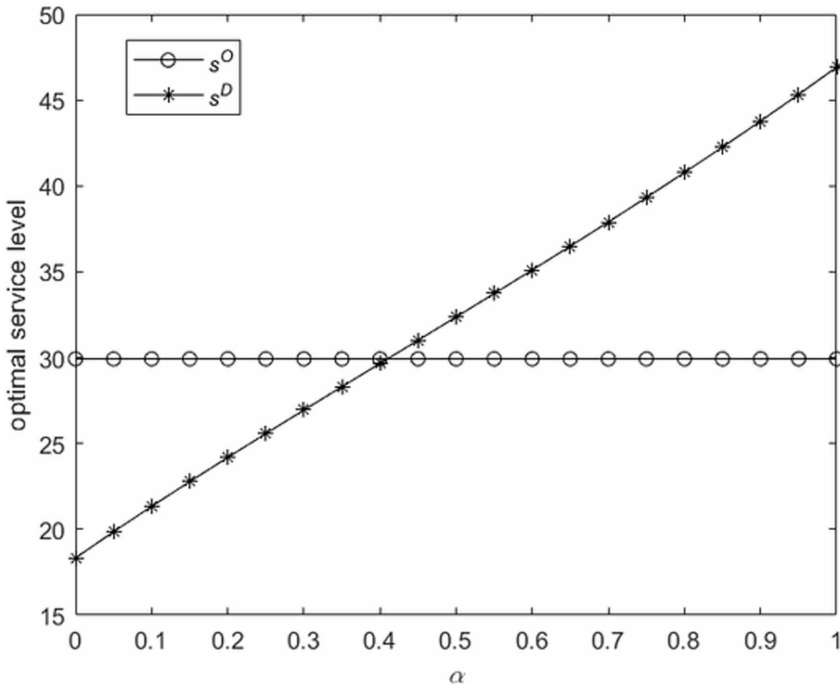
Figure 4 indicates that, with the increase of the consumer channel acceptance coefficient μ , the profits of the manufacturer, retailer and supply chain increase in the model D . In the three models, the change trends of the profits of the manufacturer and supply chain are the same. When the consumer channel acceptance coefficient is very small, the profits of the manufacturer, retailer and supply chain are the highest in the model O . While when the consumer channel acceptance coefficient is very high, the profits of the manufacturer, retailer and supply chain are the highest in the model D . That is to say, showrooming effect improves the profits of the members and systems of the supply chain, which is beneficial to the operation of the supply chain. Affecting by market segmentation, when the consumer channel acceptance is small, the single-channel structure is optimal, while when the consumer channel acceptance is high, the O2O structure is optimal.

6.2. Effects of Showrooming Coefficient α on Supply Chain Performances

In this part, we set $\mu = 0.4$ and $\alpha \in [0, 1]$. Thus, the impacts of α on these supply chain performances are illustrated in the following Figures 5-8.

From Figure 5 we can find that, with the increase of showrooming effect coefficient α , the retailer increases the service level. When the showrooming effect coefficient is small, comparing the case in single-channel supply chain, the retailer decreases the service level in O2O supply chain.

Figure 5. The effect of showrooming effect coefficient α on service level



While when the showrooming effect coefficient is high, the retailer increases the service level in O2O supply chain. That is to say, when the intensity of showrooming effect is large, the retailer is willing to improve the showrooming service level, and makes up for the increase of service cost through the benefits brought by the increase of demand.

Figure 6 indicates that, with the increase of showrooming effect coefficient α , the retailer will increase the retail prices of online and offline channels, while the manufacturer will decrease the wholesale price. Comparing the case without offline showrooming service, the retailer and the manufacturer will respectively increase the retail prices and wholesale price in O2O supply chain with offline showrooming service. Comparing the case in single-channel supply chain, when the showrooming effect is small, considering the market segmentation and consumer self-selection behavior, the retailer cannot set high retail prices, while the manufacturer will set high wholesale price to obtain more profit in O2O supply chain. When the showrooming effect is high, the retailer will increase the retail prices, but the manufacturer will decrease the wholesale price.

From Figure 7 we can find that, in the model D , with the increase of the showrooming effect coefficient, the demands of offline, online and total channels are all increasing. The demands of online and offline channels in the model D are all higher than these in the model W . The showrooming effect can increase market demand. When the showrooming effect coefficient is small, the demand of offline channel in the model D is lower than that in the model O . But the total demand in the model D is always higher than that in the model O or W . That is to say, in the model D , the showrooming effect increase the total demand, and the market segmentation does not decrease the total demand. Opening up online and offline channels and providing offline showrooming services not only alleviate the competition between the two channels, but also increase the demand.

Figure 6a. The effect of showrooming effect coefficient α on price

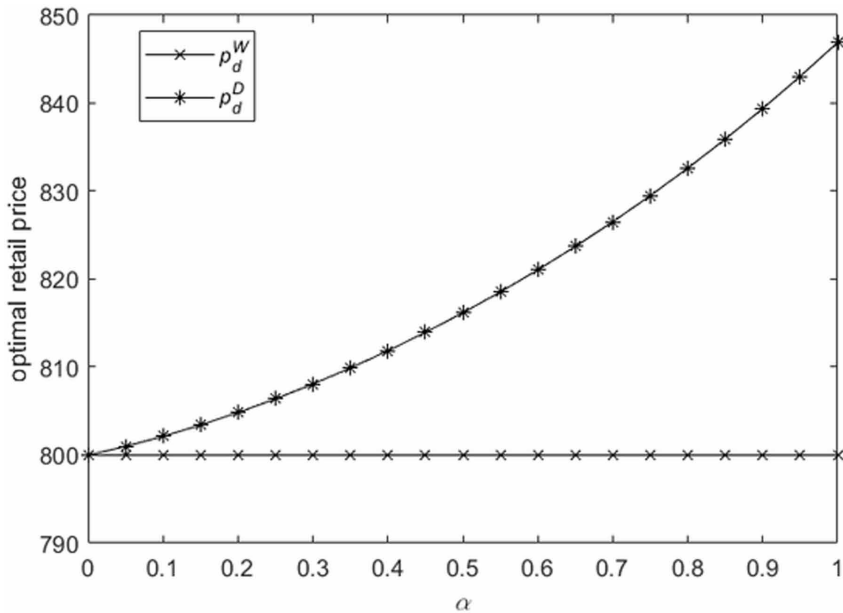
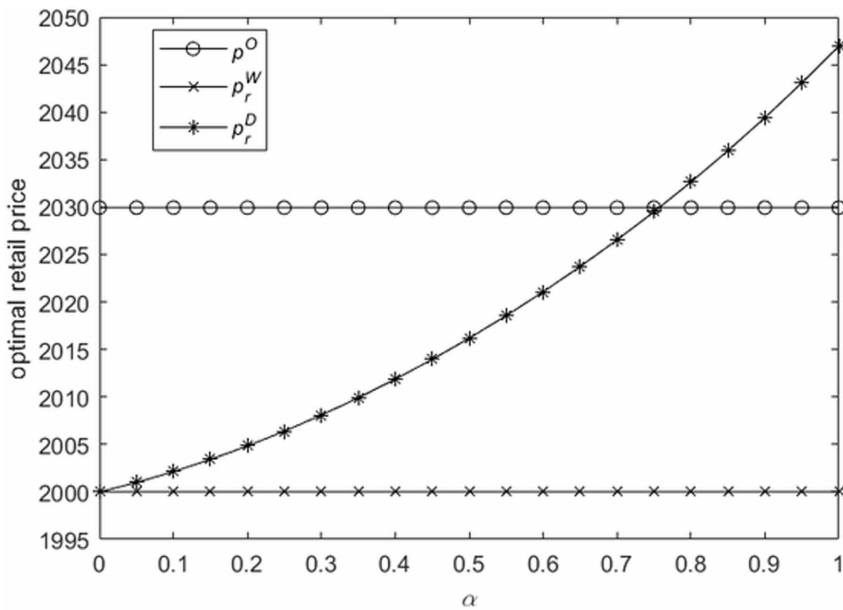


Figure 6b. The effect of showrooming effect coefficient α on price



From Figure 8 we can find that, in the model D , with the increase of showrooming effect coefficient, the profits of the manufacturer, retailer and supply chain are all increasing. The profits of the manufacturer and supply chain in the model D or O are all higher than these in the model W . That is to say, showrooming effect can increase the profits of supply chain and its members.

Figure 6c. The effect of showrooming effect coefficient α on price

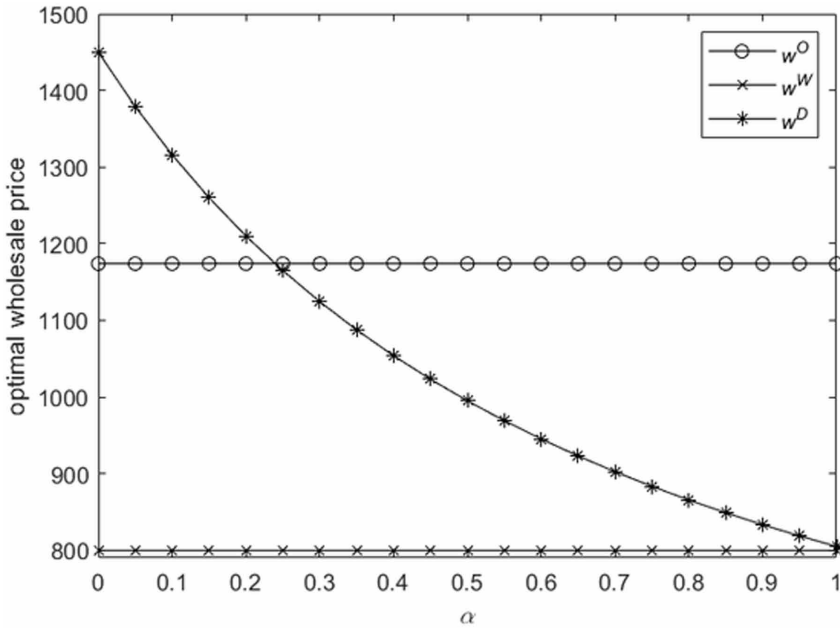


Figure 7a. The effect of showrooming effect coefficient α on demand

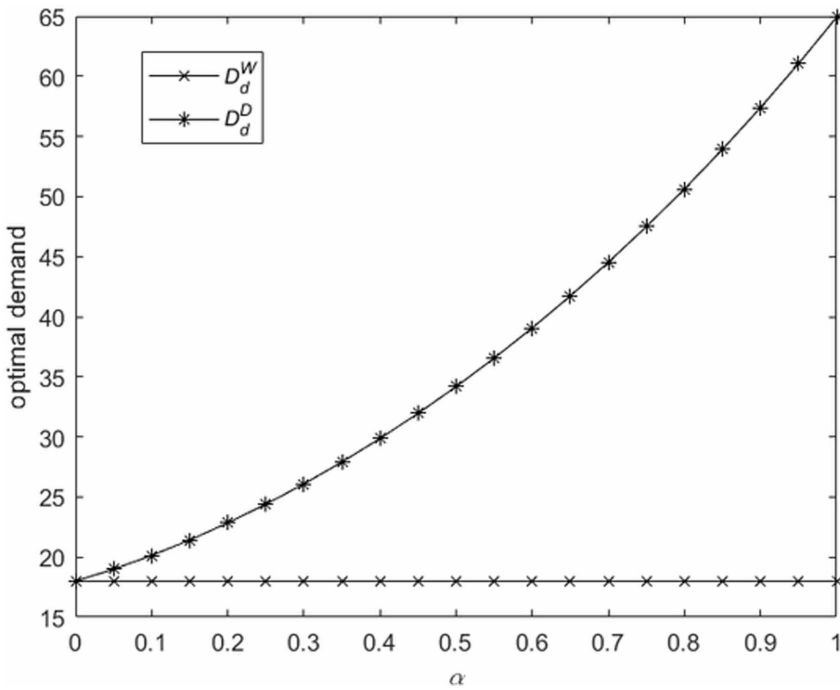


Figure 7b. The effect of showrooming effect coefficient α on demand

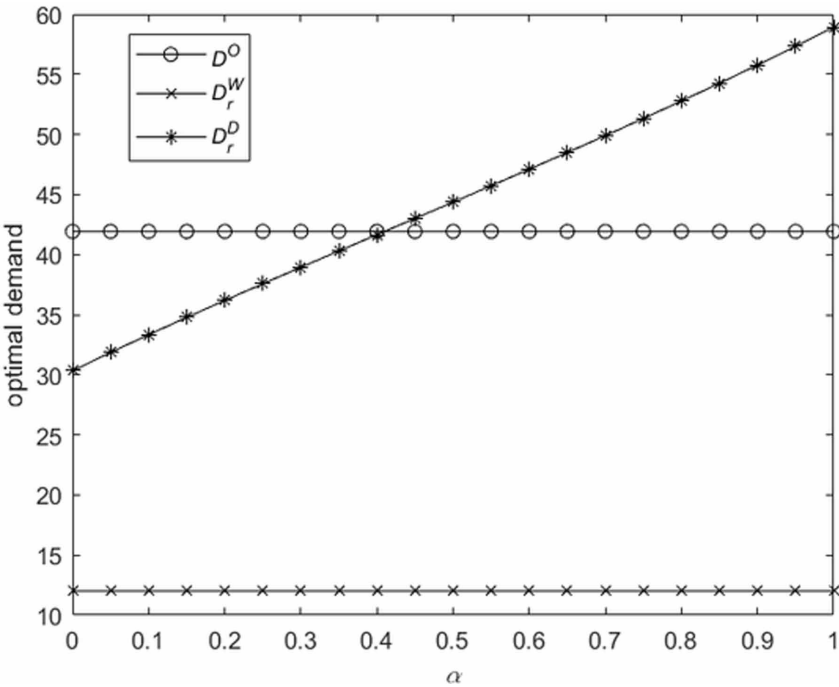


Figure 7c. The effect of showrooming effect coefficient α on demand

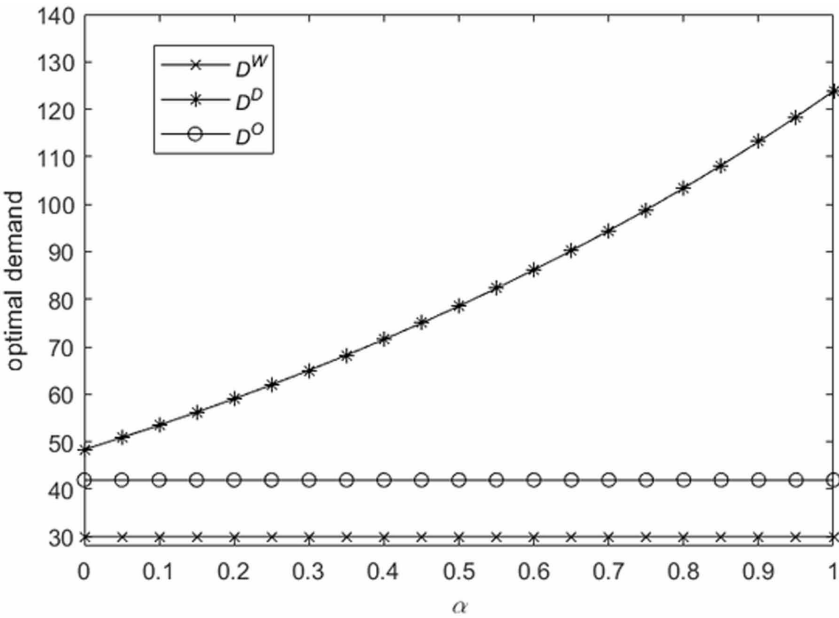


Figure 8a. The effect of showrooming effect coefficient α on profit

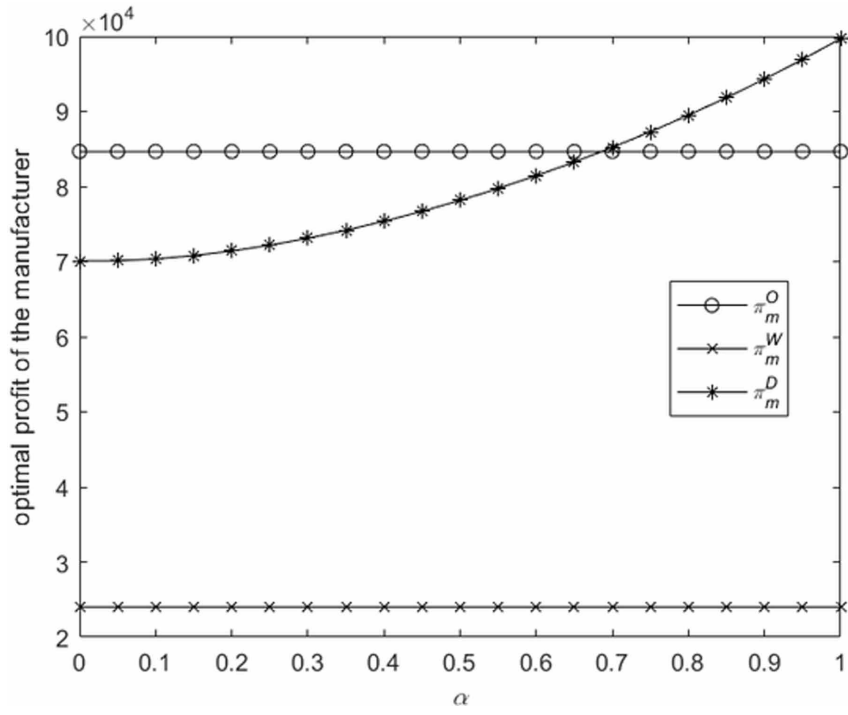


Figure 8b. The effect of showrooming effect coefficient α on profit

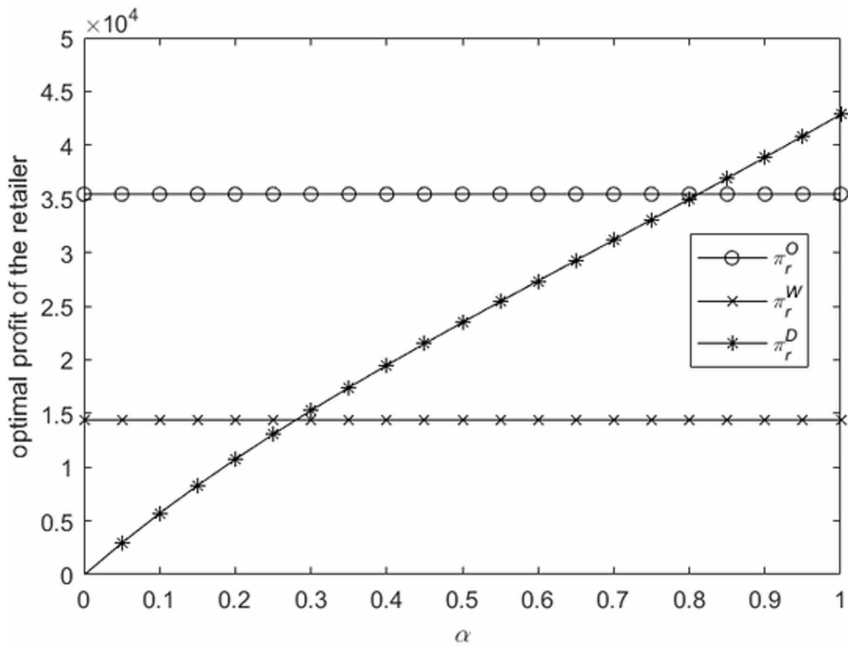
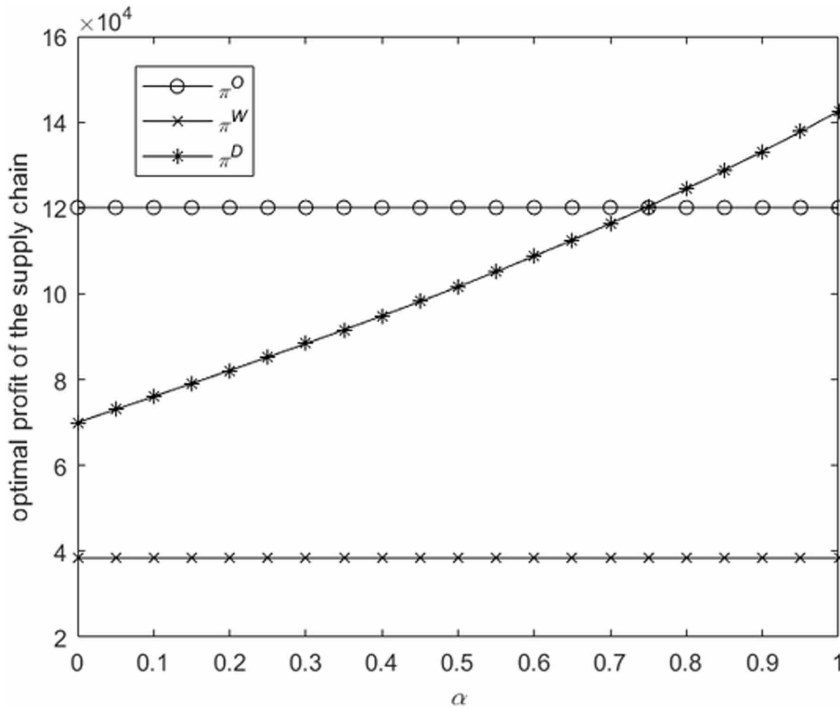


Figure 8c. The effect of showrooming effect coefficient α on profit



When the showrooming effect coefficient is small, the profits of the manufacturer, retailer and supply chain in the model O are the highest, the single-channel structure is optimal, while when the showrooming effect coefficient is higher, the profits of the manufacturer, retailer and supply chain in the model D are the highest, the O2O structure is optimal.

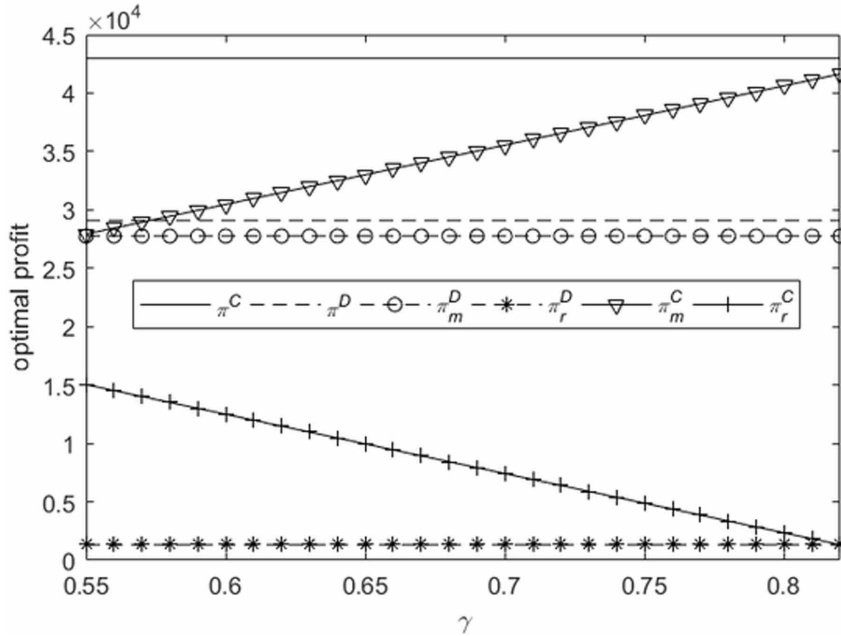
Figure 4 and 8 indicates that, when the consumer channel acceptance and showrooming effect are small, enterprises should adopt single-channel supply chain, while they are high, enterprises should adopt O2O supply chain. In order to realize the successful transformation from single-channel mode to O2O mode, enterprises must improve consumers' channel acceptance and showrooming service effect through advertising and other methods.

6.3. Effects of Cost Sharing Coefficient γ on Supply Chain Performances

In this part, we set $\alpha = 0.4$ and $\mu = 0.4$. According to the value range of cost sharing coefficient γ from the Theorem 1, we have $\gamma \in [0.55, 0.82]$. And then, the changes of profits after using the service cost sharing contract are shown in the following Figure 9.

From Figure 9 we can find that, with the increase of cost sharing coefficient γ , the manufacturer's profit increases, but the retailer's profit decrease in the model C , and they are all higher than these in the model D . Comparing the decentralized scenarios of the O2O supply chain with market segmentation and showrooming effect, the service cost sharing contract can increase the profits of the manufacturer, the retailer and the supply chain, and the Pareto improvement is achieved. Since the supply chain profit under the cooperation scenarios is the same as that under the centralized scenarios, the service cost sharing contract can perfectly coordinate the O2O supply chain with showrooming effect.

Figure 9. The effect of the service cost sharing contract



7. DISCUSSION AND CONCLUSION

7.1 Discussion

Under E-commerce environment, in order to meet the different needs of consumers, market segmentation and offline showroom service have become the means for enterprises to obtain competitive advantage (Basak et al., 2020; Li et al., 2019; Liu et al., 2019; Kieu et al., 2018; Qin et al., 2020). Existing studies show that market segmentation can provide personalized services for consumers and bring benefits to enterprises (Kim et al., 2020; Liu et al., 2019). However, market segmentation will also lead to consumer's self-selection behavior. Considering consumer's choice behavior, how to choose the appropriate channel structure is worthy of further research. In addition, many scholars have also investigated the influence of showrooming effect (Basak et al., 2017; Li et al., 2020). Will retailers provide offline showroom service? Will manufacturers choose O2O supply chain mode, and how to coordination the O2O supply chain?

Different from the existing research, we find that the retailer will provide offline showroom service, which is beneficial for the manufacturer, retailer and supply chain system. Considering the market segmentation, the optimal channel structure depends on the performance characteristics of consumers. When the consumer channel acceptance is small, single-channel structure is optimal, otherwise, O2O structure is optimal. Moreover, a service cost sharing contract is designed to perfectly coordinate the O2O supply chain by considering both market segmentation and showrooming effect.

The findings of the study have a range of implications for enterprise managers. By considering consumer choice behavior, manufacturers can use the research results to constructing the optimal channel structure and encourage retailers to provide better service for consumers, so as to improve the operational efficiency of the supply chain. Retailer can use the information to decide the optimal pricing strategy and offer the appropriate level of offline showroom service. The research conclusions enrich the theoretical understanding of market segmentation and showrooming effect. It also provides

a method of choosing channel structure and new perspective on the design of coordination contract to improve the efficiency of the supply chain system.

7.2 Conclusion

Based on a two-stage supply chain, this paper takes market segmentation and showrooming effect into account, and five models are constructed: O , W , D , I and C . The influence of market segmentation and showrooming effect is analyzed. The results reveal that, (1) in an O2O supply chain, with the increase of channel acceptance and showrooming effect coefficients, the retailer will increase service level and retail prices of online and offline channels. The manufacturer will decrease the wholesale price with showrooming effect coefficient increases, but it will increase the wholesale price with consumer channel acceptance coefficient increases. (2) Considering market segmentation, comparing the single-channel supply chain, in O2O supply chain, only when consumer acceptance is high, the retailer will increase service level and retail price of offline channel, and the manufacturer will increase wholesale price. Although affected by market segmentation, O2O supply chain can increase total demand compared with single-channel supply chain. (3) Showrooming effect makes the retailer increase retail prices of online and offline channel, which increases the demands of online channel, offline channel and supply chain. But it makes the manufacturer decrease wholesale price only when consumer channel acceptance is high. (4) Offering offline service can increase the profits of the manufacturer, retailer and supply chain, the retailer will provide offline service. When the consumer channel acceptance is small, single-channel structure is optimal, on the contrary, O2O structure is optimal. Moreover, a service cost sharing contract is put forward, which can perfectly coordinate the O2O supply chain with market segmentation and showrooming effect.

This paper only considers single-channel and O2O structure supply chains with one manufacturer and one retailer by considering market segmentation and showrooming effect. The decision problem of a more complex supply chain with more types of structure is worth further study. In addition, this research does not consider the decision-making problem of supply chain members with fairness concern behavior. It would be interesting to incorporate supply chain members' fairness concerns into the model and examine their impact on the decisions and coordination of O2O supply chain.

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APPENDIX A. PROOF OF THE OPTIMAL DECISIONS IN MODEL O

From the constraint of model (1), we have $p^O \leq v + s^O$. The profit π_r^O is an increasing function of retail price p^O . Thus, the optimal price is set as to be $p^O = v + s^O$. Substituting $p^O = v + s^O$ into π_r^O , since $\frac{\partial^2 \pi_r^O}{\partial s^{O2}} = 2 - k < 0$, π_r^O is strictly concave in s^O . By setting $\frac{\partial \pi_r^O}{\partial s^O} = 0$, we have $s^O = \frac{\lambda M + v - w^O}{k - 2}$. Substituting $s^O = \frac{\lambda M + v - w^O}{k - 2}$ into π_m^O , since $\frac{\partial^2 \pi_m^O}{\partial w^{O2}} = \frac{-2}{k - 2} < 0$, π_m^O is strictly concave in w^O . By setting $\frac{\partial \pi_m^O}{\partial w^O} = 0$, we have $w^{O*} = \frac{(k-1)\lambda M + v + c}{2}$. Thus, we have $s^{O*} = \frac{(3-k)\lambda M + v - c}{2(k-2)}$ and $p^{O*} = v + s^{O*}$.

APPENDIX B. PROOF OF THE OPTIMAL DECISIONS IN MODEL W

Since π_r^W is an increasing function of p_d^W and p_r^W , and from the constraints of model (2), we have $p_d^{W*} = \mu v$, $p_r^{W*} = v$. Since π_m^W is an increasing function of w^W , the optimal wholesale price is given as $w^{W*} = \mu v$.

APPENDIX C. PROOF OF THE OPTIMAL DECISIONS IN MODEL D

Since π_r^D is an increasing function of p_d^D and p_r^D , and from the constraints of model (3), we have $p_d^D = \mu v + \alpha s^D$, $p_r^D = v + \alpha s^D$. Substituting p_d^D and p_r^D into π_r^D , since $\frac{\partial^2 \pi_r^D}{\partial s^{D2}} = 2\alpha^2 + 2\alpha - k < 0$, by setting $\frac{\partial \pi_r^D}{\partial s^D} = 0$, we have $s^D = \frac{\alpha M + \alpha(\mu v - w^D) + v - w^D}{k - 2\alpha(1 + \alpha)}$. Substituting s^{D*} into π_m^D , since $\frac{\partial^2 \pi_m^D}{\partial w^{D2}} = \frac{-2(1 + \alpha)^2}{k - 2\alpha(1 + \alpha)} < 0$, by setting $\frac{\partial \pi_m^D}{\partial w^D} = 0$, we have $w^{D*} = \frac{(k - \alpha - \alpha^2)M + (1 + \alpha)(\alpha\mu + 1)v + (1 + \alpha)^2 c}{2(1 + \alpha)^2}$. Thus, we have $s^{D*} = \frac{(3(1 + \alpha)\alpha - k)M + (1 + \alpha)(\alpha\mu + 1)v - (1 + \alpha)^2 c}{2(1 + \alpha)(k - 2\alpha(1 + \alpha))}$, $p_d^{D*} = \mu v + \alpha s^{D*}$, $p_r^{D*} = v + \alpha s^{D*}$.

APPENDIX D. PROOF OF THE PROPOSITION 1

From the optimal results in the model D , we can easily verify that,

$$\begin{aligned} \frac{\partial s^{D*}}{\partial \alpha} &= \frac{3(1+2\alpha)M + (2\alpha\mu + 1 + \mu)v - 2(1+\alpha)c}{2(1+\alpha)(k - 2\alpha(1+\alpha))} \\ &\quad - \frac{(3(1+\alpha)\alpha - k)M + (1+\alpha)(\alpha\mu + 1)v - (1+\alpha)^2 c}{2(1+\alpha)(k - 2\alpha(1+\alpha))} \cdot \frac{k - 2(1+3\alpha)(1+\alpha)}{2(1+\alpha)(k - 2\alpha(1+\alpha))} > 0 \end{aligned} \quad (1)$$

$$\frac{\partial s^{D*}}{\partial \mu} = \frac{(1+\alpha)\alpha v}{2(1+\alpha)(k - 2\alpha(1+\alpha))} > 0$$

$$\frac{\partial p_d^{D*}}{\partial \alpha} = \alpha \cdot \frac{\partial s^{D*}}{\partial \alpha} > 0, \quad \frac{\partial p_r^{D*}}{\partial \alpha} = \alpha \cdot \frac{\partial s^{D*}}{\partial \alpha} > 0, \quad \frac{\partial p_d^{D*}}{\partial \mu} = v + \alpha \cdot \frac{\partial s^{D*}}{\partial \mu} > 0, \quad \frac{\partial p_r^{D*}}{\partial \mu} = \alpha \cdot \frac{\partial s^{D*}}{\partial \mu} > 0 \quad (2)$$

$$\frac{\partial w^{D*}}{\partial \alpha} = \frac{-(1+2\alpha)(1+\alpha) + 2(k - \alpha - \alpha^2)]M + (\mu - v)(1+\alpha)}{2(1+\alpha)^3} < 0, \quad \frac{\partial w^{D*}}{\partial \mu} = \frac{\alpha v}{2(1+\alpha)} > 0 \quad (3)$$

APPENDIX E. PROOF OF THE PROPOSITION 2

By comparing the optimal service levels in the models D and O , we have,

$$s^{D*} - s^{O*} = \frac{[(3(1+\alpha)\alpha - k)M + (1+\alpha)(\alpha\mu + 1)v - (1+\alpha)^2 c](k-2) - [(3-k)\lambda M + v - c](1+\alpha)(k - 2\alpha(1+\alpha))}{2(1+\alpha)(k - 2\alpha(1+\alpha))(k-2)}.$$

It can be easily verified that if $\mu \geq \hat{\mu}$, then $s^{D*} - s^{O*} \geq 0$, where:

$$\hat{\mu} = \frac{[(3-k)\lambda M + v - c](k - 2\alpha(1+\alpha))}{(k-2)\alpha v} + \frac{(1+\alpha)^2 c - (3(1+\alpha)\alpha - k)M - (1+\alpha)v}{(1+\alpha)\alpha v}$$

APPENDIX F. PROOF OF THE PROPOSITION 3

By comparing the retail prices in the model D with these in models W and O , we have:

$$1. \quad p_d^{D*} - p_d^{W*} = \mu v + \alpha s^{D*} - \mu v = \alpha s^{D*} \geq 0, \quad p_r^{D*} - p_r^{W*} = v + \alpha s^{D*} - v = \alpha s^{D*} \geq 0$$

$$p^{O*} - p_r^{W*} = v + s^{O*} - v = s^{O*} > 0$$

$$2. \quad p_r^{D*} - p^{O*} = \frac{\alpha[(3(1+\alpha)\alpha - k)M + (1+\alpha)(\alpha\mu + 1)v - (1+\alpha)^2 c]}{2(1+\alpha)(k - 2\alpha(1+\alpha))} - \frac{[(3-k)\lambda M + v - c]}{2(k-2)}$$

it can be easily verified that if $\mu \geq \hat{\mu}_2$, then $p_r^{D*} - p^{O*} > 0$, where:

$$\hat{\mu}_2 = \frac{[(3-k)\lambda M + v - c](k - 2\alpha(1+\alpha))}{(k-2)\alpha^2 v} + \frac{(1+\alpha)^2 c - (3(1+\alpha)\alpha - k)M - (1+\alpha)v}{(1+\alpha)\alpha v}$$

$$3. \quad w^{D*} - w^{W*} = \frac{(k - \alpha - \alpha^2)M + (1+\alpha)(\alpha\mu + 1)v + (1+\alpha)^2 c}{2(1+\alpha)^2} - \mu v$$

it can be easily verified that if $\mu \geq \hat{\mu}_3$, then $w^{D*} \leq w^{W*}$, where $\hat{\mu}_3 = \frac{(k - \alpha - \alpha^2)M + (1+\alpha)^2 c + (1+\alpha)v}{(2+\alpha)(1+\alpha)v}$,

$$w^{D*} - w^{O*} = \frac{[(1 - (1+\alpha)^2 \lambda)k - \alpha - \alpha^2 + (1+\alpha)^2 \lambda]M - (1-\mu)\alpha(1+\alpha)v}{2(1+\alpha)^2},$$

it can be easily verified that if $\mu \geq \hat{\mu}_4$, then $w^{D*} \geq w^{O*}$, where $\hat{\mu}_4 = 1 - \frac{[k - \alpha - \alpha^2 - (k-1)(1+\alpha)^2 \lambda]M}{\alpha(1+\alpha)v}$.

APPENDIX G. PROOF OF THE PROPOSITION 4

By comparing the optimal demands in the model D with these in models W and O , we have,

$$D_d^{D^*} - D_d^{W^*} = \alpha s^{D^*} \geq 0, \quad D_r^{D^*} - D_r^{W^*} = s^{D^*} > 0, \quad D^{D^*} - D^{W^*} = (1 + \alpha)s^{D^*} > 0, \\ D^{D^*} - D^{O^*} = (1 - \lambda)M + (1 + \alpha)s^{D^*} - s^{O^*} > 0. \quad D_r^{D^*} - D^{O^*} = s^{D^*} - s^{O^*},$$

from the Proposition 2, we have if $\mu \geq \hat{\mu}_1$, then $D_r^{D^*} - D^{O^*} = s^{D^*} - s^{O^*} \geq 0$, where $\hat{\mu}_1 = \frac{[(3 - k)\lambda M + v - c](k - 2\alpha(1 + \alpha))}{(k - 2)\alpha v} + \frac{(1 + \alpha)^2 c - (3(1 + \alpha)\alpha - k)M - (1 + \alpha)v}{(1 + \alpha)\alpha v}$.

APPENDIX H. PROOF OF THE OPTIMAL DECISIONS IN MODEL I

From the objective function and constraints of model (4), we have $p_d^I = \mu v + \alpha s^I$ and $p_r^I = v + \alpha s^I$. Substituting p_d^I and p_r^I into π^I , since $\frac{\partial^2 \pi^I}{\partial s^{I2}} = 2\alpha(1 + \alpha) - k < 0$, by setting $\frac{\partial \pi^I}{\partial s^I} = 0$ gives $s^{I*} = \frac{\alpha M + \alpha(\mu v - c) + v - c}{k - 2\alpha(1 + \alpha)}$. Thus, we have $p_d^{I*} = \mu v + \alpha s^{I*}$, $p_r^{I*} = v + \alpha s^{I*}$.

APPENDIX I. PROOF OF THE PROPOSITION 5

Comparing the optimal results between models I and D , we can easily verify that:

$$s^{I^*} - s^{D^*} = \frac{(k - \alpha(1 + \alpha))M + (1 + \alpha)(\alpha\mu + 1)v - (1 + \alpha)^2 c}{2(1 + \alpha)(k - 2\alpha(1 + \alpha))} > 0$$

$$p_d^{I^*} - p_d^{D^*} = \alpha(s^{I^*} - s^{D^*}) \geq 0, \quad p_r^{I^*} - p_r^{D^*} = \alpha(s^{I^*} - s^{D^*}) \geq 0$$

$$D_d^{I^*} - D_d^{D^*} = \alpha(s^{I^*} - s^{D^*}) \geq 0, \quad D_r^{I^*} - D_r^{D^*} = s^{I^*} - s^{D^*} > 0$$

$$\pi^{I^*} - \pi^{D^*} = \frac{(k - \alpha(1 + \alpha))M + (1 + \alpha)(\alpha\mu + 1)v - (1 + \alpha)^2 c}{4(1 + \alpha)} (s^{I^*} - s^{D^*}) > 0$$

APPENDIX J. PROOF OF THE OPTIMAL DECISIONS IN MODEL C

From the objective function and constraints of model (5), we have $p_d^C = \mu v + \alpha s^C$, $p_r^C = v + \alpha s^C$. Substituting p_d^C and p_r^C into π_r^C , since $\frac{\partial^2 \pi_r^C}{\partial s^{C2}} = 2\alpha(1 + \alpha) - (1 - \gamma)k < 0$, by setting $\frac{\partial \pi_r^C}{\partial s^C} = 0$ gives $s^C = \frac{\alpha M + (\alpha\mu + 1)v - (1 + \alpha)w^C}{(1 - \gamma)k - 2\alpha(1 + \alpha)}$. The service cost sharing contract should make $s^{I*} = s^{C*}$, and then we have $w^{C*} = \frac{\gamma k \alpha M + \gamma k (\alpha\mu + 1)v - (1 + \alpha)[(1 - \gamma)k - 2\alpha - 2\alpha^2]c}{(k - 2\alpha(1 + \alpha))(1 + \alpha)}$, $p_d^{C*} = \mu v + \frac{\alpha^2 M + \alpha^2(\mu v - c) + \alpha(v - c)}{k - 2\alpha(1 + \alpha)}$, $p_r^{C*} = v + \frac{\alpha^2 M + \alpha^2(\mu v - c) + \alpha(v - c)}{k - 2\alpha(1 + \alpha)}$.

APPENDIX K. PROOF OF THE THEOREM 1

The service cost sharing contract should satisfy $\pi_m^{C^*} \geq \pi_m^{D^*}$ and $\pi_r^{C^*} \geq \pi_r^{D^*}$, and then we have:

$$\left\{ \begin{array}{l} (w^{C^*} - c)(M + (1 + \alpha)s^{C^*}) - \frac{\gamma ks^{C^{*2}}}{2} \geq (w^{D^*} - c)(M + (1 + \alpha)s^{D^*}) - \frac{ks^{D^{*2}}}{2} \\ (\mu v + \alpha s^{C^*} - w^{C^*})((1 - \lambda)M + \alpha s^{C^*}) + (v + \alpha s^{C^*} - w^{C^*})(\lambda M + s^{C^*}) - \frac{(1 - \gamma)ks^{C^{*2}}}{2} \\ \geq (\mu v + \alpha s^{D^*} - w^{D^*})((1 - \lambda)M + \alpha s^{D^*}) + (v + \alpha s^{D^*} - w^{D^*})(\lambda M + s^{D^*}) - \frac{ks^{D^{*2}}}{2} \end{array} \right.$$

Therefore, the value range of γ is $1 - \frac{2(A + B)}{ks^{C^{*2}}} - \frac{s^{D^{*2}}}{s^{C^{*2}}} \leq \gamma \leq \frac{2E}{ks^{C^{*2}}} + \frac{s^{D^{*2}}}{s^{C^{*2}}}$, where,
 $A = (v + \alpha s^{C^*} - w^{C^*})(\lambda M + s^{C^*}) - (v + \alpha s^{D^*} - w^{D^*})(\lambda M + s^{D^*})$,
 $B = (\mu v + \alpha s^{C^*} - w^{C^*})((1 - \lambda)M + \alpha s^{C^*}) - (\mu v + \alpha s^{D^*} - w^{D^*})((1 - \lambda)M + \alpha s^{D^*})$,
 $E = (w^{C^*} - c)(M + (1 + \alpha)s^{C^*}) - (w^{D^*} - c)(M + (1 + \alpha)s^{D^*})$.

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