Research Article

Optimal Omnichannel Development Strategy in O2O Supply Chain under the Impact of Webrooming

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This study analyzes how webrooming affects the O2O supply chain of an e-tailer and a brick-and-mortar store. Two types of brick-and-mortar stores are considered: self-owned and franchised. We first determine via game theory the optimal pricing and service decisions for the e-tailer and brick-and-mortar store when prices are uniform or nonuniform online and offline. The results indicate that webrooming benefits both the e-tailer and brick-and-mortar store when prices are nonuniform. For self-owned stores, the online market share and consumer traveling costs weaken the positive webrooming effect on the e-tailer’s profit when the price is nonuniform. For the franchised store, webrooming weakens the positive role of online market share and reinforces the negative effect of traveling costs for the e-tailer. The positive effect of webrooming on franchised stores in the case of nonuniform pricing is more significant than in the case of uniform pricing when online market share or traveling costs are lower. These results have important implications for management and should help e-tailers develop an omnichannel strategy.

1. Introduction

Omnichannel marketing involves combining online and offline sales channels. It not only satisfies the consumers’ pursuit of a “shopping” experience but also drives a rapid recovery of offline consumption. Despite Internet and mobile devices providing more shopping channels for consumers, offline stores are still consumers’ preferred purchasing channel [1]. Therefore, more and more e-tailers have begun to lay out their offline channels to respond to consumer shopping desires of an omnichannel environment. For instance, Suning, one of the top three Chinese consumer electronics businesses in China’s B2C market, has focused on its offline business layout since 2017. By 2018, Suning opened 17 brick-and-mortar (BM) stores. By the first quarter of 2019, it had 4800 Cloud stores. Vipshop, the largest brand discount site of China, has already finished its self-own logistics and is now exploring comprehensive online and offline integration.

However, “webrooming” is increasingly affecting the demand for offline channels in omnichannel marketing. In webrooming, consumers may search for product information online but make their purchases offline [2–4]. In omnichannel retailing, webrooming is the most prevalent cross-channel strategy [5]. Accenture Consulting [6] reports that 81% of American shoppers, 72% of UK shoppers, and 76% of Canadian shoppers frequently partake in webrooming [4]. In the consumer electronics market (e.g., mobile phones and laptops), 44% of European consumers indulge in webrooming [7]. Webrooming stems from consumers’ pursuit of a seamless omnichannel shopping experience. Accenture consulting reports that, under the rules of new consumption, Chinese consumers implement “two-line (online and offline) buying,” with 61% of active online Chinese consumers also being active in offline shopping [6]. When shopping offline, about 50% of consumers use mobile phones to search the Internet and compare products. Although webrooming increases with the increase of omnichannel consumers, it produces a significant negative impact on the performance of the online channel [8]. Yet, despite this, little research has focused on the phenomenon of webrooming [4, 9].
In practice, the specific forms used by e-commerce brand manufacturers to expand offline channels vary. In general, there are two main types of offline BM stores: the first type involves self-owned stores fully financed and operated by the e-tailers. The second type of offline BM stores is the franchised store. Besides selling the same products as the e-tailer, franchised stores also sell their own products as independent retailers. In this case, the franchised store and e-tailer are both competing and collaborating. Previous studies have focused more on how webrooming develops. However, the research presented herein differs in that it analyzes how webrooming affects the e-tailer and different types of BM stores. In particular, we answer the following questions about webrooming: (1) If the e-tailer sets up a self-owned store, what service level and pricing strategy optimize the O2O supply chain? (2) If the e-tailer sets up a franchised store, what service level and pricing strategy should they adopt when a Nash equilibrium exists between online and offline sales? (3) How does webrooming affect the profits of the e-tailer and the BM store? To ensure the validity of our research, we focus on consumer electronics, which is one of the most popular categories amongst webroomers [10].

To answer these questions for different types of BM stores, we analyze the O2O supply chain, which involves an e-tailer and a BM store. We consider two strategies, namely, the self-owned store strategy and the franchised store strategy. When the e-tailer sets up a self-owned store, the O2O supply chain is operated in a centralized-decision-making mode. The goal of this business model is to maximize overall profit by setting the appropriate price and optimizing both online and offline service levels. However, when a BM store joins an e-tailer as a franchised store, the O2O supply chain operates in a decentralized-decision-making mode. We develop herein a game theory model to analyze which case is most beneficial for the e-tailer.

Two cases are considered for each strategy. First, to cater to the tendency of "new retail," we assume that online and offline prices charged by the e-tailer are the same. This is very common in the offline layout practice of e-tailers. For instance, to realize "cloud business," the first case for Suning is to offer the same price for the same products online and offline. The second case is to offer a different price online and offline. This means that, in the self-owned-store strategy, the prices charged by the e-tailer vary according to the online and offline demand. In the franchised store strategy, the e-tailer and the franchised store set their own price (e.g., Bestore, a high-end snack brand in China, varies its prices during its different types of BM stores online and offline). We will give specific examples in the cases in 4.1 and 4.2.

An analysis of the equilibrium solutions produces several interesting results. For either the self-owned strategy or the franchise strategy, applying nonuniform prices online and offline benefits both the e-tailer and BM store. For the self-owned store strategy, a uniform online and offline price implies the same service level online and offline, so the e-tailer’s optimal price, service level, and profit are independent of webrooming. When the online and offline prices are nonuniform, the self-owned store provides better service than the online channel when the online market share is lower and charges a higher price when webrooming is greater (and vice versa).

For the franchise strategy, a uniform online and offline price means that the franchised store provides better service than the online channel when the online market share is greater. When the online and offline prices differ, the franchised store provides better service than the online channel when the online market share is greater and charges a higher price when webrooming is greater (and vice versa). In addition, the e-tailer charges a higher wholesale price to the franchised store in the nonuniform-price case when the online market share is greater.

We also numerically analyze how webrooming affects the profits for the two strategies. For self-owned stores, when the online and offline prices are the same, both the online market share and the cost to the consumer of traveling to the offline store weaken the correlation between webrooming and higher e-tailer profits. For the franchise strategy, webrooming weakens the online market share and reinforces the cost for the consumer to travel to the e-tailer. In addition, for the franchised store, the profit due to webrooming in the case of nonuniform prices is greater than in the case of uniform pricing when either the online market share or consumer traveling cost is lower.

The remainder of the paper is organized as follows: Section 2 reviews prior literature on the subject, and Section 3 describes the problem and the notation. Section 4 proposes the models for different strategies. Section 5 compares the equilibrium results of different strategies. Section 6 numerically analyzes how webrooming affects each strategy and provides managerial insights. Finally, we conclude and discuss the implications and limitations of the research as well as future research directions. The Appendix gives the proofs of the propositions.

2. Literature Review

O2O service in the omnichannel retailing landscape has received significant research attention in recent years. Online channels have seen continuous growth, which has triggered momentous changes in supply chain management [11]. However, online shopping sometimes results in consumers receiving products that do not match their expectations, which leads to higher return rates [12, 13]. More and more retailers are thus pursuing an omnichannel strategy to create an integrated shopping experience across channels [14]. The objective of the present research is to study how webrooming affects the O2O supply chain. Thus, this research is motivated by the following three issues: (1) omnichannel management, (2) O2O supply chain, and (3) webrooming.

Studies on omnichannel management and retailing have emerged in recent years [15, 16]. Verhoeof et al. [17] considered that omnichannel involves a wider variety of channel choices. Beck and Rygl [18] defined an omnichannel as a seamless retail world where customers can shop across channels, anywhere and at any time. Chopra [19] thought that, under omnichannel management, e-tailers should operate both online and offline channels in an integrated
manner. To help manage omnichannel distribution, Ailawadi and Farris [20] presented specific metrics that facilitate the reliable analysis of the relationship between distribution and marketing objectives. They presented a basic framework for managing distribution and summarized the metrics that are relevant to each element of the framework. Saghiri et al. [21] developed a conceptual framework configured by the three dimensions of channel stage, channel type, and channel agent for omnichannel systems following the consumer through the value-added journey. Choi et al. [22] also considered the blockchain technology in omnichannel supply chain operation modes with social media platforms.

As an increasing number of consumers spend more of their shopping time in omnichannels, researchers have also focused their attention on the omnichannel shopping experience. Lemon and Verhoef [23] defined customer experience as customers’ subjective responses to the contact with a company, and it helps capture their general assessments of companies’ products or services. Gupta et al. [24] considered omnichannel shopping as a customer-centered focus featuring a “holistic” shopping experience. Compared with multichannel and cross-channel, the features of omnichannel shopping are unclear. To clarify the situation, Huré et al. [25] identified three specific characteristics of omnichannel shopping: increased complexity of shopping behavior, the omnichannel shopping experience as a brand experience, and an expected consistent and seamless omnichannel shopping experience. Finding that the various uncertainties between online and offline trigger low-value and stock-out disappointment, Du et al. [26] incorporated the disappointment-aversion emotion in an omnichannel environment and characterized how consumers’ anticipated disappointment-aversion behavior affects the optimal pricing decisions of retailers with or without inventory constraints in the omnichannel environment. To satisfy consumers, more e-tailers are now launching physical stores in addition to their online presence. Zhang et al. [27] studied the e-tailer’s omnichannel operations and found that the e-tailer will not always benefit from omnichannel strategy if consumers can cancel their order before payment and return the product. Fan et al. [28] developed a game-theoretical model wherein two competitive e-tailers launch physical stores only for showing the product or only for actual transactions. Gao and Fan [29] explored dyadic nature of omnichannel consistency on customer experience and found that customers prefer consistent online and offline experience. The prior studies mentioned above began investigating omnichannel shopping by considering customers’ shopping experience. Herein, we examine how webrooming affects omnichannel shopping as a function of online and offline pricing strategies.

Second, our research is related to the literature on the optimization and coordination of the O2O supply chain. Chen et al. [30] studied the pricing strategy between two O2O channels: mixed dual-channel from the Supplier-Stackelberg, Retailer-Stackelberg, and Nash game-theoretical perspectives, and discussed how the supply chain power structure affects pricing decisions and performance. He et al. [31] studied the optimal pricing and location strategies of multistore service firms and how the more socialized customer behavior impacts these strategies in competitive O2O markets. Pan et al. [32] proposed a novel O2O service recommendation method based on multidimensional similarity measurements encompassing three similarity measures: collaborative similarity, preference similarity, and trajectory similarity. The results show that a combination of multiple similarity measures performed better than any single similarity measure. Xu et al. [33] modeled the O2O supply chain with online subsidy services and analyzed how demand disruption affects O2O supply chain performance. They then discussed the optimization of O2O supply chains with online subsidy services to face demand disruption. Li et al. [34] studied the three strategies of pricing and service effort in a dual-channel supply chain with showrooming and found that showrooming allows firms to benefit the most from the ex-post service efforts. Govindan and Malomfalean [35] compared the three coordination mechanisms based on the O2O approach: revenue-sharing, buy-back, and quantity flexibility contracts, and found that the highest profit was obtained under the quantity flexibility agreement with O2O deterministic demand as well as with stochastic demand. Sett et al. [36] developed an advanced supply chain model to increase service in O2O channel system in which it has an unreliable vendor. He et al. [37] analyzed the common phenomenon “Buy-Online-and-Deliver-from-Store” (BODS) and report that if the competition between the online and offline channels is stronger, implementing the BODS strategy is better for the dual-channel supply chain, and vice versa. Zhang et al. [38] analyzed a similar preorder-online, pickup-in-store (POPU) strategy and report that it has different effects on different cost types. Note that these studies do not focus on how the different types of BM stores affect the online and offline channels.

Finally, since channels are interchangeably and seamlessly used in the search and purchase process, Verhoef et al. [17] considered it difficult or virtually impossible for firms to control this use, which means that showrooming and webrooming become increasingly important issues, the latter of which is related to the present research. Fernández et al. [39] contrasted webroomers with showroomers and found that webroomers focus more on attributes directly associated with the product, whereas showroomers are more likely to purchase products of a higher value and price. Flavián et al. [40] proposed a conceptual foundation of webrooming and found that the combination of an online search and an offline purchase improves the consumer’s purchase experience. Kim et al. [1] investigated how focused shopping motivations affect offline shoppers, specifically at the search stage. The results show that the price-consciousness and shopping-enjoyment orientations positively influence the probability of engaging in webrooming while the convenience orientation had a negative influence. Jing [41] examined how webrooming interacts with showrooming, and the results show that when webrooming fully reveals a match, it can eliminate showrooming and relax the competition, thereby increasing the profit of the online retailer. Arora and Sahney [4] used an integrated technology acceptance model to better understand consumers'
webrooming behavior and revealed that, besides a perceived ease of searching online and overall usefulness of webrooming, perceived search benefits online and purchase benefits offline were the significant factors that determined consumer webrooming behavior. Flavián et al. [42] analyzed the influence of specific combinations of online and offline channels especially on smart shopping perceptions and feelings and found that webrooming leads to higher personal attribution, which means that customers feel responsible on their purchase outcomes. Sun et al. [43] found that customers’ webrooming behavior is heavily dependent on the cost of viewing web showrooms and the travel cost of visiting BM store and investigate the channel strategies for e-tailer on whether to introduce web showrooms according to customers’ webrooming behavior. Unlike those scholars, we further analyze herein the impact of webrooming and focus on how webrooming affects different types of O2O supply chain participants.

The present research thus makes the following contributions: First, this study considers the prevalent webrooming phenomenon in the context of omnichannel environment and provides a new perspective on the research of omnichannel management. Second, we extend the research into O2O supply chain management by studying two different types of offline BM stores: self-owned and franchised, which is a major trend in the retail industry in China when webrooming relates to service. We then compare and analyze uniform and nonuniform pricing. Third, this study highlights how webrooming affects decisions within the O2O supply chain, especially pricing and service effort, and then discusses how profits are affected by webrooming. Finally, we describe the problem and detail the analytical models used.

3. Problem Description and Notation

We consider an O2O supply chain system in which an e-tailer sells his products directly via the online channel o and indirectly via a BM store b. The BM store is of two types: one is a self-owned store that belongs to the e-tailer, and the other is a franchised store, which is an independent retailer and functions in a cooperation relationship with the e-tailer. Both the e-tailer and the BM store can stimulate customer demand through their own efforts and services. Let Q represent the primary demand potential and a denote the market demand coefficient. aQ and (1 − a)Q are the demand through the online and offline channels, respectively. Given that both the e-tailer and BM store must furnish a sales effort to attract customers to their own channel, we denote by so the service effort furnished by the e-tailer (e.g., enquiring, paying online, and home delivery) and by sb the service effort furnished by the BM store (e.g., providing free trials for the new products, introducing new functions, and giving suggestions on product collocation). In line with the studies of Taylor [44]; Tsay and Agrawal [45]; Chen [46]; Liu et al. [47]; Li et al. [48], the costs of providing the services are represented as C(so) = 1/2so2, C(sb) = 1/2sb2, respectively. It satisfies that C(0) = 0, dC(so)/ds_o > 0, dC^2(so)/ds_o^2 > 0, dC(sb)/ds_b > 0, dC^2(sb)/ds_b^2 > 0.

Webrooming happens when a customer searches for useful information online but ends up purchasing offline, thereby acting as a free rider of the online service. We denote by y the webrooming coefficient, which represents the net change in offline demand per unit service effort provided by the e-tailer, and (1 − y) is the fraction of the increase in demand retained by the e-tailer. This is consistent with the current literature [49–51]. t is the cost for the consumer to travel to the BM store, and h is the hassle cost of buying online (e.g., consumers are not comfortable with paying online or are not patient when waiting for the order) [41].

We let p_o and p_b denote the prices of the online and offline channels, respectively. We follow some existing studies, including Yue and Liu [52]; Huang and Swaminathan [53]; Li et al. [54]; Pu et al. [51]; Li et al. [34]; etc., and use e to represent the cross price elasticity coefficient between online and BM store with respect to the retail price.

If the BM store is a franchised store, the e-tailer will offer herself the wholesale price w before she determines her retail price. Both the self-owned store and the franchised store must pay the fixed cost F. In addition, the e-tailer pays C_o to the self-owned store as an initial investment, and the franchised store pays e to the e-tailer as the franchise fee. We normalize production costs and logistics costs from online to offline, and the cost of delivering to consumers is set to zero. The variables are defined in Table 1.

We use the previous research [34, 49, 55–57] as bases to propose the linear demand functions for the online channel and BM store as follows. And we assume that market demand in each channel is price sensitive and is also influenced by the service effort.

Thus, the demand functions for the online channel and BM store are

\[ D_o = aQ - p_o + e p_o + (1 - y)s_o - h, \]  \hspace{1cm} (1)

\[ D_b = (1 - a)Q - p_b + e p_o + y s_o + s_b - t. \]  \hspace{1cm} (2)

In this paper, we focus on how the service level and price change vary in the two different types of BM stores when exposed to webrooming and then discuss how these changes affect the profits of the online and offline channels.

4. Model Analysis

This section discusses the optimal service level and pricing strategy under the two different strategies and with webrooming included. We also separately analyze situations where the e-tailer runs the BM store as a self-owned store and as a franchised store.

4.1. BM Store Run as Self-Owned Store. We first consider the strategy whereby the e-tailer establishes a self-owned store to expand the offline channel. As both online and offline channels belong to the e-tailer, we model this scenario in the form of a centralized-decision-making mode in which the e-tailer acts as a central decision-maker to assign the following key decision variables: online and offline retail price and online and offline service level.

We consider two different cases: in the first case, the e-tailer sets a uniform price for both the online and offline
channels. This is very common in the offline layout practice of e-tailers to cater to the new retail. For instance, to implement a cloud business, the first step for Suning is to charge the uniform price for the same products online and offline. We next consider nonuniform pricing, which means that the e-tailer can charge different prices for the different channels according to the demand. For example, according to gross margin of terminal retail price, the famous leisure food e-tailer Bestore calculates its price in different way: for online B2C channel, the price is based on product cost, while for its self-owned store, the price is based on product purchase cost. The O2O supply chain structure when BM store is run as self-owned store is shown in Figure 1.

The superscript $s$ denotes the symbols of this strategy and the subscripts 1 and 2 denote the two cases, respectively.

Case 1. Uniform price online and offline ($p_a = p_b = p$)
In this case, the demand functions for the e-tailer and BM store are

$$D_a = aQ - p + (1 - \gamma)s_{a1} - h,$$  \hspace{1cm} (3)

$$D_b = (1 - a)Q - p + \gamma s_{b1} + s_{b1} - t.$$  \hspace{1cm} (4)

The e-tailer’s online channel profit function is

$$\pi_a = pD_a - \frac{1}{2}s_{a1}^2 - C_o.$$  \hspace{1cm} (5)

Similarly, the self-owned store’s profit function is

$$\pi_b = pD_b - \frac{1}{2}s_{b1}^2 - F.$$  \hspace{1cm} (6)

Therefore, the e-tailer’s profit function is

$$\pi_a^s(p, s_{a1}, s_{b1}) = \pi_a + \pi_b = pQ - ph - tp - 2p^2$$

$$+ p\left(s_{a1} + s_{b1}\right) - \frac{1}{2}s_{a1}^2 - \frac{1}{2}s_{b1}^2 - F - C_o.$$  \hspace{1cm} (7)

Proposition 1. When $Q > h + t$, if the BM store is a self-owned store and the prices are the same online and offline, the optimal decisions and the maximum profits are in Table 2.

Case 2. Nonuniform price online and offline ($p_a \neq p_b$)
In this case, the demand functions for the e-tailer and BM store are (1) and (2), respectively. The e-tailer’s online channel and the self-owned store’s profit function are

$$\pi_a = p_a D_a - \frac{1}{2}s_{a1}^2 - C_o,$$  \hspace{1cm} (8)

$$\pi_b = p_b D_b - \frac{1}{2}s_{b1}^2 - F.$$  \hspace{1cm} (8)

Therefore, the e-tailer’s profit function is

$$\pi_a^s(p_a, p_b, s_{a1}, s_{b1}) = \pi_a + \pi_b$$

$$= p_a\left(aQ - p_a + \epsilon_{ph} + (1 - \gamma)s_{a1} - h\right)$$

$$+ p_b\left(1 - a\right)Q - p_b + \epsilon_{ph} + \gamma s_{a1}$$

$$+ s_{b1} - t\right) - \frac{1}{2}s_{a1}^2 - \frac{1}{2}s_{b1}^2 - F - C_o.$$  \hspace{1cm} (9)

Proposition 2. If the BM store is self-owned and the prices differ online and offline, the optimal decisions and the maximum profits are in Table 3.

4.2. BM Store Run as Franchised Store. This section considers the situation in which the e-tailer invites an offline retailer to join his operation as a franchised store. We define this scenario as a decentralized-decision-making mode and model it as a Stackelberg game in which the e-tailer acts as leader. We use the superscript $f$ to denote the symbols of this strategy. As in the previous section, we consider two different cases: uniform pricing and nonuniform pricing. These two cases are also quite common in the actual operation for the e-tailers. For example, Xiaomi, a famous Internet company in China, focusing on the development of electronic products, has made a big push into new retail since 2016. Xiaomi promises the same price for their offline franchised stores as for their online channel. Different from Xiaomi, Bestore combines different regional business conditions and its business development plan, differentiates pricing, and develops different discount or markup levels for...
Case 2. Nonuniform price online and offline ($p_0 \neq p_b$)

In this case, the e-tailer acts as the Stackelberg leader in setting the price $p_o$, the wholesale price $w$ for the franchised store, and service level $s_o$ before the franchised store. Thereafter, the franchised store responds by setting the price $p_b$ and service level $s_b$ to maximize its profit. The e-tailer maximizes her profit function by inserting the best response of the franchised store into her profit function. Thus, the demand functions for the e-tailer and franchised store are given by (1) and (2), respectively, and the related profit functions of the e-tailer and franchised store are

For convenience, we use the following expressions:

\begin{align*}
M &= t - Q + Qa - 2Qy + hy + 2yt + Qy^2 - hy^2 - y^2t + Qay, \\
N &= 2h - 2Qa - Qy + y' + Qy^2 - hy^2 - y't + Qay, \\
J &= -2y^2 + 2y + 1, \\
K &= h - Qa - hy + y't + 2Qay.
\end{align*}

When $K < 0$, $N < M < 0$, we obtain the following proposition.

**Proposition 3.** If the BM store is a franchised store and charges the same prices online and offline, the optimal results and maximum profits of the e-tailer and franchised store are in Table 4.

Case 2. Nonuniform price online and offline ($p_0 \neq p_b$)

In this case, the e-tailer acts as the Stackelberg leader in setting the price $p_o$, the wholesale price $w$ for the franchised store, and service level $s_o$. Thereafter, the franchised store responds by setting the price $p_b$ and service level $s_b$ to maximize its profit. The e-tailer maximizes her profit function by inserting the best response of the franchised store into her profit function. Thus, the demand functions for the e-tailer and franchised store are given by (1) and (2), respectively, and the related profit functions of the e-tailer and franchised store are

\begin{align*}
\pi_o &= wD_b + pD_o - \frac{1}{2}s_{o2}^2 + \varepsilon, \\
\pi_b &= (p_o - w)D_b - \frac{1}{2}s_{b2}^2 - F - \varepsilon.
\end{align*}

For convenience, we use the following expressions:

\begin{align*}
U &= 2e2y^2 + 5e2 - 6ey2 + 6ey + 4y^2 - 4y - 2. \\
V &= 2h - 2Qa - 3Qe - Qy + 3et + y't + Qy2 - hy2 - y2t + 3Qae + Qay, \\
X &= 2h - 2Qa - 3Qe - 2Qy + 3et - 2hy + 2yt + 2e2yt + 3Qae + 4Qay + 3Qey + 3ehy - 3eyt - 2Qe2y + 2Qae2y - 6Qay. \\
Y &= t - Q + Qa - 2Qy + eh + hy + 2yt + Qe2 + Qy^2 - e^2t - hy^2 - y^2t + ey^t + Qae + Qay + Qey - eyt - Qae^2 - Qey^2 + eh^2 + Qae.
\end{align*}

For convenience, we use the following expressions:

\begin{align*}
M &= t - Q + Qa - 2Qy + hy + 2yt + Qy^2 - hy^2 - y^2t + Qay, \\
N &= 2h - 2Qa - Qy + y' + Qy^2 - hy^2 - y't + Qay, \\
J &= -2y^2 + 2y + 1, \\
K &= h - Qa - hy + y't + 2Qay.
\end{align*}

When $K < 0$, $N < M < 0$, we obtain the following proposition.

**Proposition 3.** If the BM store is a franchised store and charges the same prices online and offline, the optimal results and maximum profits of the e-tailer and franchised store are in Table 4.
Table 4: Optimal results of Case 1 when BM store is run as franchised store.

|                | E-tailer | Franchised store |
|----------------|----------|------------------|
| Price, $p^*_1$, w, $w^*_1$ | $-N/2J$ | $-N/2J$ |
| Service level, $s_{o1}^*$, $s_{o1}^*$ | $-K/2J$ | $M - N/2J$ |
| Maximum profit, $\pi_{o1}^*$, $\pi_{o1}^*$ | $-Q(1-a) + t$ | $(N-M)[2yK - M/2J]$ |
| $\pi_{o1}^*$ | $+Qa - h(2J - K^2/2J)^2$ | $-1/2(N-M/2J)^2/F - \epsilon$ |

Thus, when $U > 0$, $V > 0$, $X > 0$, $Y > 0$, we obtain the following proposition.

Proposition 4. When $\max(2 - 3e - \sqrt{(3e - 2)^2 - 2(5e^2 - 2)(e - 2)(e - 1)/2(e - 1)}, 1 - \sqrt{2(1 - e^2)/1 - e, 0}) < \gamma < \min(2 - 3e + \sqrt{(3e - 2)^2 - 2(5e^2 - 2)(e - 2)(e - 1)/2(e - 1)}, 1 + \sqrt{2(1 - e^2)/1 - e, 1})$, the optimal results and maximum profits of the e-tailer and franchised store are in Table 5.

5. Equilibrium Analysis

In the preceding section, we derive the optimal service level and pricing decisions for two different strategies and consider the webrooming effect. In this section, we compare the optimal results of the two strategies for the e-tailer and BM store. Thereafter, we obtain the following propositions.

Proposition 5. If the BM store is self-owned store and sets uniform prices with the e-tailer, (1) the service levels online and offline are equal; (2) the e-tailer’s optimal price, service level, and profit are independent of the level of webrooming.

Proposition 5 shows that when a self-owned store is set up and the price is uniform in both channels, the e-tailer should provide equal service online and offline. Only then can the e-tailer maximize her profit. Given that the self-owned store belongs to the e-tailer and that pricing is uniform, the equilibrium results are independent of whether the consumers buy directly online or offline. This explains why the e-tailer’s optimal price, service level, and profit are independent of the level of webrooming.

Proposition 6. If the BM store is a self-owned store and uses nonuniform pricing with the e-tailer, then, (1) if $0 < a < \bar{a}$, then $s_{o2}^* > s_{o2}^*$; otherwise, $s_{o2}^* < s_{o2}^*$. (2) If $\gamma > \gamma_1$, then $p_{o2}^* > p_{o2}^*$; otherwise, $p_{o2}^* < p_{o2}^*$, where $\bar{a} = (Q + h - t)[2e(1 - \gamma) - 1] + \gamma^2(Q - h - t) + 2h/2Q(1 - \gamma)(2e - 1)$, $\gamma_1 = (1 - 2e)$.

Proposition 6 shows that when a self-owned store is set up, the pricing is nonuniform, and the online market share is lower than the threshold, the self-owned store provides a higher level of service than the offline channel. This means that, as the decision-maker of the centralized supply chain, the e-tailer should use the advantage of larger market demand via the offline channel and provide greater service to retain customers and maximize the total profits of the O2O supply chain. However, once the online market demand exceeds the threshold, the e-tailer should lower the service level of the offline channel and focus on the online service. The prices set are associated with the webrooming activities of customers. When a larger fraction of customers engages in webrooming, the offline channel could benefit from advantageous pricing due to the higher offline demand. Thus, to maximize the e-tailer’s profit, the self-owned store should charge higher prices than the e-tailer’s online channel. In contrast, when a smaller fraction of customers...
engages in webrooming, the e-tailer’s online channel captures more demand from the market and therefore charges a higher price when webrooming activities are lower.

**Proposition 7.** If the BM store is a franchised store and uses uniform pricing with the e-tailer, then when $1 > a > \bar{a}_2$, $s_{b_1}^* > s_{b_2}^*$; otherwise, $s_{b_1}^* < s_{b_2}^*$, where $\bar{a}_2 = \left( Q - t \right) \left( 1 + 3t \right) + h y / Q \left( 4 + 1 + t \right)$.

Proposition 7 shows that a franchised store that uses uniform pricing produces a different conclusion than a self-owned store with uniform pricing. In other words, if the online market share exceeds the threshold, the franchised store should increase efforts to attract consumers to improve its profit. However, once the online market share decreases below the threshold, the franchised store has the advantage in market share and so should decrease the service level to lower costs. Thus, as a follower of this Stackelberg game, the franchised store does not have the pricing power and so can only adjust the service level to attract customers and control costs.

**Proposition 8.** If the BM store is a franchised store and uses nonuniform pricing, (1) if $0 < \sigma_1 < \bar{a}_1$, then $s_{b_1}^* > s_{b_2}^*$; otherwise, $s_{b_1}^* < s_{b_2}^*$. (2) If $a > \bar{a}_1$, then $w_2^* > w_1^*$. (3) If $y > \bar{y}_3$, then $p_{b_1}^* > p_{b_2}^*$; otherwise, $p_{b_1}^* < p_{b_2}^*$, where $\bar{a}_1 = (t - Q)(1 - 3e - c + (1 - e) + h y (1 - e)(y - 3) + 2 - e]/Q[e^2 + 4e - 3 + y(2e - 3)(e - 1)].

In Proposition 8, when the offline market demand has no advantage, the franchised store, as a competitor of the e-tailer, should improve its service level to attract consumers. When the online market share exceeds the threshold, the e-tailer, to increase profits, should increase the wholesale price if using nonuniform pricing. In addition, Proposition 8 shows that as webrooming increases above the threshold, the franchised store should charge higher prices than the e-tailer to increase profits.

**6. Numerical Analysis and Managerial Insights**

To gain a better understanding of the analytical findings and generate additional insights about how webrooming affects the profits of the e-tailer and the different types of BM stores, this section compares the two strategies. Given that the expressions are complicated, we numerically analyze various scenarios as a function of the parameters $y$, $a$, and $t$. The figures presented in this section are for a set of parameters that are repeatedly verified to ensure that the prices and service levels are positive. We obtain distinct results and derive important managerial insights from these figures.

**6.1 How Webrooming Affects the Profits of Self-Owned Stores.** First, we numerically analyze how webrooming affects the profits of self-owned stores.

Figure 3 shows that, for reasonable parameters, the profit in Case 2 is greater than that in Case 1. We conclude that, for a self-owned store, implementing nonuniform pricing earns the e-tailer greater profits than does uniform pricing. Figure 3(a) shows how market share and webrooming affect the profit of the O2O system when the e-tailer sets up a self-owned store. In Case 2, when the online market share is low, the e-tailer profit increases with increased webrooming activity. Combined with Proposition 6, the offline service level is higher when the online market share is lower, which attracts more consumers, and the self-owned store charges higher prices as the webrooming activity increases, leading to greater profits. The larger $y$ is, the faster the profit increases. However, as the online market share increases, the profit increases, albeit at a slow rate. In addition, increasing $y$ does not make profits soar, so the online market share seems to significantly weaken the webrooming effect, which decreases the overall profit of the supply chain.

Figure 3(b) shows how customer traveling costs and webrooming affect the profit of the O2O system when online and offline market shares are comparable. $t$ negatively affects profits in both Cases 1 and 2. In Case 2, when $t$ is low, $y$ has a significant positive effect on the e-tailer’s profit. However, as $t$ increases, the rate of profit growth decreases with increasing $y$, which indicates that customer travel cost also weakens the webrooming effect, which affects the profit of the O2O system.

**6.2 How Webrooming Affects the Profits of Franchised Store.** This section numerically analyzes how webrooming affects the profits of franchised stores.

Figures 4(a) and 2(b) focus on how the market share and webrooming phenomenon affect profits when a franchised store joins the operation. Figure 4(a) shows that when the online market share is low, the profits decrease in both cases until $y$ reaches a high level, at which point the profits rise slightly. When the online market share increases, both online and offline profits increase rapidly and maximize at the highest $a$. In addition, when $a$ is high, the rates of decline of both profits increase with the increasing $y$. This illustrates how webrooming weakens the positive effect of online market share for the e-tailer.

Figure 4(a) shows that, with parameters, the profit in Case 2 exceeds that in Case 1. However, including Figure 4(b) shows that when the pricing is uniform, the franchised store has negative profit, which means that it exits the market unless $a$ is sufficiently low and $y$ is sufficiently high. Therefore, we conclude that, for a franchised store and independent of pricing uniformity, the e-tailer’s profits have almost the same dependence on $a$ and $y$. However, uniform pricing negatively influences the franchised store. When the fixed cost $F$ and franchise fee $\epsilon$ decline, the negative situation for the franchised store may improve.

Figure 4(b) shows that, compared with Case 1, $\gamma$ plays a more positive role in Case 2, whereas the negative role of $a$ in...
Figure 3: Profits of self-owned stores for Cases 1 and 2 as functions of $\gamma$, $(a)$, and $(t)$. (a) Profits of e-tailer as a function of $(a)$ and $\gamma$. (b) Profits of e-tailer as a function of $(t)$ and $\gamma$.

Figure 4: Profits of franchised store in Cases 1 and 2 as functions of $\gamma$, $(a)$, and $(t)$. (a) Profits of e-tailer as a function of $(a)$ and $\gamma$. (b) Profits of franchised store as a function of $(a)$ and $\gamma$. (c) Profits of e-tailer as a function of $(t)$ and $\gamma$. (d) Profits of franchised store as a function of $(t)$ and $\gamma$. 
Case 1 is greater than in Case 2. This is about pricing power: when pricing is uniform, the e-tailer has the pricing power. Combined with Proposition 7, when the online market share in Case 1 exceeds the threshold, the franchised store improves the service level, but the stable price reduces the profits of the franchised store. In addition, a greater value of \( a \) makes the situation more serious.

Figures 4(c) and 2(d) show how customer traveling costs and webrooming affect the profits of the e-tailer and the franchisee when the market share is comparable online and offline. Figure 4(c) shows that when \( t \) changes over a reasonable range, the e-tailer’s profit in Case 2 is significantly greater than in Case 1. The smaller \( t \) is, the more profitable the e-tailer in Case 2 is. Furthermore, with respect to Case 1, the profit drops noticeably in Case 2 upon increasing \( t \), and this trend remains stable with increasing \( \gamma \). In addition, a bigger \( t \) endows webrooming with a more negative effect on the e-tailer in both Cases 1 and 2, which indicates that increased webrooming activities reinforce the negative effect of traveling costs for the e-tailer.

Figure 4(d) shows that the profit of the franchised store is negative in Case 1, with the situation becoming more (less) serious with increasing \( t \) (\( \gamma \)). Like Case 1, when \( t \) is low in Case 2, \( \gamma \) plays a positive role. The franchised store can maximize profit at the lowest \( t \) and highest \( \gamma \) in both Cases 1 and 2. When \( t \) is high, webrooming does little to improve the profit of the franchised store in Case 2. Therefore, we conclude that when \( t \) is low, the positive effect of increasing \( \gamma \) in Case 2 exceeds that in Case 1. As \( t \) increases, the effect of \( \gamma \) switches in Cases 1 and 2. Furthermore, including Figure 4(c) shows that lower traveling costs are beneficial to both the e-tailer (when \( \gamma \) is low) and the franchisee (when \( \gamma \) is high).

7. Conclusions

The omnichannel development strategy has dramatically changed the world of retailing not only for consumers but also for the supply chain participants. Webrooming is also a significant issue faced by firms in the O2O business. Consumers often search for product information online but purchase offline. This research focuses on webrooming in an O2O supply chain system, which comprises an e-tailer and a BM store. The e-tailer offers consumers information searching and comparison services, whereas the BM store provides experience service, takes a free ride on the online services, and makes the final sales. We consider two strategies: the first is a BM store run as the e-tailer’s self-owned store, and the second is that the e-tailer runs the BM store as a franchise. This research primarily analyzes and compares the optimal decisions of the O2O supply chain participants when executing these two strategies. In addition, this research analyzes how webrooming affects the two strategies of the O2O supply chain participants. This research produces the following results: For both the self-owned store strategy and the franchised strategy, applying nonuniform pricing online and offline benefits both the e-tailer and the BM store. With self-owned strategy, when pricing is uniform, the e-tailer’s optimal price, service level, and profit are independent of the level of webrooming. When pricing is nonuniform, the self-owned store provides more service than the online channel when the online market share is high and charges a higher price when webrooming activities are high (and vice versa).

With the franchised store strategy and uniform pricing, the store will provide greater service than the online channel when the online market share is high. For nonuniform pricing, the franchised store provides more service than the online channel when the online market share is low and charges a higher price when webrooming activity is high (and vice versa). In addition, with nonuniform pricing, the e-tailer can charge higher wholesale prices to the franchised store when the online market share is high.

We also numerically analyze how webrooming affects the profits under the two strategies. For the self-owned store strategy with nonuniform pricing, both the online market share and consumer traveling costs weaken the ability of webrooming to improve the e-tailer’s profits. Under the franchised store strategy, webrooming weakens the positive role of online market share and reinforces the negative effect of traveling costs for the e-tailer. In addition, with nonuniform pricing, the positive webrooming effect on the profit of the franchised store is more serious than for uniform pricing when either the online market share or traveling costs are low.

These results should help e-tailers manage their O2O operations. However, the research has several limitations. First, to rule out trivial cases, it assumes zero production costs and logistics costs. Future studies should incorporate these costs to verify whether the results still hold. In addition, this research only considers the same products selling online and offline. As more e-tailers recognize the importance of organic integration between channels, the modeling framework could be extended in future research by considering selling different product types online and offline. Furthermore, the question arises of what happens when the two omnichannel strategies coexist simultaneously, which should also be a subject of future research.

### Appendix

**Proof of Proposition 1.** According to equation (7), the Hessian matrix \( H \) of \( \pi(p, s_{so1}, s_{sb1}) \) in terms of \( p, s_{so1} \) and \( s_{sb1} \) is

\[
\begin{bmatrix}
\frac{\partial^2 \pi_{s_{so1}}}{\partial p^2} & \frac{\partial^2 \pi_{s_{so1}}}{\partial p \partial s_{sb1}} & \frac{\partial^2 \pi_{s_{so1}}}{\partial p \partial s_{sb1}} \\
\frac{\partial^2 \pi_{s_{so1}}}{\partial p \partial s_{so1}} & \frac{\partial^2 \pi_{s_{so1}}}{\partial s_{so1}^2} & \frac{\partial^2 \pi_{s_{so1}}}{\partial s_{sb1} \partial s_{so1}} \\
\frac{\partial^2 \pi_{s_{so1}}}{\partial p \partial s_{sb1}} & \frac{\partial^2 \pi_{s_{so1}}}{\partial s_{sb1} \partial s_{so1}} & \frac{\partial^2 \pi_{s_{so1}}}{\partial s_{sb1}^2}
\end{bmatrix} = \begin{bmatrix}
-4 & 1 & 1 \\
1 & -1 & 0 \\
0 & 1 & -1
\end{bmatrix} = -2 < 0.
\]

(A.1)
Thus, $|H|$ must be a negative definite matrix, which indicates that $\pi_s(p_o, s_{o1}, s_{b1})$ is strictly concave with respect to $p_o$, $s_{o1}$, and $s_{b1}$. Therefore, if $\partial \pi_o / \partial p = 0$, $\partial \pi_o / \partial s_{o1} = 0$, $\partial \pi_o / \partial s_{b1} = 0$, then we can get the equilibrium solutions in Table 2.

Proof of Proposition 2. According to equation (10), the Hessian matrix $H$ of $\pi_o(p_o, p_b, s_{o2}, s_{b2})$ in terms of $p_o$, $p_b$, $s_{o2}$, and $s_{b2}$ is

$$
\begin{bmatrix}
-2 & 2e & 1 - y & 0 \\
2e & -2 & y & 1 \\
1 - y & y & -1 & 0 \\
0 & 1 & 0 & -1
\end{bmatrix}
$$

(A.2)

Given that $c^2 - c^2 + e^2 > 0$, $|H|$ must be a negative definite matrix, which indicates that $\pi_o(p_o, p_b, s_{o2}, s_{b2})$ is strictly concave with respect to $p_o$, $p_b$, $s_{o2}$, and $s_{b2}$. Therefore, if $\partial \pi_o / \partial p_o = 0$, $\partial \pi_o / \partial p_b = 0$, $\partial \pi_o / \partial s_{o2} = 0$, $\partial \pi_o / \partial s_{b2} = 0$, then we get the equilibrium solutions in Table 3.

Proof of Proposition 3. The optimal decision variables are derived by the backward-induction method. The e-tailer is the leader of the Stackelberg game. By substituting equation (4) into equation (11), we get

$$
\begin{bmatrix}
\frac{\partial^2 \pi_o}{\partial p_o^2} & \frac{\partial^2 \pi_o}{\partial p_o \partial s_{o1}} & \frac{\partial^2 \pi_o}{\partial p_o \partial w} \\
\frac{\partial^2 \pi_o}{\partial p_o \partial s_{o1}} & \frac{\partial^2 \pi_o}{\partial s_{o1}^2} & \frac{\partial^2 \pi_o}{\partial s_{o1} \partial w} \\
\frac{\partial^2 \pi_o}{\partial p_o \partial w} & \frac{\partial^2 \pi_o}{\partial s_{o1} \partial w} & \frac{\partial^2 \pi_o}{\partial w^2}
\end{bmatrix}
$$

(A.3)

Thus, $|H|$ must be a negative definite matrix, which indicates that $\pi_o$ is strictly concave with respect to $p$, $w$, and $s_o$. Therefore, if $\partial \pi_o / \partial p = 0$, $\partial \pi_o / \partial w = 0$, $\partial \pi_o / \partial s_o = 0$, then we get the equilibrium solutions in Table 4.

Proof of Proposition 4. The optimal decision variables are derived by the backward-induction method. The e-tailer is the leader of the Stackelberg game. By substituting equation (2) into equation (13), the Hessian matrix of $\pi_s$ in terms of $p_{o2}$ and $s_{b2}$ is

$$
\begin{bmatrix}
\frac{\partial^2 \pi_s}{\partial p_{o2}^2} & \frac{\partial^2 \pi_s}{\partial p_{o2} \partial s_{b1}} \\
\frac{\partial^2 \pi_s}{\partial p_{o2} \partial s_{b1}} & \frac{\partial^2 \pi_s}{\partial s_{b1}^2}
\end{bmatrix}
$$

(A.4)

Thus, $|H|$ must be a negative definite matrix, which indicates that $\pi_s$ is strictly concave with respect to $p_o$ and $s_b$. Therefore, if $\partial \pi_s / \partial p_o = 0$, $\partial \pi_s / \partial s_b = 0$, then the profit $\pi_s$ of the franchised store is first obtained to seek first-order partial derivatives of $p_o$ and $s_b$: $p_o = Q_a Q + e p_o + r s_o - t$, $s_b = Q_a Q + e p_o + r s_o - t$.

By substituting $p_o$ and $s_b$ into equation (12), the Hessian matrix of $\pi_o$ in terms of $p_o$, $s_o$, and $w$ is

$$
\begin{bmatrix}
\frac{\partial^2 \pi_o}{\partial p_o^2} & \frac{\partial^2 \pi_o}{\partial p_o \partial s_o} & \frac{\partial^2 \pi_o}{\partial p_o \partial w} \\
\frac{\partial^2 \pi_o}{\partial p_o \partial s_o} & \frac{\partial^2 \pi_o}{\partial s_o^2} & \frac{\partial^2 \pi_o}{\partial s_o \partial w} \\
\frac{\partial^2 \pi_o}{\partial p_o \partial w} & \frac{\partial^2 \pi_o}{\partial s_o \partial w} & \frac{\partial^2 \pi_o}{\partial w^2}
\end{bmatrix}
$$

(A.5)

Given that $\max(2 - 3e^{-\sqrt{(3e - 2)^2 / 2(1 - e^2)}} / 2 - 1 - e)< e < \min(2 - 3e + \sqrt{(3e - 2)^2 - 2(5e^2 - 2)(e - 2) / 2(1 - e^2)}, 1 + 2(1 - e^2) / e)$, $|H|$ must be a negative definite matrix, which indicates that $\pi_s(p_o, s_o, w)$ is strictly concave with respect to $p_o$, $s_o$, and $w$. Therefore, if $\partial \pi_s / \partial p_o = 0$, $\partial \pi_s / \partial s_o = 0$, $\partial \pi_s / \partial w = 0$, we get the equilibrium solutions in Table 5.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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