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Full Research Paper

Dual-channel Service Operations with the BOPS Option Considering Infection Risk Aversion Behavior

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Abstract: Nowadays many restaurants adopt a new retailing strategy of buying online and picking up in store (BOPS) to offer diversified service efficiently. During the epidemic period of coronavirus, customers behave with infection risk aversion, leading to the alteration in consuming demands for the three ways (pure online, pure offline and BOPS). Therefore, this paper establishes two models to investigate the problem on how restaurants allocate service contributions between online and offline channels. Firstly, we build utility equations to classify consumers with heterogeneous perceptions of infection risk. Considering the trait of infection risk aversion, we can obtain consuming demands of different channels and the aggregate revenues. Then, the optimal service levels of both online and offline can be calculated, as well as the optimal profits. We find that BOPS can help restaurants increase profits by adjusting the service level of both online and offline channels even in the case of consumer risk aversion. Finally, we draw out numerical experiments to verify our findings.

Keywords: dual-channel, BOPS, restaurant service levels, customer’s infection risk aversion behavior

1. INTRODUCTION

Since its outbreak in December 2019, coronavirus has caused a severe blow to the catering industry. For fear of being infected with coronavirus, consumers eat out less frequently and turn to order online or takeout instead, generating a plummet in the revenue of the catering industry. Besides, restaurants are obligated to meet governments’ anti-epidemic protests by adopting the measure of sitting at intervals to reduce the number of people gathering, exposing themselves to a worsening situation. Hence, it’s not uncommon to witness more and more restaurants making efforts online to maximally compensate the losses brought by offline stores. They commonly take the action of strengthening take-out service, such as more delicate packaging and better appearance, boasting of having the same dining experience as in the store. This approach enhances consumers’ stickiness but brings in more expense as well. In fact, a few restaurants raise the price instead because sometimes customers are intent to eat non-homemade food regardless of higher price, which obviously isn’t feasible in the long run.

On top of the above measures, BOPS seems to be a better choice. BOPS, which literally means ordering goods online and then picking them up at a physical store, is a combination of online and offline service. For some customers, BOPS can reduce the risk of infection caused by in-store dining effectively, and is more affordable than take-out. In addition, restaurants can also benefit from this option. Studies show that people often have made a new purchase when they step into the store. For restaurants, they aren’t supposed to throw away offline sales completely even in the critical epidemic period if they can ensure the consumers’ physical safety or abide by epidemic prevention demands governments proposed strictly. However, once BOPS is implemented, among three purchasing means, which one do

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consumers averting infection risk choose and how should restaurants decide on online and offline service levels to maximize revenue when we are in epidemic period?

To answer these questions, we consider two models that contain main features needed, which are two restaurants who operate dual-channel and omnichannel respectively. Firstly, we analyze utility equations of two channels to classify heterogeneous customers with different choices. Based on that, we can calculate their optimal online and offline service levels and optimal profits further. For the channel with BOPS, two different cases are involved. Finally, some managerial propositions are drawn out for restaurants.

The rest part of this paper is organized as follows. Related literature reviews are given in Section 2. Section 3 describes the theoretical models. Section 4 contains model analysis in details about consumer classification. Then several numerical experiments are included in Section 5. Finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

The paper is highly related with three streams of research: consumer behavioral modeling, omnichannel strategy management and service decisions.

2.1 Consumer behavioral modeling

Numerous literatures used consumer behavioral modeling on marketing studies. One of appealing and research-passionate branches is about the consumer choices on purchasing channels in retailing market. Usually, people choose purchasing online or offline first. Based on them, plenty of new cross-selling channels have appeared. Gu and Tayi[1] examined one cross-channel strategy: pseudo-showrooming, where consumers inspect one product at a seller's physical store before buying a related but different product at the same sellers online store. They investigated optimal product placement strategies to achieve better coordination between retailers' online and offline channels. He, Xu and Zhao[2] innovatively have added consumer's environmental awareness in behavioral model to explore the environmental impact reduction after BOPS is implemented.

2.2 Omnichannel strategy management

The second stream of studies are omnichannel strategy management. Currently, there exists two main genres in this field. One genre focuses on multichannel management in supply chain. These models involve the role of manufacturers, whose marketing demands are not simply affected by their traditional wholesales to retailers. In empirical researches, Chen, Kaya and Özer [3] solved a manufacturer's problem of managing his direct online sales channel together with an independently owned bricks-and-mortar retail channel. By building a consumer channel choice model and conducting a sequence of controlled experiments, they identified optimal dual channel strategies. Tamer[4] explored one manufacturer's channel inefficiencies induced by the presence of simultaneous vertical competition with double-marginalization and horizontal competition of substitutability similarly between an independent retailer and his wholly-owned channel. Additionally, Andy and Narendra[5] added one more retailer into the model that one manufacturer supplies a common product to two independent retailers.

Other scholars focus on omnichannel choices on retailers. Among many cross-selling strategies, BOPS has grabbed most attentions, which describes the action of buying online and picking up in store for consumers. Santiago and Antonio[6] used a data set and a stylized model, analyzing the impact of the implementation of BOPS. Like Gao and Su[7], Liu and Xu [8], they also investigated the impact of the BOPS initiative on store operations. Besides that, Gao and Su contributed greatly to other studies on omnichannel retailing. They did not only research the impact of online and offline self-order technologies on customer demand, employment levels and restaurant profits[9], but also analyzed three information mechanisms: physical showrooms, virtual showrooms and availability information[10].

Moreover, Bell, Gallino and Moreno[11] took quasi-experimental methods to explore how offline showrooms benefit demand generation and operational efficiency for online-first and traditional retailers.

In contrast, we constructively introduce probability of available seats in restaurants into the models because the rule of sitting at intervals in epidemic period make vacancy much less probable. Sitting restrictions can avoid the risk of infection to a great extent. Whereas if no sitting availability, BOPS may be a much better choice.

2.3 Service decisions

There exists a substantial body of work concerning service decisions, which can be broadly classified into two streams. The first concentrates on marketing competitions about service levels as well as other influencing factors. In empirical investigation, scholars assumed two independent retailers competing for customers with service strategy, like Zhao and Atkins[12], who focused on inventory service. They noticed that competing retailers have the service option of either agreeing in advance to transship excess inventory to each other or seeing unsatisfied customers switch to the competitor for a substitute. Some researchers conducted relevant studies on supply chain. Wu[13] considered service competition in a closed-loop supply chain with remanufacturing. By a model with two manufacturers producing the new products and remanufactured products from used cores and a retailer, four competitive interactions are considered in terms of price and service. Raymond and James[14] discussed the problem when consumer demand is stochastic. Other scholars explored service allocation purely. Tao, Gou and Zhang[15] constructed first decision model which incorporates a seller's decision about its delivery service coverage within the framework of hoteling model. In the work of Jin, Li and Chen[16], the optimal decisions on the product price and recommended service radius were derived for the retailer adopting BOPS.

In this paper, we grasp two influencing elements about consuming utilities, one being service level and the other, infection risk level. Our model is the first one that delineate consuming utilities by incorporating epidemic effects.

3. MODELS

We first consider such a scenario that a restaurant owns both online and offline channels. To research consumer behaviors, we assume that the choice of channel is up to themselves strategically. Struck by the rapid spread of coronavirus, they encounter varying degrees of infection perceived risk and the implementation of BOPS is likely to make a difference to consuming demands. Meanwhile we assume the order price remains constant at p while discrepancy exists between service levels in different channels. We assume all consumers have the same valuation v for an order and one consumer's utility in some channel is only related to dining service level s and risk level of infection r.

Following notations are used throughout the remainder of the paper:

Table 1. Notations

Notation	Definition
u_s, u_o and u_b	Consumer utilities of consuming online, offline and in BOPS channel in models respectively
v	Consumer valuation of the order
p	Price per order
s_s, s_o and s_b	Service levels of consuming online, offline and in BOPS channel in models respectively
r_s, r_o and r_b	Risk levels of consuming online, offline and in BOPS channel respectively
D_s, D_o and D_b	Consuming demands of consuming online, offline and BOPS channel in models respectively
φ	Probability of finding available seats in the restaurant

Notation	Definition
δ_1 and δ_2	Fraction of service costs of consuming online and offline in models respectively
α_1 and α_2	The fractions of BOPS service incorporate online and offline service respectively
k	Additional profit per order

3.1 Base model

Without BOPS put into effect, this restaurant sells an order by two channels, purely online or offline. Under the scenario of offline, consumers find an available seat for having deals in the probability φ and enjoy offline service level s_s while confronting face infection risk level r_s since exposed to other potentially infected individuals. Apropos of those who fail to find any vacancy, we assume they will leave this restaurant with utility being 0. Then we can obtain the equation:

$$u_s = \varphi(v - p + s_s - r_s) \tag{1}$$

If directly buying online, consumers will face infected risk level r_o since receiving the extraneous packaging bags possibly contaminated by virus and enjoy online service level s_o. Then we can obtain the equation:

$$u_o = v - p + s_o - r_o \tag{2}$$

To enable consumers to consider consuming in two channels, we assume both utilities are positive.

3.2 Model with BOPS

Adopting the strategy of BOPS, restaurants can operate through three channels: online, offline and BOPS. Through BOPS channel, people still need to get to the store and face offline risk. The avoidance of dine-in enables a risk level r_b smaller than that offline and the fraction is β. The BOPS service s_b consumers enjoy includes part of online service in fraction α_1 and part of offline service in fraction α_2 simultaneously. Then we can obtain the equation:

$$u_b = v - p + s_b - r_b \tag{3}$$

$$r_b = \beta r_s, \; s_b = \alpha_1 s_o + \alpha_2 s_s$$

If consumers can find a vacant seat in the restaurant, the utility is the same with that in the base model. But for those who fail to seat, they can turn to a new option, BOPS. We can obtain the equation:

$$u_s = \varphi(v - p + s_s - r_s) + (1 - \varphi)(v - p + s_b - r_b) \tag{4}$$

Concerning buying online, the utility equation is totally same as Equation (2).

4. ANALYSIS

We can use these above equations to depict some figures about utilities in different channels whose horizontal axis is the offline risk r_s and vertical axis is the online risk r_o. We assume they are both distributed uniformly with a range of from 0 to H, i.e., $r_s \sim U[0, H]$, $r_o \sim U[0, H]$. According to these utilities of relationship in size, we can classify several types of consumers in different cases. Next, we still illustrate the base model and then model with BOPS in order.

4.1 Base model

In dual-channel scenario, consumers have three choices, buying online or offline and leaving out directly. When $u_o > u_s$ and $u_o > 0$, customers will purchase online. Similarly, customers will purchase in offline channel if $u_s > u_o$ and $u_s > 0$. When $u_s < 0$ and $u_o < 0$, they will decide to leave out.

$r_{u_s=0}$ is the offline risk level derived from the Equation (1) and $r_{u_o=0}$ is the online risk level derived from the Equation (2). Given above class conditions, these lines $u_s = u_o$, $u_s = 0$ and $u_o = 0$ divide all consumers into three categories. We can demonstrate them as three parts in the Figure 1.

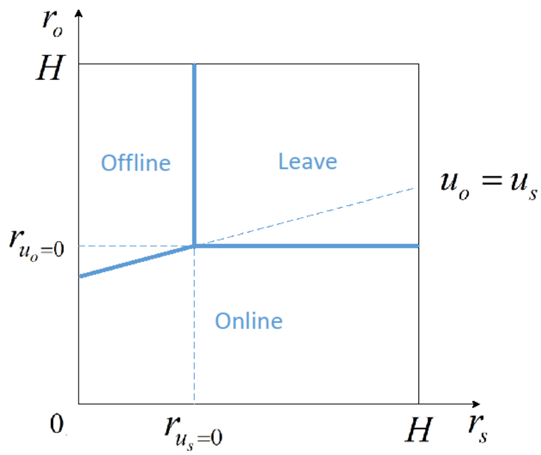


Figure 1. Consumer behavior in the dual-channel scenario

From this figure, the values of demands buying both online and offline, D_s and D_o, can be obtained.

$$D_s = \int_{r_s=0}^{r_s=r_{u_s=0}} \int_{u_o=u_s}^{r_o=H} dr_o \, dr_s$$

$$D_o = \int_{r_s=0}^{r_s=r_{u_s=0}} \int_{r_o=0}^{u_o=u_s} dr_o \; dr_s + \int_{r_s=r_{u_s=0}}^{r_s=H} \int_{r_o=0}^{r_o=r_{u_o=0}} dr_o \, dr_s$$

Then we assume consuming demands are identical with volumes of sales in different channels, so we can obtain the equations of restaurant's aggregate profit and total volume of sales.

$$D_B = D_s + D_o \tag{5}$$

$$\Pi_B = p(D_o + \; D_s) - \frac{\delta_1}{2} s_o{}^2 - \frac{\delta_2}{2} s_s{}^2 + kD_s \tag{6}$$

Next, we can derive partial derivatives of Π_B about s_o and s_s from Equation (6).

Finally, we can calculate the optimal service level $s_{o}{}_B^*, s_{s}{}_B^*$.Then insert them into Equation (5) and (6) to obtain optimal demand D_B^*, optimal profit Π_B^*, which are shown in Proposition 1.

Proposition 1. *In the dual-channel scenario, the restaurant's optimal service level* $s_{o}{}_B^*$*,* $s_{s}{}_B^*$ *can be calculated from following equations.*

$$\begin{cases} s_{s}{}_B^* = \dfrac{\left(1 + \dfrac{k}{\delta_1} - \dfrac{p}{\delta_1}\right)(H - v + p)p + (1 - \dfrac{k}{\delta_1} + \dfrac{p}{\delta_1})(v - p)k - kH}{\delta_2 - k\varphi - \dfrac{p^2}{\delta_1} + \dfrac{k^2}{\delta_1}} \\ s_{o}{}_B^* = \dfrac{p(H - v + p) - k(v - p)}{\delta_1} - \dfrac{p + k}{\delta_1} s_{s}{}_B^* \\ s_{s}{}_B^* > 0, s_{s}{}_B^* \; > 0 \end{cases}$$

The optimal demand D_B^**, optimal profit* Π_B^* *are as follows.*

$$\begin{cases} D_B^* = {D_o}_B^* + {D_s}_B^* \\ \Pi_B^* = p\left({D_o}_B^* + {D_s}_B^*\right) - \frac{\delta_1}{2}({s_o}_B^*)^2 - \frac{\delta_2}{2}({s_s}_B^*)^2 + k{D_s}_B^* \end{cases}$$

4.2 Model with BOPS

In omnichannel scenario, consumers can be classified into four groups: buying online, offline or BOPS and leaving out directly. When $u_o > u_s$, $u_o > u_b$ and $u_o > 0$, customers will purchase online. Similarly, customers will purchase in offline channel if $u_s > u_o$, $u_s > u_b$ and $u_s > 0$ and consume by BOPS if $u_b > u_o$, $u_b > u_s$ and $u_b > 0$. When $u_s < 0$, $u_o < 0$ and $u_b < 0$, they will decide to leave out.

$r_{u_s=u_b}$ is the offline risk level derived from the equation $u_s = u_b$, while other two offline risks, $r_{u_b=0}$ and $r_{u_s=0}$, are from equation (3) and (4) respectively. We can't confirm the size of three values so there actually exist six cases: $r_{u_b=0} < r_{u_s=u_b} < r_{u_s=0}$, $r_{u_s=0} < r_{u_s=u_b} < r_{u_b=0}$, $r_{u_s=u_b} < r_{u_s=0} < r_{u_b=0}$, $r_{u_s=u_b} < r_{u_b=0} < r_{u_s=0}$, $r_{u_s=0} < r_{u_b=0} < r_{u_s=u_b}$, $r_{u_b=0} < r_{u_s=0} < r_{u_s=u_b}$. However, after analyzing, we can derive only two meaningful cases in practice. Case 1 is $r_{u_s=u_b} < r_{u_s=0} < r_{u_b=0}$ and Case2 is $r_{u_b=0} < r_{u_s=0} < r_{u_s=u_b}$.

4.2.1 Case1

In Case1, if $\beta < \alpha_2$ and $\frac{S_o}{S_s} < \frac{1-\alpha_2}{\alpha_1}$, we can obtain $r_{u_s=u_b} < r_{u_s=0} < r_{u_b=0}$. Then according to above class conditions, these lines $u_s = u_o$, $u_b = u_o$, $u_s = u_b$, $u_s = 0$, $u_b = 0$ and $u_o = 0$ divide all consumers into four types. These four parts are demonstrated in the Figure 2.

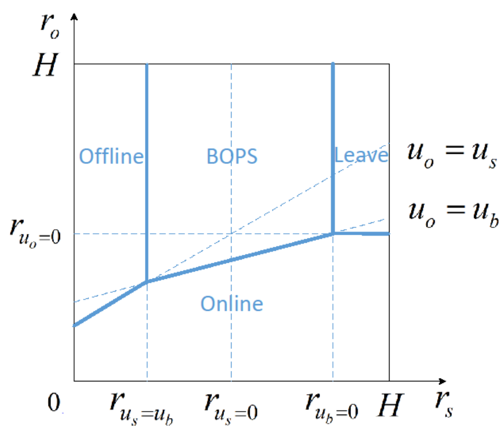


Figure 2. Consumer behavior in the omnichannel scenario in Case1

From this figure, we can obtain the values of consuming demands in three channels, buying online or offline and by BOPS, which are D_s, D_o and D_b respectively.

$$D_s = \int_{r_s=0}^{r_s=r_{u_s=u_b}} \int_{r_o=u_o=u_s}^{r_o=H} dr_o\, dr_s$$

$$D_o = \int_{r_s=0}^{r_s=r_{u_s=u_b}} \int_{r_o=0}^{u_o=u_s} dr_o\ dr_s + \int_{r_s=r_{u_s=u_b}}^{r_s=r_{u_b=0}} \int_{r_o=0}^{u_o=u_b} dr_o\, dr_s + \int_{r_s=r_{u_b=0}}^{r_s=H} \int_{r_o=0}^{r_o=r_{u_0=0}} dr_o\, dr_s$$

$$D_b = \int_{r_s=r_{u_s=u_b}}^{r_s=r_{u_b=0}} \int_{u_o=u_b}^{r_o=H} dr_o\ dr_s$$

Like the base model, we still assume consuming demands are identical with volumes of sales in different channels.

So we can obtain the equations of restaurant's aggregate profit and total volume of sales.

$$D_1 = D_s + D_o + D_b \tag{7}$$

$$\Pi_1 = p(D_o + D_s + D_b) - \frac{\delta_1}{2}{s_o}^2 - \frac{\delta_2}{2}{s_s}^2 + kD_s \tag{8}$$

Next, we can derive partial derivatives of Π_1 about s_o and s_s from Equation (8).

Finally, we can calculate the optimal service level ${s_o}_1^*, {s_s}_1^*$.Then insert them into Equation (7) and (8) to obtain optimal demand D_1^*, optimal profit Π_1^*, which are shown in Proposition 2.

Proposition 2. *In the dual-channel scenario, the restaurant's optimal service level* ${s_o}_1^*$, ${s_s}_1^*$ *can be calculated from following equations.*

$$\begin{cases} {s_s}_1^* = \dfrac{\dfrac{\Lambda_5\Lambda_3}{\Lambda_2} - \Lambda_6}{\Lambda_4 - \dfrac{\Lambda_5\Lambda_1}{\Lambda_2}} \\ {s_o}_1^* = -\dfrac{\Lambda_1}{\Lambda_2}{s_s}_1^* - \dfrac{\Lambda_3}{\Lambda_2} \\ {s_s}_1^* > 0, {s_s}_1^* > 0 \end{cases}$$

where

Λ_1
$$p\left(-\frac{\alpha_2}{\beta}\right) + k\left[\frac{\beta(1-\alpha_1-\alpha_2) - \alpha_1(2\alpha_2+2\alpha_1-3) + \alpha_2 - 1}{2(1-\beta)^2} - \frac{1-\alpha_1-\alpha_2+2\varphi\alpha_1+2\alpha_1\alpha_2-2\varphi\alpha_1\alpha_2}{2(1-\beta)}\right]$$

Λ_2
$$p\left(-\frac{2\alpha_1}{\beta}\right) + k\left[\frac{\alpha_1(1-\alpha_1+\varphi\alpha_1)}{1-\beta} - \frac{\alpha_1(1-\alpha_1-\beta)}{(1-\beta)^2}\right] - \delta_1$$

Λ_3
$$p\left[H\left(\frac{\alpha_1}{\beta}+1\right) - \frac{(v-p)(1+\alpha_1)}{\beta}\right] - k\frac{H\alpha_1}{1-\beta}$$

Λ_4
$$k\left[\frac{(1-\alpha_2)(\varphi+\alpha_2-\varphi\alpha_2)}{1-\beta} - \frac{(\beta-\alpha_2)(1-\alpha_2)}{(1-\beta)^2}\right] - \delta_2$$

Λ_5
$$p\left(-\frac{\alpha_2}{\beta}\right) + k\left[\frac{(\beta-\alpha_2)\alpha_1 - (1-\alpha_1-\beta)(1-\alpha_2)}{2(1-\beta)^2} - \frac{(1-\alpha_2)(1-\alpha_1+\varphi\alpha_1)+\alpha_1(\varphi+\alpha_2-\varphi\alpha_2)}{2(1-\beta)}\right]$$

Λ_6
$$p\frac{\alpha_2(H-v+p)}{\beta} + k\frac{H(1-\alpha_2)}{1-\beta}$$

The optimal demand D_1^*, *optimal profit* Π_1^* *are as follows.*

$$\begin{cases} D_1^* = {D_o}_1^* + {D_s}_1^* + {D_b}_1^* \\ \Pi_1^* = p\left({D_o}_1^* + {D_s}_1^* + {D_b}_1^*\right) - \dfrac{\delta_1}{2}({s_o}_1^*)^2 - \dfrac{\delta_2}{2}({s_s}_1^*)^2 + k{D_s}_1^* \end{cases}$$

4.2.2 Case2

In Case2, if $\beta > \alpha_2$ and $\frac{s_o}{s_s} < \frac{1-\alpha_2}{\alpha_1}$, we can obtain $r_{u_b=0} < r_{u_s=0} < r_{u_s=u_b}$. Next all analytical procedures are totally same with the case1. However, the only difference is we obtain three types of consumers: buying online or offline and leaving out.

Then Figure 3 about consumer classification is as follows:

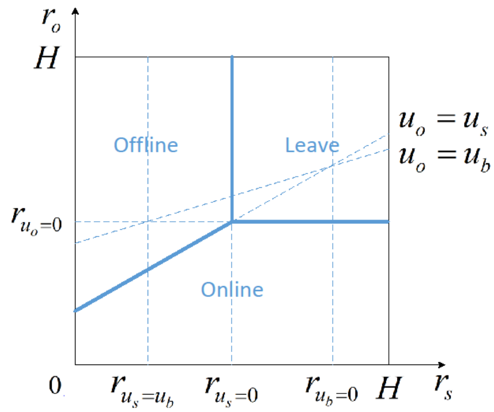


Figure 3. Consumer behavior in the omnichannel scenario in Case2

The following equations are the values of customer demands both online and offline, D_o and D_s.

$$D_s = \int_{r_s=0}^{r_s=r_{u_s=0}} \int_{u_o=u_s}^{r_o=H} dr_o\, dr_s$$

$$D_o = \int_{r_s=0}^{r_s=r_{u_s=0}} \int_{r_o=0}^{u_o=u_s} dr_o\, dr_s + \int_{r_s=r_{u_s=0}}^{r_s=H} \int_{r_o=0}^{r_o=r_{u_o=0}} dr_o\, dr_s$$

the equations of restaurant's aggregate profit and total volume of sales are presented next.

$$D_2 = D_s + D_o \tag{9}$$

$$\Pi_2 = p(D_o + D_s) - \frac{\delta_1}{2} s_o{}^2 - \frac{\delta_2}{2} s_s{}^2 + kD_s \tag{10}$$

Next, we can derive partial derivatives of Π_2 about s_o and s_s from Equation (10).

Finally, we can calculate the optimal service level $s_{o}{}_2^*, s_{s}{}_2^*$.Then insert them into Equation (9) and (10) to obtain optimal demand D_2^*, optimal profit Π_2^*, which are shown in Proposition 3.

Proposition 3. *In the dual-channel scenario, the restaurant's optimal service level* $s_{o}{}_2^*$, $s_{s}{}_2^*$ *can be calculated from following equations.*

$$\begin{cases} s_{s}{}_2^* = \dfrac{\dfrac{\Lambda_{11}\Lambda_9}{\Lambda_8} - \Lambda_{12}}{\Lambda_{10} - \dfrac{\Lambda_{11}\Lambda_7}{\Lambda_8}} \\ s_{o}{}_2^* = -\dfrac{\Lambda_7}{\Lambda_8} s_{s}{}_2^* - \dfrac{\Lambda_9}{\Lambda_8} \\ s_{s}{}_2^* > 0, s_{s}{}_2^* > 0 \end{cases}$$

Where

Λ_7 $$\frac{(\alpha_2 + \varphi - \varphi\alpha_2)(\alpha_1 k - \varphi\alpha_1 k - p)}{\beta - \beta\varphi + \varphi}$$

Λ_8 $$\frac{\alpha_1{}^2(1-\varphi)^2 k - 2\alpha_1(1-\varphi)p}{\beta - \beta\varphi + \varphi} - \delta_1$$

Λ_9 $$p\left[\frac{(1-\varphi)\alpha_1 H - (v-p)(\alpha_1 - \alpha_1\varphi + 1)}{\beta - \beta\varphi + \varphi} + H\right] + k\frac{\alpha_1(1-\varphi)(H + 2v - 2p)}{2(\beta - \beta\varphi + \varphi)}$$

Λ_{10}	$k\dfrac{(\varphi+\alpha_2-\varphi\alpha_2)^2}{\beta-\beta\varphi+\varphi}-\delta_2$
Λ_{11}	$\dfrac{(\varphi+\alpha_2-\varphi\alpha_2)(\alpha_1 k-\varphi\alpha_1 k-p)}{\beta-\beta\varphi+\varphi}$
Λ_{12}	$p\dfrac{(\varphi+\alpha_2-\varphi\alpha_2)(H-v+p)}{\beta-\beta\varphi+\varphi}+k\dfrac{(\varphi+\alpha_2-\varphi\alpha_2)(H+2v-2p)}{2(\beta-\beta\varphi+\varphi)}$

The optimal demand D_2^*, *optimal profit* Π_2^* *are as follows.*

$$\begin{cases} D_2^* = {D_o}_2^* + {D_s}_2^* \\ \Pi_2^* = p\left({D_o}_2^* + {D_s}_2^*\right) - \dfrac{\delta_1}{2}({s_o}_2^*)^2 - \dfrac{\delta_2}{2}({s_s}_2^*)^2 + k{D_s}_2^* \end{cases}$$

4.3 Discussion

From above analysis, we can find out in Case1，customers have four purchasing behaviors: ordering online, eating in restaurant, buying in BOPS and leaving, while in Base Model and Case2, customers can only choose from consuming online and offline or just leaving without BOPS option.

By comparing Base Model with Case1, absolutely after implementing BOPS, the consuming demand in online and offline channels have decreased for consuming in BOPS instead and some people choosing leaving in Base Model also transferred to BOPS channel. Thanks to the BOPS strategy, the holistic consuming proportion of the restaurant has risen obviously, which is mostly closed to the managerial facts as well.

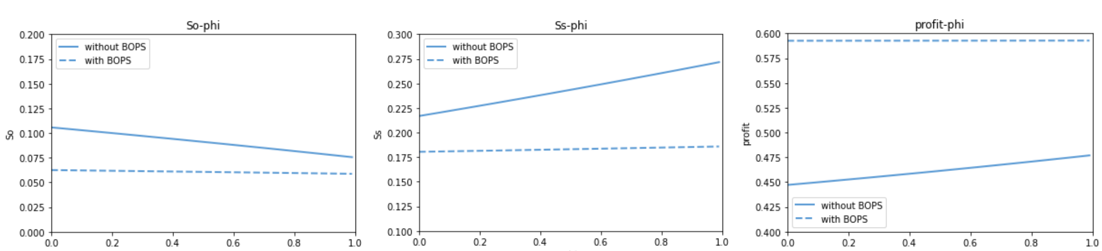
In particular, the channel-choosing situations of Base Model and Case2 are the same even if in Case2 the restaurant has put BOPS into effect. In other words, though the restaurant has provided BOPS option, no guests choose it. But it still influences customers' options potentially in that more people leave the restaurant. The shifts of demand of consuming online and offline can be identified depending on some variables' values by further numeric experiments.

5. NUMERIC EXPERIMENTS

Given the two models are too complicated, we use some specific numbers to imitate them to prove the above all propositions. We divide numeric experiments into two parts. The first part is for the contrary between dual channel and case 1. Then in the second part, case1 and case2 get compared. all figures' horizontal axis is φ and vertical axises are optimal online service level s_o^*, offline service level s_s^* and profit Π^* respectively.

5.1 With and without BOPS under case1

when $v=1$, $p=0.5$, $H=1$, $\delta_1=1$ and $\delta_2=1$, $k=0.05$, $\alpha_1=0.5$, $\alpha_2=0.5$ and $\beta=0.4$ we can draw following sub-figures (a), (b) and (c) in Figure 4.



(a) (b) (c)

Figure 4. the values of s_o, s_s and Π in dual-channel and omnichannel

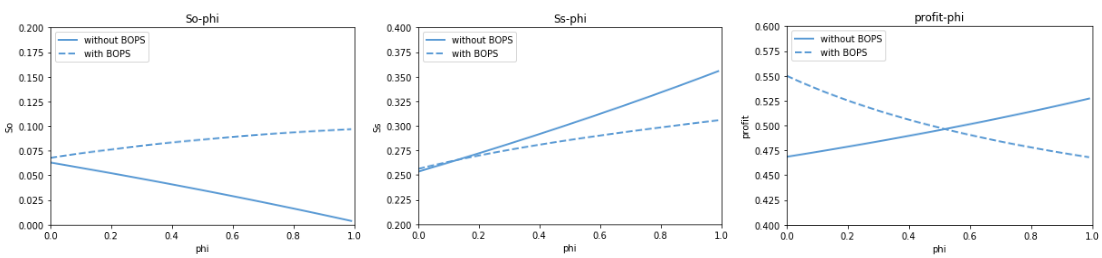
From them, we can find that under these conditions, s_o^* and s_s^* in dual-channel are both bigger than that in omnichannel at every value of φ ranging from 0 to 1, while Π^* is smaller. And as the value of φ increases gradually, s_o^* will reduce but s_s^* and Π^* will rise in dual-channel. In terms of omnichannel, s_o^* and Π^* fall down very slightly and s_s^* increase subtly. Hence, in channel management with BOPS, the values of s_o^*, s_s^* get lower but Π^* turns higher.

We can also find out in dual-channel, as the probability of available seats is increasing, the optimal offline service level will go up simultaneously so that the restaurants can reach the optimal revenue and the optimal revenue rises as well. On the contrary, the online service level changes conversely. In omnichannel ,service levels and revenue experience subtle changes. The revune always keeps relatively stable even with more vacancy in restaurants.

In closing, BOPS strategy boosts restaurant's revenue dramatically. Under certain conditions, BOPS strategy is a excellent implemention for restaurants in relatively both lower optimal online and offline service levels as a result of much higher optimal profits.

5.2 With and without BOPS under case2

when $v = 1$, $p = 0.5$, $H = 1$, $\delta_1 = 1$ and $\delta_2 = 1$, $k = 0.08$, $\alpha_1 = 0.2$, $\alpha_2 = 0.5$ and $\beta = 0.6$, we can draw following sub-figures (a), (b) and (c) in Figure 5.



(a) (b) (c)

Figure 5. the values of s_o, s_s and Π in dual-channel and omnichannel

Accordingly, we can find that under these conditions, s_o^* in dual-channel is smaller than that in omnichannel at every value of φ ranging from 0 to 1. In terms of s_s^*, when φ is smaller than raound 0.15, it in omnichannel is little more than that in dual-channel, while it falls behind the dual-channel strategy much more after φ is bigger than 0.15. The values of Π^* are similar with s_s^*, but the intersection of curve with BOPS and without BOPS is at approximately 0.5. Interestingly, the bigger the value of φ is, the bigger the value of s_s^* and Π^* is and the smaller s_o^* is in dual-channel. In addition, as the value of φ increases gradually, s_o^* and s_s^* will rise slowly but Π^* drop dramatically in BOPS scenario. Hence, after BOPS is implemented, the values of s_o^*, s_s^* and Π^* are all higher.

In Case 2 with BOPS, although the restaurant has provided BOPS option, no comsumers choose it. Despite of the inappearance of BOPS option, it is still a brilliant inspiration for consuming ratio and optimal profits in restaurants especially when there are less available seats at higher optimal offline and online service levels.

6. CONCLUSIONS

In this paper, our whole research is based on the epidemic social background. Given this exogeneous condition, BOPS as a type of omnichannel strategy plays an important role on consumers and retailers, decreasing consumers' risk of infection and sparking substantially higher revenue for restaurants. Therefore, we establish two models on respective scenarios to illustrate consumer purchasing behavior. After deriving the optimal values of service levels both online and offline, consuming demands and profits, we make comparisons between different scenarios in two cases by a series of numerical experiments. Eventually, we can draw out some enlightened conclusions in respect of channel management and omnichannel strategy. We cannot solely derive the optimal service levels and optimal profits in different scenarios by three cases, but also analyze significance of BOPS strategy implemented in epidemic background. In some situations, BOPS plays an important role in boosting restaurants' revenue but are not chosen apparently under certain conditions.

Despite of above research, some extensions about the models can be included in the future work. At the beginning, there is an assumption about offline utility in dual channel that if there are no available seats in the restaurant, the customers will leave it and their utility is 0. In fact, it's very likely to cause a negative utility. Upon the decision to leave the restaurant, the customer will probably turn to a new one or simply return home. Whatever the destination is, the utility is sure to be negative because of hassle costs consumed on transportation without enjoying deals in present restaurant and the amount of utility is hard to estimate. Given complexity, we just simply assume them as 0 in our models. Second, in realistic lives, judgements about risk levels are closely inseparable from governments' attitude toward current epidemic circumstances. In this paper, these influencing factors are ignored. Finally, in numerical experiments, we fixed all other variables' valuations except probability of finding available seats in the restaurant. For further research, changing different values about different variables can explore more managerial propositions. In Case 2 of model with BOPS, it puzzles that nobody chooses BOPS but profits are still much higher. All of these problems can keep digging deeply.

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