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Benefit from a high store visiting cost in an omnichannel with BOPS

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A B S T R A C T
Omnichannel sales surge in the coronavirus pandemic. This paper establishes an analytical model to study when a firm can benefit from implementing the omnichannel strategy of buy-online and pick-up in-store (BOPS), where the market characteristics are captured by the two-dimensional heterogeneity of product valuation and online waiting cost. The increase in the store visiting cost will reduce BOPS consumers’ willingness to pay, but it will also strengthen the encroachment of BOPS on traditional dual-channel. The results show that the firm can benefit from the BOPS strategy when the store visiting cost is relatively high. This well explains the rapid development of the omnichannel with BOPS because of a high store visiting cost during COVID-19. Furthermore, sharply contrasting to the traditional dual-channel sales in which a higher store visiting cost always hurts the firm, the profit under BOPS can be nonmonotonic in the store visiting cost and the firm can benefit from a higher store visiting cost. Specifically, the combination of cross-selling effect, \textit{BOPS encroachment effect} and \textit{BOPS expansion reduction effect} associated with the store visiting cost can result in a U-shaped or inverse U-shaped BOPS profit. In addition, introducing BOPS motivates the firm to either increase or decrease the optimal price, conditional on the store visiting cost. For consumers, online and offline consumers can also indirectly benefit from the BOPS strategy, though they may not enjoy the BOPS service.

1. Introduction

Omnichannel sales integrate all available channels to serve consumers and have outstanding advantages compared with traditional single-channel and multichannel sales (Beck and Rygl, 2015). The omnichannel strategy attracts widespread attention from the academic community (Saghiri et al., 2017; Verhoef et al., 2015; Ailawadi and Farris, 2017; Mishra et al., 2021; Zhang et al., 2018a) and the industry (Parker and Hand, 2009; Rigby, 2011; Ortis and Casoli, 2009), which is practiced more and more in the industry. However, omnichannel is still unexplored water for many firms. In fact, a study by JDA Software and PwC reveals that only 16% of companies’ efforts are profitable when it comes to satisfying omnichannel demand (Tode, 2017).

The buy-online and pick-up in-store (BOPS) strategy is an important representative of the omnichannel strategy, which means that consumers who purchase by it first select the product online and pay, the physical store clerk packs the order in advance, and the consumers come to the store to pick it up. BOPS has the convenience of online shopping while saving the consumer waiting cost. BOPS strategy also helps consumers save the store visiting cost as consumers do not need to choose the product in-store and firms often provide extra conveniences for BOPS consumers, such as special pickup counters and reserved parking spaces (Cao et al., 2016). However, as the order is placed online, consumers cannot know the precise value of the product through experience when they decide whether to buy (Shi et al., 2018), which leads to a loss of product valuation. For the firm, BOPS generates more potential...
sales by increasing the number of consumers who visit the physical store (Clifford, 2011). According to UPS, 45% of consumers who pick up their orders in the store make additional purchases (UPS, 2015). Consumers’ additional purchases bring considerable revenue to the firm: it is estimated that every $100 of BOPS consumption results in an additional $40 of in-store consumption when the consumer comes into the store to retrieve the order.1

It is noticeable that the BOPS strategy develops explosively during the epidemic. In early 2020 and mid-2020, the top 1000 retail chains that provide curbside pickup services were 6.6% and 8.1%, respectively, but by early 2021, this proportion had reached 50.7% (Melton, 2021). At the peak of COVID-19, Kibo clients experienced a 563% surge in BOPS orders (Alonso, 2020). An intuition for the driving force of BOPS mode is the additional revenue brought by BOPS consumers’ additional purchases. However, this intuition cannot explain the surge in BOPS during the pandemic. During the COVID-19 epidemic, shopping in physical stores increases the risk of infection, consumers reduce purchase in physical stores for safety reasons. According to a recent survey, 84.5% of consumers say they are worried about contracting the coronavirus while shopping in a physical store (Melton, 2020). That is to say, the store visiting cost is greatly increased during the COVID-19 epidemic. Our article aims to explore the internal driving force of firms adopting the BOPS strategy, and several questions are raised: How does the store visiting cost affect the conditions for implementing BOPS, especially for a negligible additional revenue brought by BOPS consumers’ additional purchases? When BOPS is launched, how does profit vary with store visiting cost under different levels of cross-selling effect and BOPS service efficiency? How do demand and prices differ with and without the launch of BOPS?

To answer these questions, this paper establishes an analytical model for a firm operating online and offline sales channels to capture the key factors of omnichannel retailing with BOPS, which combines the impacts of online and offline services. The firm strategically chooses to develop BOPS, and further prices to maximize profits. The two-dimensional heterogeneity of product value and online waiting cost is modeled to reflect the essential characteristics of omnichannel sales. It is shown that there coexist BOPS encroachment effect and BOPS expansion reduction effect associated with the store visiting cost, where the former increases the BOPS demand while the latter works oppositely. By comparing the scenarios with and without BOPS, this paper shows when it is profitable for the firm to develop the BOPS strategy.

The main results obtained are summarized as follows. First, it is beneficial to develop BOPS only when the store visiting cost is relatively high. The rationale behind this is that the launch of BOPS reduces the negative impact of a large store visiting cost due to the convenience provided by the firm for the BOPS consumers, and at this time the BOPS encroachment effect works significantly. This result well explains the boom in BOPS caused by the high store visiting cost when consumers purchase in-store during the epidemic. Furthermore, for an exogenous price setting, introducing a BOPS service is profitable once the BOPS channel is active (i.e., the BOPS demand is positive). However, under the endogenously optimized price, taking the BOPS channel can hurt the firm even when the BOPS channel is active. This is because introducing the BOPS channel expands the heterogeneity of consumers, which in turn weakens the ability of pricing to extract consumer surplus. Second, driven by the combined impacts of the BOPS encroachment effect and BOPS expansion reduction effect, the profit under BOPS can be nonmonotonic in the store visiting cost, which is in sharp contrast to the traditional dual-channel sales that a higher store visiting cost always hurts the firm. Specifically, when the BOPS service efficiency is relatively high and the cross-selling revenue is relatively low, the BOPS profit is decreasing–increasing (i.e., U-shaped) in the store visiting cost; while when the BOPS service efficiency is relatively low and the cross-selling revenue is relatively high, the BOPS profit is increasing–decreasing (i.e., inverse U-shaped) in the store visiting cost. Finally, when the store visiting cost is relatively high (low), offering BOPS will increase (decrease) the optimal price. The optimal price under BOPS is first decreasing and then increasing in the store visiting cost. The results obtained suggest that the firm should carefully choose whether to launch BOPS based on the market environment and adjust prices and services reasonably after launching to maximize the profit.

The remaining part of the paper proceeds as follows. Section 2 reviews the related literature. Section 3 introduces the model. Section 4 analyzes the cases with and without BOPS, respectively, and compares the two cases. Section 6 summarizes the main findings of the paper and puts forward the future outlook. All proofs are given in Appendix.

2. Related literature

Two streams of research are closely related to our study, i.e., pricing decisions under omnichannel and operational decisions related to BOPS service.

First, our study falls into omnichannel management. Omnichannel retail refers to the integration of the online channel and the offline physical store channel. It allows consumers to compare the online price with offline price and allows the store to fulfill online orders at any location (Harsha et al., 2019). Kireyev et al. (2017) study the motivations of firms to provide or not the price strategy of self-match, which allows the firm to offer the lowest price of its multichannel to consumers. Zhang et al. (2018b) find that the retail price is lower after the online retailer opens physical stores and that the omnichannel strategy does not always benefit the retailer. The study of Shao (2021) indicates that the omnichannel strategy is beneficial for the physical retailer but can hurt the e-tailer and the manufacturer. Yan et al. (2022) study the strategic investment between competing channels. Considering retailer’s location advantage, He et al. (2020) find that firms are more likely to take buy-online-and-deliver-from-store strategy if the competition between channels is stronger. Furthermore, He et al. (2021) analyze the option of ship-from-store under competition, and Jiu (2022) studies the ship-from-store operation through robust optimization. Li et al. (2021) focus on the coupons strategy under omnichannel and indicate that a higher cross-selling revenue from BOPS promotes the firm’s willingness to offer coupons

1 https://kibocommerce.com/case-studies/boscovs/.
and leads to a higher profit. Zhang et al. (2021) find the “win-win” zone of the supplier and retailer with “showrooming”, their study indicates that the omnichannel strategy will decrease the “win-win” zone due to the competition effect. Existing studies have realized the changes that omnichannel brings to the operation, but most of them explain the influence of omnichannel from the relationship between the omnichannel members and the external benefits brought by the new channel. This paper analyzes the impact of the new channel under the endogenous consumer utility. It is assumed that the firm manages all channels and sets a uniform price among different channels, thus focusing more on the essential impact of BOPS on omnichannel. This paper shows that even if excluding the influence of omnichannel members’ strategy interactions and external benefits brought by BOPS, it can be better off for the firm to develop the omnichannel strategy.

Second, our study is closely linked to operational decisions related to BOPS strategy. In order to better understand consumers’ channel choices under the BOPS model, it is necessary to distinguish the BOPS model from traditional channel consumption. Gao and Su (2017) point out that the BOPS service saves consumers the time of choosing products in the store, and can also avoid the loss of consumers caused by the store shortages. They find that for the original hot-selling products in the store, and when the BOPS cost-effectiveness is low, the implementation of the BOPS strategy will actually reduce the profit. Cao et al. (2016) develop an analytical framework to describe the trade-off that BOPS can generate additional demand but will hurt the existing channels and increase operating costs. However, as consumer product valuation does not vary with channels and the online price is no higher than the offline price in their model, the “online-to-store” (OS) channel is always better than the offline channel, thus no consumer will purchase offline when the OS channel is offered. Furthermore, Kong et al. (2020) analyze the effects of BOPS implementation under different pricing strategies and find that BOPS increases the profit if and only if the unit operating cost in the BOPS channel is relatively low. Shi et al. (2018) obtain the threshold of unit production cost and demand uncertainty under the BOPS strategy by establishing a two-stage consumption model with pre-orders. In line with the previous literature (Wu and Chen, 2022; Cao et al., 2016), our model reflects the convenience of BOPS to consumers. The result shows that it may be unprofitable for the firm to offer BOPS when the store visiting cost is relatively low even if the operating cost of BOPS is negligible, which is different from the findings of Cao et al. (2016) and Lin et al. (2021). Cao et al. (2016) and Lin et al. (2021) model the BOPS consumer utility to be higher than the offline consumer utility. Our model simultaneously considers consumers’ choice from online, offline, and BOPS channels when the firm implements the BOPS strategy, which is more realistic.

Many theoretical studies discuss the implementation conditions of the BOPS strategy from different perspectives. Most studies show that the BOPS strategy can increase the benefit of the firm under certain conditions (Lin et al., 2021; Zhang et al., 2019; Niu et al., 2019). Hu et al. (2022) research the impact of the BOPS from an inventory perspective and find that the firm will be hurt when both the store visiting and the online waiting costs are relatively high. Gao et al. (2022) investigate how should the firm decide on the number and size of physical stores. They show that under BOPS, the firm should have fewer stores with larger sizes. The increase in store demand and the decrease in returns motivate the firm to increase the inventory of goods in the store, while the decrease in the number of stores can further reduce the cost of facility investment. Considering extra losses in-store of fresh produce, Song et al. (2021) study the omnichannel strategies for fresh produce retailers and find that fresh produce with a higher loss rate is more beneficial for omnichannel sales. Fan et al. (2022) focus on the service decisions of a manufacturer and an independent retailer under BOPS, separately. They show that BOPS would be beneficial when the service levels of all channels are low, as a low service level could reduce the service investment cost. In this paper, the market characteristics are captured by the two-dimensional heterogeneity of product value and online waiting cost. In addition, a partially covered market can reflect the role of BOPS in expanding demand. Different from the findings of the existing literature, this paper shows that the firm can benefit from offering BOPS service when the store visiting cost is relatively high, though the increase of store visiting cost will decrease the utility of BOPS consumers. Especially, the study of Hu et al. (2022) is the only paper focusing on the store visiting cost in BOPS model currently. They model the pickup cost to be the same as the store visiting cost, and find that BOPS can benefit the firm if the store visiting cost is relatively low, otherwise, hurt the firm. Note that the firm usually offers convenience to BOPS adopters, and the pickup cost is less than the store visiting cost in practice. We take the convenience degree of BOPS into consideration to examine whether the firm could benefit from a high store visiting cost.

With the continuous development and improvement of the BOPS service, pricing and service researches under the BOPS strategy also attract the attention of more researchers. Xu et al. (2021) show that the firm will maintain or lower the price after implementing BOPS. Jin et al. (2018) give the recommended service radius of BOPS by establishing a theoretical model and comparing the BOPS strategy with the “reserve-online-pick-up-and-pay-in-store” (ROPS) strategy. It is concluded that the ROPS model is better than or equal to the BOPS model when factors of consumer cancellation of the order are included. However, this model only considers consumers’ purchases in-store and BOPS purchase. It does not consider consumers who transfer from an online channel, nor does it consider the influence of service level on consumer channel selection. In addition, Liu et al. (2022) study the service effort timing scheme strategies and Yan et al. (2020) focus on the return rate in a competitive market. In this paper, we firstly consider an exogenous price to focus on the impact of store visiting cost on the firm’s BOPS strategy, and then further endogenize the price to study the changes in optimal prices and profits with and without BOPS development. Our study finds that taking the BOPS strategy motivates the firm to either increase or decrease the optimal price, depending on the store visiting cost, which is also different from the findings of the existing literature (e.g., Xu et al., 2021). In addition, we find that the combination of cross-selling effect, BOPS encroachment effect and BOPS expansion reduction effect associated with the store visiting cost can result in a U-shaped or inverse U-shaped BOPS profit, which is a new discovery for the impact of store visiting cost on the BOPS profit.

To clearly present the similarities and differences between this paper and existing literature, we summarize the most relevant literature in Table 1 and highlight our contributions.
Consumers evaluating products online face a loss of product value perception (i.e., perceived value loss) compared to those visiting a physical store. Note that perceived value loss is an important feature of online sales (Akturk and Ketzenberg, 2022; Kacen et al., 2013). Although there are many studies in channel management (Chiang et al., 2003; Luo and Sun, 2016; Shin, 2007; Zhang et al., 2019), it is rarely studied in the BOPS framework. Furthermore, in terms of consumer heterogeneity, although some articles have studied the heterogeneity of consumer valuation, and some have studied the heterogeneity of online shopping cost, there are no papers that have studied the two-dimensional heterogeneity of consumer valuation and online shopping cost. In addition, although the cross-selling effect has been integrated in some BOPS studies, this paper finds other important effects of the cross-selling on BOPS profit. By considering the loss of consumer perceived value, the two-dimensional heterogeneity of consumer valuation and online waiting cost and cross-selling effect, this paper presents important findings supplementing to the previous literature.

Our study focuses on when it is beneficial for the firm to provide the omnichannel strategy with BOPS, and the price decisions under different market environment. Consumers with heterogeneous product valuations and online waiting costs can endogenously choose among all purchase channels provided by the firm. Although under the conditions of centralized decision-making by the firm, uniform price in all channels, and cost-free of implementing the BOPS strategy, the results show that it is not always profitable to develop BOPS.

### 3. Model

Consider a firm that sells the same product to consumers normalized to a mass of one through multichannel: (1) Online channel, where consumers buy the product online and wait for the delivery after payment; (2) Offline channel, where consumers visit a physical store, experience there, and make a purchase; (3) BOPS channel, where consumers buy the product online and pick it up in a physical store.

The consumer product valuation $v$ is heterogeneous, uniformly distributed in $[0,1]$. Compared with those who visit a physical store, consumers evaluating products online face a loss of product value perception due to the lack of physical inspection (Akturk and Ketzenberg, 2022; Kacen et al., 2013). In line with Chiang et al. (2003) and Luo and Sun (2016), we assume that the consumers with valuation $v$ who inspect the product online (i.e., online consumers and BOPS consumers) can only get utility $\delta v$ ($\delta \in (0,1)$) due to the loss of product value perception with the inability to touch and feel the product. In fact, $\delta$ captures the relative efficiency of the online channel.

The price $p$ is uniform among channels, which is often applied in the real business environment (e.g., Uniqlo and Decathlon) and is a standard assumption under BOPS (Gao and Su, 2017; Zhang et al., 2019; Jin et al., 2018). Although some studies have found that the online price can be lower than offline, it is infeasible under BOPS. Specifically, due to the lower price of paying online, all the consumers buy offline before will order online, and the physical store will have no demand.

Consumers have different shopping costs for each channel. When buying online, consumers incur waiting cost $\chi$, such as waiting for the delivery process of product packaging, transportation, etc. As the waiting sensitivity differs across consumers, the cost $\chi$ is heterogeneous and is assumed to uniformly distribute on $[0,1]$, which is in line with Gao and Su (2017) and Kong et al. (2020). When buying offline, consumers incur store visiting cost $c$ ($0 < c < 1$), such as traveling to the store and searching for the product. When picking up in the store, consumers incur a pickup cost $rc$. Following existing literature (Wu and Chen, 2022; Cao et al., 2016) and practices (e.g., Walmart and JD.com), the firm usually offers convenience to BOPS adopters, and the pickup cost is less than the store visiting cost. Note that $1 - r$ represents the convenience degree of BOPS, where $0 < r < 1$. 

### Table 1

| Similarities and differences of the most relevant literature. |
|---------------------------------------------------------------|
| Channel management | Perceived value loss | BOPS | BOPS consumer heterogeneity | Cross-selling effect |
|---------------------|---------------------|-----|------------------------------|---------------------|
| Yoo and Lee (2011) | ✓                   | ✓   | ✓                           | ✓                   |
| Chiang et al. (2003)| ✓                   | ✓   | ✓                           | ✓                   |
| Luo and Sun (2016) | ✓                   | ✓   | ✓                           | ✓                   |
| Shin (2007)        | ✓                   | ✓   | ✓                           | ✓                   |
| Shulman et al. (2010)| ✓                   | ✓   | ✓                           | ✓                   |
| Shi et al. (2013)  | ✓                   | ✓   | ✓                           | ✓                   |
| Hu et al. (2022)   | ✓                   | ✓   | ✓                           | ✓                   |
| Cao et al. (2016)  | ✓                   | ✓   | ✓                           | ✓                   |
| Kong et al. (2020) | ✓                   | ✓   | ✓                           | ✓                   |
| Yan et al. (2020)  | ✓                   | ✓   | ✓                           | ✓                   |
| Xu et al. (2021)   | ✓                   | ✓   | ✓                           | ✓                   |
| Jin et al. (2018)  | ✓                   | ✓   | ✓                           | ✓                   |
| Gao and Su (2017)  | ✓                   | ✓   | ✓                           | ✓                   |
| Niu et al. (2019)  | ✓                   | ✓   | ✓                           | ✓                   |
| Zhang et al. (2019)| ✓                   | ✓   | ✓                           | ✓                   |
| Harsha et al. (2019)| ✓                   | ✓   | ✓                           | ✓                   |
| Shi et al. (2018)  | ✓                   | ✓   | ✓                           | ✓                   |
| Lin et al. (2021)  | ✓                   | ✓   | ✓                           | ✓                   |
| Our work           | ✓                   | ✓   | ✓                           | ✓                   |
According to the above considerations, consumers are uniformly distributed across the “square” \{(v,x)\mid v \in [0,1], x \in [0,1]\}. We use subscripts \(r\), \(o\), and \(b\) to denote offline, online, and BOPS channels, respectively. The consumers’ utility functions for each type are respectively given by:

\[
\begin{align*}
 u_r &= v - p - c, \\
 u_o &= \delta v - p - x, \\
 u_b &= \delta v - p - rc.
\end{align*}
\]

Consumers strategically make purchasing decisions to maximize their utilities. When \(v\) is relatively high, consumers are more willing to visit stores due to the relatively low efficiency of online. This setting follows the fact that the consumers associated with high-valued products usually purchase in physical stores. When \(v\) is relatively low, consumers choose between online and BOPS channels, depending on the comparison of costs \(x\) and \(rc\). Additionally, consumers will leave the market when they face a disutility in each channel.

Furthermore, BOPS adopters may make extra purchases when they visit stores, which is so-called cross-selling effect. In our model, \(\beta\) represents the cross-selling revenue brought about by each consumer who visits the store to pick up. Production cost and selling cost are normalized to zero (Huang et al., 2018; Ha et al., 2022, 2016; Li et al., 2014). These assumptions allow us to focus on the main effect of BOPS while retaining analytical tractability.

A summary of the notations used is presented in Table 2.

### Table 2

| Notations | Meaning |
|-----------|---------|
| \(v\)     | Consumer product valuation, uniformly distributed on \([0,1]\) |
| \(p\)     | Product price, the decision variable |
| \(c\)     | The store visiting cost |
| \(\delta\) | The relative efficiency of the online channel |
| \(x\)     | The online waiting cost, uniformly distributed on \([0,1]\) |
| \(r\)     | \(1 - r\) representing the convenience degree of BOPS |
| \(u\)     | The utility of consumers buying in a certain channel |
| \(D\)     | Demand for a certain channel |
| \(\beta\) | Revenue per unit of cross-selling |
| \(r, o, b\) | Offline, online, and BOPS channels |
| \(T, B\)  | Traditional dual-channel and BOPS available scenarios |
| \(br, bo, bb\) | BOPS encroachment of offline, online channel, and newly expanded |
| \(i, f\)  | Online and offline consumer surplus, total consumer surplus |

4. Analysis

In this section, we study the demand and pricing under two scenarios (with and without BOPS), respectively. We first study the incentive for the firm to launch BOPS under the exogenous price, and then study the optimal prices with and without BOPS and the impacts of BOPS on the profit and consumer surplus under the endogenous price. The exogenous price setting happens when the menu cost for the firm is large, such as when a firm’s goodwill may suffer huge losses due to changes in product prices (Luca and Reshef, 2021). To exclude trivial cases with non-positive demand in a certain channel, we assume that \(c \in (\frac{1 - \delta}{1 + \delta}, \frac{1}{1 + \delta}), \delta > r \).

4.1. Demand analysis

Consider a benchmark where the firm operates traditional dual-channel without BOPS service, which is called scenario DC and denoted by a superscript ’’\(T\)’’. Consumers have three options: buy offline, buy online, or leave the market. According to \(D^T_r = \{(v,x)\mid u_r > 0, u_o > u_r\} \), \(D^T_o = \{(v,x)\mid u_o > 0, u_o > u_r\} \), the demands illustrated in Fig. 1 can be calculated as

\[
\begin{align*}
 D^T_r &= \begin{cases} 
 1 - p - c - \frac{(c-\delta)(p+c)}{2(1-\delta)} & , \ c \leq 1 - \delta, \\
 \frac{1-p-c}{2} - \frac{2(1-\delta)}{2(1-\delta)(1-\delta)} & , \ c > 1 - \delta,
\end{cases} \\
 D^T_o &= \begin{cases} 
 \frac{(\delta\delta + \delta p^2)}{2\delta(1-\delta)} & , \ c \leq 1 - \delta, \\
 \frac{(\delta\delta + \delta p^2 - \delta(\delta\delta - 1)^2)}{2\delta(1-\delta)} & , \ c > 1 - \delta,
\end{cases} \\
 D^T &= 1 - p - c + \frac{(c\delta - (1 - \delta)p)^2}{2\delta}.
\end{align*}
\]
Consumers have four options: buy offline, buy online, buy BOPS, or leave the market. According to $D$, consumers can now choose from the online channel and BOPS, depending on the shopping cost. It is found that BOPS can not only encroach on the online channel but also expand the online channel demand while simultaneously cannibalizing the offline channel demand. Except for the potential demand shift from offline to the online channel, a higher $\delta$ can also prevent the consumers from entering the market while a higher $c$ works inversely. We show in Appendix (Lemma A1) the impacts of parameters on demand. Intuitively, the increases in $c$ and the total demand is $\delta$ works inversely.

We then consider the case where the firm offers BOPS service, which is called scenario BOPS and denoted by a superscript "$B$". Consumers have four options: buy offline, buy online, buy BOPS, or leave the market. According to $D^B = \{(v, x)|u_0 > 0, u_1 > u_2, u_p > u_b\}$, $D^B_o = \{(v, x)|u_0 > 0, u_0 > u_1, u_0 > u_b\}$, and $D^B_b = \{(v, x)|u_0 > 0, u_b > u_1, u_b > u_p\}$, the demands illustrated in Fig. 2 can be calculated as

$$D^B = \begin{cases} 
1 - c \frac{c - rc}{2(1 - \delta)}, & c \leq 1 - \delta, p \leq \frac{c - rc}{1 - \delta}, \\
1 - p - c \frac{(c - (1 - \delta)(p + rc))^2}{2(1 - \delta)}, & c \leq 1 - \delta, p > \frac{c - rc}{1 - \delta}, \\
\frac{1}{2}(1 - (c - 1 - \delta)(3 - rc - c - \delta)), & c > 1 - \delta, p \leq \frac{c - rc}{1 - \delta}.
\end{cases}$$

(7)

$$D^B_o = \begin{cases} 
\frac{(c - 2c + 2cp + 2rcp)}{2(1 - \delta)}, & c \leq 1 - \delta, p \leq \frac{c - rc}{1 - \delta}, \\
\frac{(c + 2c + 2c) - (c - \delta - c)^2}{2(1 - \delta)}, & c > 1 - \delta, p \leq \frac{c - rc}{1 - \delta}.
\end{cases}$$

(8)

$$D^B_b = \begin{cases} 
\frac{(1 - rc)(c - rc - (1 - \delta)p)}{2(1 - \delta)}, & p \leq \frac{c - rc}{1 - \delta}, \\
0, & p > \frac{c - rc}{1 - \delta}.
\end{cases}$$

(9)

and the total demand is

$$D^B = \begin{cases} 
\frac{(c + 2c + 2c - 2c)}{2(1 - \delta)}, & p \leq \frac{c - rc}{1 - \delta}, \\
1 - p - c \frac{(c - (1 - \delta)p)^2}{2(1 - \delta)}, & p > \frac{c - rc}{1 - \delta}.
\end{cases}$$

(10)

Similar to scenario DC, the online channel is more popular with consumers who have a relatively low valuation, while the offline channel is more popular with consumers who have a relatively high valuation. However, consumers who have a moderate valuation can now choose from the online channel and BOPS, depending on the shopping cost. It is found that BOPS can not only encroach on the
the original online and offline channels but also expand the total market coverage. Among those existing consumers, some online buyers who have relatively high online waiting costs and some offline buyers who have relatively low product valuations can now choose to pick up their orders instead. Compared to the online channel, BOPS can save the heavy waiting cost of some online buyers while having the same product value. Compared to the offline channel, BOPS will decrease the perceived value of the product by consumers, reducing the willingness to pay. BOPS attracts consumers who have a relatively low product valuation by reducing the cost of visiting the store while saving the online waiting cost. In one word, BOPS, which offers convenience for pick-up, combines the online and offline services and provides consumers with a more compromised choice.

It is noted from Eq. (9) that consumers purchase through BOPS only when the price is relatively low, that is, \( p \leq \frac{(\delta c - rc)}{(1 - \delta)} \).

The threshold \( \frac{(\delta c - rc)}{(1 - \delta)} \) is increasing in \( \delta \) and \( c \), while decreasing in \( r \). Specifically, a relatively low \( \delta \) will lead the loss of utility that purchased through BOPS \((1 - \delta)\) to be relatively high, and a relatively low \( c \) will make the advantage of BOPS compared to offline \((1 - r)c\) not significant. Additionally, a relatively high \( r \) will lead to a relatively high pickup cost \( rc \). When the price is relatively high (i.e., \( p > \frac{(\delta c - rc)}{(1 - \delta)} \)) in which the firm would focus on the consumers with a high product valuation \( v \), the BOPS channel is less attractive due to the loss of product valuation.

To better explore the demand of BOPS \( D_b^B \), we divide it into three parts: the encroachment of offline channel, online channel, and newly expanded, denoted by \( D_{br}^B \), \( D_{bo}^B \) and \( D_{bb}^B \), respectively, which are shown in Appendix. The influence of \( c \) on demand is shown in Lemma 1.

**Lemma 1.** \( D_{br}^B \) and \( D_{bo}^B \) are both increasing in \( c \). \( D_{bb}^B \) is firstly increasing and then decreasing in \( c \) with the turning point \( c = c_1 \), where \( c_1 \) is put in Appendix.

It is shown that more consumers switch from the offline channel to BOPS facing with a higher store visiting cost. This is because the reduced shopping cost due to the convenience of BOPS (i.e., \((1 - r)c\)) is increasing in \( c \). That is, the higher the store visiting cost, the more obvious the advantages of BOPS, and the more encroachment from the online channel of BOPS \( D_{bo}^B \).

Note that the demand newly expanded \( D_{bb}^B \) is nonmonotonic in \( c \). To facilitate the analysis later, we outline two different effects of store visiting cost in scenario BOPS. First, consumer pickup cost is increasing in \( c \), which leads some consumers to leave the market. We refer to this as the BOPS expansion reduction effect associated with the store visiting cost. Second, due to the increase in the store visiting cost, more consumers choose to purchase online. It also means that more consumers in traditional dual-channel who would leave the market due to a relatively high online waiting cost can be partially captured by BOPS. Specifically, purchasing through BOPS can save the online waiting cost, which caters to those consumers sensitive to waiting. Therefore, the increase in the store visiting cost can also enable BOPS to serve more new consumers. As the increase in BOPS expansion at this time is due to the increase in online consumers, it can be understood as an encroachment on the remaining online consumers, we refer to this as the BOPS encroachment effect associated with the store visiting cost. Note that the BOPS encroachment effect relates to the impacts of store visiting cost on \( D_{br}^B \) and \( D_{bo}^B \).

The BOPS encroachment effect and the BOPS expansion reduction effect are both intensified by an increasing store visiting cost \( c \), however, the combined impacts depend on which effect being dominant. Within a certain range (i.e., \( c \leq c_1 \)) for relatively low store visiting costs, the BOPS encroachment effect dominates the BOPS expansion reduction effect, and an increasing \( c \) can highlight the advantage of BOPS. Thus, the BOPS demand newly expanded increases. However, when the store visiting cost is large enough
(i.e., $c > c_1$), the \textit{BOPS expansion reduction effect} dominates the \textit{BOPS encroachment effect}. Even if BOPS offers some convenience, consumers may still leave the market due to the high pickup cost. Hence, the BOPS demand newly expanded is decreasing in $c$.

Similarly, Lemma 2 shows that how the demands under scenario BOPS vary with $\delta$, $c$, $p$, respectively.

**Lemma 2.** (i) $D^p_A$, $D^p_h$ and $D^h$ are all increasing in $\delta$, while $D^p_B$ is decreasing in $\delta$. (ii) $D^p_A$ and $D^h$ are both decreasing in $c$, while $D^p_B$ is increasing in $c$. If $p > (\delta c - rc)/(1 - \delta)$, $D^p_B$ is always zero; otherwise, $D^p_B$ is firstly increasing and then decreasing in $c$ with the turning point $c = c_2$, where $c_2$ is put in Appendix. (iii) $D^p_A$, $D^p_h$, $D^p_B$ and $D^h$ are all decreasing in $p$.

The monotonicity of the demands in $p$ and $\delta$ can be easily verified from the utility functions (1)–(3). An increase in the utility from a channel leads to an increase in demand for that channel, except for $D^p_B$. It is shown that within a certain range, the reduction of BOPS purchase utility (i.e., the increase of pickup cost $rc$) can increase the BOPS demand, which can be illustrated by the \textit{BOPS encroachment effect}.

For the total demand under BOPS, a higher store visiting cost decreases the purchasing utility and eventually reduces the demand. However, note that under scenario BOPS the offline or online consumers can switch to BOPS. Changes in purchase strategies inevitably change the profit. Although the total demand is reduced by a higher $c$, it is shown that the demand of BOPS could increase. It can be profitable for the firm to sacrifice total demand and transfer demand to a more favorable selling channel.

### 4.2. BOPS strategy under an exogenous price

In this part, we examine the impact of BOPS on the profit by comparing the equilibrium results under an exogenously given price $p$.

In scenario DC, the total profit includes two items: the profit from an offline channel and the profit from an online channel, which is expressed as

$$\Pi^T = p(D^T_d + D^T_o).$$

(11)

In scenario BOPS, the total profit includes three items: the profit from an offline channel, the profit from an online channel, and the profit from BOPS, which is expressed as

$$\Pi^B = p(D^B_d + D^B_o) + (p + b)D^B.$$

By comparing the profits in the two cases, we can obtain the following result.

**Proposition 1.** Under an exogenously given price $p$, the firm can benefit from offering BOPS service if and only if $c > p(1 - \delta)/(\delta - r)$.

One of the important roles of BOPS is to help consumers save the cost of choosing products in the store. The higher the store visiting cost, the more obvious the impact of BOPS in saving the offline shopping cost. Besides, more consumers in traditional dual-channel who would leave the market due to a relatively high online waiting cost will also transfer to BOPS channel. On the other hand, consumers who pick up at the store need to browse product information online and place an order first, thus those who purchase through BOPS will have a reduced product value. When consumers’ original store visiting cost is relatively high, the \textit{BOPS encroachment effect} works significantly. Consumers are willing to sacrifice part of the product experience and choose a more favorable purchase channel, i.e., BOPS service. Conversely, when consumers’ original store visiting cost is relatively low, consumers who want a high sense of experience will choose the offline channel, and consumers who want to save the store visiting cost can choose the online channel, thus the BOPS channel has no obvious advantage for the two types of consumers.

Under scenario DC, the increase in the store visiting cost $c$ can directly lead a large part of consumers who purchase offline to leave the market. In the case of BOPS as an alternative purchase channel, consumers have more choices when the cost of offline purchase increases. The consumers who are sensitive to waiting can choose to purchase through BOPS when the store visiting cost is relatively high. Although the increase in the store visiting cost $c$ will have a certain negative impact on demand, compared to scenario DC, this negative impact is reduced by the cost saved $(1 - r)c$ under BOPS. In other words, the firm that offers BOPS is less affected by the change in store visiting cost $c$. From this perspective, the firm that develops BOPS has an advantage in responding to huge changes in the market environment, such as changes in the shopping environment caused by emergencies. During the COVID-19 epidemic, the store visiting cost $c$ is greatly increased. BOPS happens to provide consumers with a good choice to eliminate the time in the store and gain their favorite products quickly (Ali, 2021). Thus, the BOPS service has developed greatly during the epidemic.

**Corollary 1.** Under an exogenously given price $p$, the firm benefits from introducing the BOPS service once the BOPS channel is active.

For an exogenous price setting, the prices with and without BOPS are fixed at the same level. It can be concluded (also shown in Figs. 1 and 2) that the total demand increases once the demand of the BOPS channel is positive, leading to an immediate increase in profit.

Under the exogenously given price $p$, the firm can benefit from offering BOPS service only when the store visiting cost $c$ is relatively high, which implies a positive BOPS demand. We will show that under an endogenously optimized price, a positive BOPS demand does not guarantee the benefit from BOPS but the firm can also benefit from BOPS when the store visiting cost $c$ is relatively high.
### 4.3. BOPS strategy under pricing

In this section, we examine the impacts of BOPS on the profit and consumer surplus by comparing the equilibrium results under an endogenously optimized price.

Solving the profit maximization problem for the firm, the optimal price and profit under scenario DC are shown in Proposition 2.

**Proposition 2.** In scenario DC, the optimal price is

\[ p^* = \frac{-A - 2c\delta^2 + (2c + 2)\delta}{3(1 - \delta)^2}. \] (13)

and the optimal profit is

\[ II^* = \frac{(2\delta(1 + c - c\delta) - A) (6 - 6c + c^2\delta^2 + A(1 + c - c\delta) + (6 - 2c^2 - 2c) \delta^2 + (c^2 + 8c - 14) \delta)}{27(1 - \delta)^2}, \]

where \( A = \sqrt{\delta (c^2\delta(\delta - 1)^2 + c (-2\delta^2 - 4\delta + 6) - 6\delta^2 + 16\delta - 6)}. \)

It is expected that the store visiting cost negatively affects the firm under scenario DC, as shown in the following corollary.

**Corollary 2.** \( p^* \) and \( II^* \) are both decreasing in \( c \).

Corollary 2 indicates that, in scenario DC, a higher \( c \) is always unfavorable to the firm. A higher store visiting cost discourages consumers from purchasing, which forces the firm to lower its price to retain them. Thus, the total profit decreases due to lower demand, and consumers’ switching to online provides no extra benefit as well.

Notice that the firm has two optional price types under the BOPS strategy, the one lower (higher) than \( D_b \) as a low (high) price strategy. For the high price strategy, the BOPS channel does not generate active demand. For the case of the high price strategy associated with \( D_b = 0 \), the optimal price and profit of the firm are the same as those of scenario DC shown in Proposition 2. At this time, the BOPS channel will not bring additional benefit, thus scenario BOPS does not dominate scenario DC, as shown in Proposition 1. In the following analysis, we only need to focus on the case of low price strategy associated with \( D_b > 0 \). Substituting Eqs. (7)–(9) into the profit function, the optimal price and profit under scenario BOPS can be obtained in Proposition 3.

**Proposition 3.** In scenario BOPS, the optimal price and profit, respectively, are:

\[ p^{B*} = \frac{1}{4} (r^2c^2 - 2r(1 - \beta)c + 2(\delta - \beta)), \] (14)

\[ II^{B*} = \frac{(r^2c^2 - 2r(1 - \beta)c + 2(\delta - \beta))^2}{16\delta} + \frac{\beta c(1 - rc)(\delta - r)}{\delta(1 - \delta)}. \] (15)

Noticing that the store visiting cost is significant to the firm’s profitability under both scenarios DC and BOPS, we examine the impact of \( c \) on \( p^{B*} \) in Corollary 3.

**Corollary 3.** \( p^{B*} \) is firstly decreasing and then increasing in \( c \) with the turning point \( c = (1 - \beta)/r \).

When the store visiting cost \( c \) is relatively low, the firm first decreases the price to maintain the demand with the increase of the store visiting cost \( c \). However, when the store visiting cost \( c \) is relatively high, it has a significant negative influence on the demand, which helps the firm serve high-value consumers and increase the marginal profit.

Note that the combined impacts of the BOPS expansion reduction effect and BOPS encroachment effect have a trade off with the cross-selling effect, which can drive the BOPS profit to be increasing or decreasing in the store visit cost \( c \). We first analyze the impact of the cross-selling effect on BOPS profit in Lemma 3, and then further analyze the impact of the combination of cross-selling effect, BOPS encroachment effect and BOPS expansion reduction effect of store visiting cost on BOPS profit.

**Lemma 3.** The profit under BOPS \( II^{B*} \) is increasing in the revenue per unit of cross-selling \( \beta \).

It is shown in Lemma 3 that cross-selling effect helps increase the BOPS profit. However, the BOPS encroachment effect helps increase the BOPS demand while the BOPS expansion reduction effect decreases the BOPS demand. We analyze how the BOPS profit varies with the store visiting cost \( c \) under different level of cross-selling \( \beta \) in the following.

**Proposition 4.** When \( \beta_1 > \beta_2 \) and \( r > r_1 > r_2 \), \( II^{B*} \) is decreasing in \( c \) when \( \beta_1 < \beta \leq \beta_2 \) and \( r \leq r_2 \), \( II^{B*} \) is increasing in \( c \), where \( \beta_1 \leq \beta_2 \) and \( r_1 > r_2 \), and \( \beta_1, \beta_2, \beta_3, r_1, r_2 \) are put in Appendix.

Proposition 4 shows that when the cross-selling effect and the BOPS service efficiency are both low (high), the BOPS profit is increasing (decreasing) in the store visiting cost \( c \). It is intuitive that high (low) cross-selling revenue \( \beta \) and BOPS service efficiency \( 1 - r \) strengthen (weaken) the benefit of BOPS selling. The BOPS expansion reduction effect dominates (does not dominate) the cross-selling effect and BOPS encroachment effect, which leads the BOPS profit to be decreasing (increasing) in the store visiting cost \( c \) when \( \beta \) is relatively low (high) and \( r \) is relatively high (low).
Proposition 5. When $\beta = 0$, $II^{B_S}$ is convexly decreasing in $c$; when $\beta = 1$ and $r > r_3$, $II^{B_S}$ is firstly increasing and then decreasing in $c$. Further, there exists $\hat{\beta} \in (0, 1)$ such that $II^{B_S}$ is firstly decreasing and then increasing in $c$ with $\hat{\beta}$ and the turning point $c = c_3$, where $\hat{\beta}$ and $c_3$ are put in Appendix.

Proposition 5 shows that when the BOPS profit can be U-shaped or inverse U-shaped in the store visiting cost $c$. For the specific case where the cross-selling revenue $\beta$ is zero, as the total demand is decreasing in $c$, the BOPS profit is decreasing in $c$. Driven by the BOPS encroachment effect associated with the store visiting cost $c$, $II^{B_S}$ is convexly decreasing in $c$ (by noticing an increasing $\frac{d\Delta II^{B_S}}{dc}$ in $c$). Note that when the cross-selling revenue $\beta$ is relatively low or high (i.e., $\hat{\beta} = 0$ or $\beta = 1$), BOPS profit with respect to store visiting cost $c$ can be U-shaped or inverse U-shaped, respectively. To facilitate the analysis, in Figs. 3 and 4, we vary the store visiting cost under two different market conditions (i.e., $\beta$ and $r$ are both low or high), respectively, to examine the effects on optimal price, total demand, BOPS demand and profit.

We first analyze the case when the cross-selling revenue $\beta$ is relatively low but the BOPS service efficiency $(1 - r)$ is relatively high (corresponding to a low $r$). Note that the consumer utility is decreasing in the store visiting cost $c$. Facing with an increasing $c$, the firm has to decrease the price to maintain a suitable total demand which is still decreasing with $c$, as shown in Fig. 3(a) and (b), respectively. It is worthwhile mentioning that the BOPS encroachment effect always dominates the BOPS expansion reduction effect due to the relatively high BOPS service efficiency associated with a low $r$. Thus, the BOPS demand increases with $c$, as shown in Fig. 3(c). To sum up, an increasing $c$ brings a decreased total demand while an increased BOPS demand. Recall that the cross-selling effect of BOPS is relatively low. Therefore, when the store visiting cost $c$ is relatively small, the benefit from the increased BOPS demand which is limited by a small $c$ cannot compensate for the loss of reduced total demand, and the profit is decreasing in $c$. However, when the store visiting cost $c$ is relatively high which brings a significantly large BOPS demand, the benefit from the increased BOPS demand can well compensate for the loss of reduced total demand, and the profit is increasing in $c$. The above findings about the nonmonotonicity of profit (U-shaped) with respect to the store visiting cost $c$ are also shown in Fig. 3(d).

To examine the generality of this U-shaped in BOPS profit with respect to store visiting cost, we consider a special case where online demand is fixed. In this case, BOPS demand is always increasing in the store visiting cost $c$, corresponding to a dominant BOPS encroachment effect. Corollary 4 shows that the BOPS profit is U-shaped in the store visiting cost $c$, which verifies the finding in Proposition 5 in this case.

Corollary 4. In a special case where online demand is fixed at $\tau$, $II^{B_S}$ is firstly decreasing and then increasing in $c$ with the turning point $c_3$ which decreases with $\beta$, as shown in Appendix.

Next, we turn to the case when the cross-selling revenue $\beta$ is relatively high, but the BOPS service efficiency $(1 - r)$ is relatively low. As shown in Fig. 4(a), the price is U-shaped in the store visiting cost $c$, which is consistent with Corollary 3. Similar to the case in Fig. 3, the total demand is reduced by an increasing store visiting cost $c$, as shown in Fig. 4(b). Note that at this time the relatively low BOPS service efficiency corresponding to a high $r$ significantly increases the pickup cost $rc$, which ultimately weakens the BOPS encroachment effect. Different from the case in Fig. 3, the BOPS encroachment effect dominates the BOPS expansion reduction effect only for a relatively low store visiting cost $c$, while it is dominated by the BOPS expansion reduction effect for a relatively high $c$. Thus, the BOPS demand is inverse U-shaped in $c$, as shown in Fig. 4(c). Additionally, note that a relatively high cross-selling effect makes the BOPS demand a key role in determining the profit. So, the profit shares the same trend with the BOPS demand with respect to the store visiting cost, i.e., inverse U-shaped in $c$, as shown in Fig. 4(d).

A general finding is summarized in observation 1.

Observation 1. If $r$ and $\beta$ are both low, $II^{B_S}$ is firstly decreasing and then increasing in $c$; if $r$ and $\beta$ are both high, $II^{B_S}$ is firstly increasing and then decreasing in $c$.

We then focus on the impacts of the BOPS strategy on optimal price and profit.

Proposition 6. Under an endogenously optimized price, offering BOPS service will increase the optimal price if $c \leq c_5$ (i.e., $p^{B_S} < p^{\tau}$), while increasing the optimal price if $c > c_5$ (i.e., $p^{B_S} > p^{\tau}$), where $c_5$ is put in Appendix.

It is shown from Proposition 6 that the optimal price in scenario BOPS can be higher or lower than in scenario DC. Note that BOPS is an additional strategy for traditional dual-channel. Only when the traditional dual-channel cannot satisfy the consumers, will the BOPS channel have demand. To ensure an active BOPS channel, the price $p$ must satisfy $p \leq (6c - rc)/(1 - \delta)$, as shown in Eq. (9). When the store visiting cost $c$ is relatively low, the advantage of the BOPS channel compared to the offline channel is not obvious. However, the firm can increase the total demand by reducing the price to promote BOPS demand. Although the marginal revenue is decreased, the increase in demand can still make the firm benefit from developing the BOPS channel. When the store visiting cost $c$ is relatively high, the BOPS channel has an obvious advantage over the offline channel. Even if the firm does not reduce the price compared to the traditional dual-channel strategy, a large number of consumers will choose to purchase through the BOPS channel. Furthermore, the pickup cost is $rc$, which is less than the store visiting cost $c$. Thus, compared to the traditional dual-channel, a higher $c$ has less negative effect on the BOPS strategy. Under the BOPS strategy, the price reduction caused by the increase in the store visiting cost $c$ is smaller than that under the traditional dual-channel strategy. Therefore, when the store visiting cost $c$ is relatively high, the firm can take a higher price than the traditional dual-channel strategy to increase the marginal revenue.

Note that we omit the operating cost of offering BOPS to consumers in the main model. Thus only when the profit of offering BOPS is strictly higher than not offering, taking BOPS strategy is a better choice for the firm. Particularly, in the case that the firm gains the same profit whether offering BOPS or not, the firm will choose not to offer due to the potential operating cost. Focusing on the conditions under which the firm benefits from the BOPS strategy, we have Corollary 5.
Corollary 5. Under an endogenously optimized price, a positive BOPS demand does not guarantee a benefit from offering BOPS service.

Corollary 5 is in sharp contrast with Corollary 1 which shows that the firm always benefits from an active BOPS channel with positive demand under the exogenously given price. Intuitively, the firm will benefit from providing more convenience to consumers (as shown in Corollary 1). However, Corollary 5 shows that even if the BOPS service brings more convenience to consumers, the firm may not be able to benefit from it. Recall that, the market characteristics are captured by the two-dimensional heterogeneity of product valuation and online waiting cost. Comparing Figs. 1 and 2, it can be seen that the heterogeneity of consumers increases under scenario BOPS. When taking the BOPS strategy, the firm is faced with more dispersed consumers. To satisfy the consumers of different channels, the firm has to make a price cater to all consumers and the firm’s ability to grab consumer surplus is weakened. Thus, under the endogenously optimized price, even if the demand of the BOPS channel is positive, taking the BOPS strategy may still hurt the firm.

To gain additional insights under the endogenously optimized price, in Fig. 5, we vary the store visiting cost under two cases (i.e., $\beta$ is low or high), respectively, and then get Observation 2.

Fig. 5 numerically shows the result that it is profitable for the firm to take the BOPS strategy only when the store visiting cost $c$ is relatively high under the endogenously optimized price. That is, only a relatively high BOPS demand driven by a high store visiting cost $c$ can benefit the firm. It turns out that the endogenous pricing setting shares the same qualitative finding as that of the exogenous price setting presented in Proposition 1. Furthermore, as shown in Fig. 5, even if the cross-selling revenue $\beta$ is zero, the profit with BOPS can be higher than without when the store visiting cost $c$ is greater than a threshold. And the zone that BOPS dominates DC is expanded by a higher unit cross-selling revenue $\beta$, which is in line with Lemma 3. In addition, a higher relative efficiency of online channel $\delta$ benefits the BOPS strategy as the BOPS consumer utility is increased by a higher $\delta$.

Observation 2. Under the endogenously optimized price, offering a BOPS service would increase the total profit if $c$ is greater than a threshold, and this threshold is decreasing in $\delta$. 

Fig. 3. Price, profit and demand under low $r$ and $\beta$ with $\delta = 0.7$, $r = 0.1$, $\beta = 0.017$. 

Corollary 5. Under an endogenously optimized price, a positive BOPS demand does not guarantee a benefit from offering BOPS service.
Fig. 4. Price, profit and demand under high $r$ and $\beta$ with $\delta = 0.7, r = 0.66, \beta = 0.6$.

Fig. 5. Optimal channel strategy with $r = 0.15$. 
The impact of the BOPS strategy on the consumer can be reflected in the consumer surplus. We use $CS^S_K$ to indicate the consumer surplus under different conditions. $S = B, T$ indicates the strategy of with and without BOPS, respectively. $K = l$ indicates the online and offline consumer surplus, and $K = f$ indicates the total consumer surplus, respectively. The analytical expressions of $CS^S_K$ are presented in Table 3 of Appendix.

First, we focus on the total consumer surplus. By comparing the total consumer surplus, i.e., $CS^B_f$ and $CS^T_f$, we have Observation 3.

**Observation 3.** The total consumer surplus under BOPS strategy $CS^B_f$ is always higher than that under the traditional dual-channel strategy $CS^T_f$.

Although Proposition 6 shows that the optimal price with BOPS $p^B_*$ is higher than that without ($p^T_*$) when the store visiting cost $c$ is relatively high, we observe that the BOPS strategy always benefits the total consumer surplus in Fig. 6. Note that the advantage of the BOPS channel compared to the offline channel is highlighted when the store visiting cost $c$ is relatively high. Thus, though the price is weakly increased, the consumers can also benefit from the added BOPS channel which endows a lower shopping cost.

Comparing Figs. 1 and 2, the total demand is always increased when the BOPS service is offered. The benefits of the increased total demand outweigh the disadvantages caused by a larger price for the consumers.

Next, we focus on the online and offline consumers. By comparing the consumer surplus with and without BOPS of online and offline consumers, i.e., $CS^B_l$ and $CS^T_l$, we can obtain Observation 4.

**Observation 4.** (i) When the BOPS service efficiency $(1-r)$ is relatively high (i.e., $r$ is relatively low), the BOPS strategy benefits the online and offline consumers (i.e., $CS^B_l > CS^T_l$) only when the store visiting cost $c$ is moderate, while it hurts the online and offline consumers when the store visiting cost $c$ is relatively low or high. (ii) When the BOPS service efficiency $(1-r)$ is relatively low (i.e., $r$ is relatively high), the BOPS strategy benefits the online and offline consumers only when the store visiting cost $c$ is relatively high.

It is expected that the online and offline demand is reduced under the BOPS strategy. However, it is interesting that the online and offline consumer surplus can be higher, as shown in Figs. 7(b) and 8(b). This is mainly because the price can be lower under the BOPS strategy, as shown in Figs. 7(a) and 8(a). Although the online and offline consumers do not purchase through BOPS, they can also enjoy the benefit of increased total demand through a lower price.

Note that the beneficial region can be different under different market conditions, depending on the BOPS service efficiency $(1-r)$. When the service efficiency is relatively high (i.e., $r$ is relatively low), it is more convenient for the encroachment of the BOPS channel. Only when the benefit of decreased price dominates the loss of the reduced online and offline demands, the online and offline consumer surplus can be higher under the BOPS strategy. As the increase in the store visiting cost $c$ also strengthens the encroachment of the BOPS channel, the impact of $c$ on the online and offline consumer surplus with BOPS $CS^B_l$ is stronger than the impact of $c$ on the online and offline consumer surplus without BOPS $CS^T_l$, as shown in Fig. 7(b). That is, when the store visiting cost is moderate, the online and offline consumer surplus with BOPS can be higher than without. Oppositely, when the BOPS service efficiency $(1-r)$ is relatively low, the encroachment of BOPS channel is relatively weak. Due to the BOPS expansion reduction effect, the benefit from lower price dominates the loss of the reduced online and offline demands under a relatively high store visiting cost $c$, thus the online and offline consumer surplus can be higher under the BOPS strategy, as shown in Fig. 8(b).

**5. Extension**

In the analysis above, we consider a uniform price among channels. However, in practice, prices may not be exactly the same across channels, which can be driven by the different selling costs. In the following, we examine the implementation conditions of BOPS under inconsistent online and offline prices and selling costs.
Denote the online price as $p_o$ and the offline price as $p_r$. The selling cost in the offline channel is $s_r$ per unit, in the online channel is $s_o$ per unit and in BOPS channel is $s_b$. Following Chiang et al. (2003), Bernstein et al. (2008), and Zhang et al. (2019), we assume that $s_r > s_o$ and $s_o$ is normalized to zero. Furthermore, net revenue per unit of cross-selling is $\bar{\beta}$, where $\bar{\beta} = \beta - s_b$.

### 5.1. BOPS strategy under the exogenous prices

In this part, we examine the impact of BOPS on the profit by comparing the equilibrium results under the exogenously given prices $p_r$ and $p_o$.

In scenario DC, the total profit is

$$\Pi^T = (p_r - s_r)D_r^T + p_oD_o^T.$$  \hspace{1cm} (16)

In scenario BOPS, the total profit is

$$\Pi^B = (p_r - s_r)D_r^B + p_oD_o^B + (p_o + \bar{\beta})D_b^B.$$  \hspace{1cm} (17)

By comparing the profits in the two cases, we can obtain the following result.

**Proposition 7.** Under exogenously given prices $p_r$ and $p_o$, the firm can benefit from offering BOPS service if and only if $c > (p_o - \delta p_r)/(\delta - r)$.

Proposition 7 verifies the finding in the main model that it is profitable for the firm to take BOPS strategy when the store visiting cost $c$ is relatively high under the inconsistent online and offline prices exogenously given and selling costs.
5.2. BOPS strategy under pricing

In this section, we examine the impacts of BOPS on the profit under the endogenously optimized prices. Solving the profit maximization problem for the firm, we get the optimal prices under scenario DC and scenario BOPS.

Proposition 8. In scenario DC, the optimal online price and offline price satisfy

\[
p^*_o = \frac{1}{3} \left( 2\delta - \sqrt{\delta \left( 3p_o \left( 4c + 3p_r - 4 \right) + 3(c - 1)^2 + \delta + 6s_r - 6s_r \left( c + p_r \right) \right) } \right),
\]

\[
p^*_r = \frac{1}{3(d+1)} \left( 4 - 2c(d + 1) + 3p_o + (d + 1)s_r \right)
- \sqrt{c^2(d + 1)^2 - 4c(d + 1) + (d + 1)s_r \left( 2(c\delta + c - 2) + (d + 1)s_r \right) + 3(d - 2)\delta - 12(d - 1)p_o + 9p_o^2 + 7).\]

In scenario BOPS, the optimal online price and offline price are

\[
p^*_o = \frac{1}{4} \left( r^2 c^2 - 2r(1 - \beta)c + 2(\delta - \beta) \right),
\]

\[
p^*_r = \frac{1}{12} \left( 4s_r + c(3r(2\beta + cr - 2) - 8) - \right.
- 2 \left( 8 - 3\beta - 2\sqrt{-6\beta + 2c\delta + \epsilon \left( 3cr^2 + c + 6(\beta - 1)r - 4 \right) + 2(c + \delta - 2)s_r + \delta^2 - 4\delta + s^2 + 7 - \delta} \right).\]

Due to the complexity of the profit functions, we conduct numerical study to examine the effects of BOPS. Fig. 9 numerically shows robustness of the result that it is profitable for the firm to take the BOPS strategy only for a relatively high store visiting cost \( c \) under the endogenously optimized online and offline prices.

6. Conclusion and future research

In this paper, we formulate an analytical modeling framework to study when it is profitable for the firm to offer the BOPS service and how the price, demand, and profit vary with market conditions. The results show that offering the BOPS service does not always benefit the firm even if the setup cost is negligible. Furthermore, the price, demand, and profit under BOPS all can be nonmonotonic in the store visiting cost. Some managerial insights are summarized as follows.

Firstly, introducing BOPS motivates the firm to increase or decrease the optimal price. With the increase of store visiting cost, the BOPS encroachment effect works more significantly and the firm can charge a higher price compared to scenario DC. For the optimal price under BOPS, it can be firstly decreasing then increasing in the store visiting cost, which is different from that under scenario DC where the optimal price is always decreasing in the store visiting cost. Adjusting prices strategically according to the consumer store visiting cost can benefit the firm. When the store visiting cost is relatively low (high), it is profitable for the firm offering BOPS to charge a lower (higher) price with the increase of store visiting cost. Furthermore, the firm can benefit from decreasing (increasing) the price after offering BOPS when the store visiting cost is relatively low (high). In addition, the demand of BOPS channel is firstly increasing then decreasing in the store visiting cost, which is driven by the BOPS encroachment effect and the BOPS encroachment effect.
expansion reduction effect. The BOPS encroachment effect dominates when the store visiting cost is relatively low, while the BOPS expansion reduction effect dominates when the store visiting cost is relatively high. The combined impacts of the two effects lead to a nonmonotonic BOPS demand.

Secondly, sharply contrasting to scenario DC where a higher store visiting cost always hurts the firm, the profit under BOPS can be nonmonotonic in the store visiting cost and the firm can benefit from a higher store visiting cost. Typically, we show two conditions under which the profit is U-shaped or inverse U-shaped in the store visiting cost. In the omnichannel environment equipped with BOPS, the firm should be cautious to improve the service level. Because the improved offline service level, which implies a smaller store visiting cost may instead reduce the profit. Specifically, if the cross-selling effect is relatively low (high), raising the offline service level could hurt the firm when the store visiting cost is relatively high (low).

Furthermore, it is profitable for the firm to develop the BOPS strategy only when the store visiting cost is relatively high, which brings a relatively high BOPS demand under endogenous pricing. The BOPS encroachment effect works significantly when the store visiting cost is relatively high because the BOPS consumers enjoy a higher cost reduction. Although facing a negligible BOPS setup cost (which is assumed to be zero in our model), it is not always beneficial for the firm to offer BOPS. When the firm can price, taking the BOPS strategy can hurt the firm when the BOPS demand is small. For the firm, expanding demand in a heterogeneous consumer market may actually lead to loss because the firm has to lose part of the consumer surplus in order to cater to omnichannel consumers. When the store visiting cost is relatively low, even if the demand of the BOPS channel is active and the BOPS setup cost is negligible, the firm could be unprofitable by offering BOPS service. Finally, BOPS service always increases the total consumer surplus. The online and offline consumer surplus can also be higher under the BOPS strategy, due to the lower price.

There are many directions worthy of future research. For example, this paper considers a monopoly situation with one firm. However, in practice, there may exist other competitors. They may differ across service level, product quality, market occupancy, and so on. Thus, future studies can introduce competition between firms. In addition, it would be interesting to extend the research to the framework of supply chain and study the impacts of the BOPS strategy managed by different parties on chain members.

CRediT authorship contribution statement

Yue Feng: Writing – original draft, Formal analysis, Conceptualization, Software, Visualization. Jianxiang Zhang: Methodology, Project administration, Funding acquisition, Writing – review & editing. Lin Feng: Formal analysis, Funding acquisition, Writing – review & editing. Guowei Zhu: Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Proofs of results in main text

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References

Ailawadi, K.L., Farris, P.W., 2017. Managing multi- and omni-channel distribution: Metrics and research directions. J. Retail. 93 (1), 120–135.
Akter, M.S., Kotzenberg, M., 2022. Impact of competitor store closures on a major retailer. Prod. Oper. Manage. 31 (2), 715–730.
Ali, F., 2021. How big retail chains fared online in 2020. https://www.digitalcommerce360.com/2021/03/09/how-big-retail-chains-fared-online-in-2020/.
Alonso, B., 2020. BOPS orders: Kibo clients experienced 563% surge during COVID. https://kibocommerce.com/blog/bops-orders-covid-19/.
Beck, N., Rygl, D., 2015. Categorization of multiple channel retailing in Multi-, Cross-, and Omni-Channel Retailing for retailers and retailing. J. Retail. Consum. Serv. 27, 170–178.
Bernstein, F., Song, J.S., Zheng, X., 2008. “Bricks-and-mortar” vs. “clicks-and-mortar”: An equilibrium analysis. European J. Oper. Res. 187 (3), 671–690.
Cao, J., So, K.C., Yin, S., 2016. Impact of an “online-to-store” channel on demand allocation, pricing and profitability. European J. Oper. Res. 248 (1), 234–245.
Chiang, W.Y.K., Ghajedi, D., Hess, J.D., 2003. Direct marketing, indirect profits: A strategic analysis of dual-channel supply-chain design. Manage. Sci. 49 (1), 1–20.
Clifford, S., 2011. Wal-mart has a web plan to bolster in-store sales. https://www.nytimes.com/2011/03/11/business/11shop.html.
Fan, X., Tian, L., Wang, C., Wang, S., 2022. Optimal service decisions in an omni-channel with buy-online-and-pick-up-in-store. J. Oper. Res. Soc. 73 (4), 749–810.
Gao, F., Agrawal, V.V., Cui, S., 2022. The effect of multichannel and omnichannel retailing on physical stores. Manage. Sci. 68 (2), 890–826.
Gao, F., Su, X., 2017. Omnichannel retail operations with buy-online-and-pick-up-in-store. Manage. Sci. 63 (8), 2478–2492.
Ha, A., Long, X., Nasiry, J., 2016. Quality in supply chain encroachment. Manuf. Serv. Oper. Manage. 18 (2), 280–298.
Ha, A.Y., Tong, S., Wang, Y., 2022. Channel structures of online retail platforms. Manuf. Serv. Oper. Manage. 24 (3), 1547–1561.
Harsha, P., Subramanian, S., Uichanco, J., 2019. Dynamic pricing of omnichannel inventories. Manuf. Serv. Oper. Manage. 21 (1), 47–65.
He, P., He, Y., Xu, H., 2020. Buy-online-and-deliver-from-store strategy for a dual-channel supply chain considering retailer’s location advantage. Transp. Res. E 144, 102127.
He, Y., Xu, Q., Shao, Z., 2021. “Ship-from-store” strategy in platform retailing. Transp. Res. E 145, 102153.
Hu, M., Xu, X., Xue, W., Yang, Y., 2022. Demand pooling in omnichannel operations. Manage. Sci. 68 (2), 883–894.
