RAIRO-Oper. Res. 55 (2021) S999–S1011
https://doi.org/10.1051/ro/2020019

RAIRO Operations Research
www.rairo-ro.org

"ORDER-ONLINE-AND-PICKUP-OFFLINE" STRATEGY FOR ONLINE DIRECT SALE OF TIME-SENSITIVE COMMODITIES

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Abstract. Although recent decades have witnessed rapid development of e-commerce, direct sale of time-sensitive commodities on e-commerce platforms still faces significant challenges due to the dilemma between short delivery time and high delivery costs. To alleviate these challenges, manufacturers with online retailing operations have attempted to cooperate with offline retailers by using an "order-online, pickup-offline" (OOPO) strategy. To study the problem of effectively implementing the OOPO strategy for time-sensitive commodities, we consider a mechanism under which the manufacturer pays the retailers a cooperative service fee to ensure delivery coordination between the online and offline channels. We develop Stackelberg game-theoretic models to compare the profits of both delivery channels before and after the implementation of the OOPO strategy. By analyzing the models, we derive a feasible range on the cooperative service fee such that both channels are more profitable with the implementation. We further examine the plausibility of implementing the strategy when both channels are required to charge the same price on the commodities, which can lead to both channel coordination and pricing coordination.

Mathematics Subject Classification. 91A40.

Received May 3, 2019. Accepted February 19, 2020.

1. Introduction

In recent years, we have witnessed rapid development of e-commerce. More manufacturers begin to sell goods to consumers through their independent retailers and e-stores [5]. However, e-commerce development for time-sensitive commodities is still not as promising as that for other commodities.

In China, most e-retailers of time-sensitive commodities remain unprofitable. For example, 95% of fresh-produce e-stores reported revenue loss in 2015 [16], and average profit margin of pharmaceutical e-commerce companies is −5.5% in 2016 [11]. The reason for this unprofitability is high logistic costs associated with fast-delivery and quality-preservation technologies. In response to this challenge, e-commerce logistic system solutions are in great need. One such solution is implementing the so-called "order online, pickup offline" (OOPO) strategy in the system. With abundant community-based brick-and-mortar stores (referred to as community stores in the remainder of the paper), Chinese consumers can pick up their orders conveniently from nearby stores after they place their orders online by accepting the surcharge over the offline price. Thus, it is of practical importance to

Keywords. Dual-channel, cooperative pricing, time-sensitive, Stackelberg game theory.

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know how to implement the OOPO cooperation between the manufacturer and community stores to increase their respective profits over the situation of no such cooperation, while ensuring timely order fulfillment? In practice, the manufacturer often considers paying a service fee to incentivize the community stores to participate in the cooperation (*e.g.*, Bubugao, an electronic manufacturer, shares 5% of the total sales revenue with offline outlets; Linsy Furniture, a furniture manufacturer, gives extra remunerations to offline store salespersons) [6]. In this paper, we thereby investigate the pricing problem of determining the service fee.

For e-commerce of common products, we have witnessed success on online-to-offline (O2O) dual-channel cooperation between a manufacturer's online retailing and community stores that serve as self-pickup sites. For example, Bobbi Brown sent e-channel orders to community stores of Neiman Marcus for customer self-pickup [10]. Estee Lauder allowed its customers to carry out self-pickup at nearby stores after the customers placed orders online [23]. In 2015, Tmall, the biggest e-commence platform in China, announced its cooperation with close to ten thousand self-pickup sites in more than sixty Chinese cities [19]. However, little research is done for designing dual-channel cooperation for time-sensitive commodities.

In this paper, we focus on determining the cooperative service fee (or cooperative price). For this problem, we formulate two Stackelberg game-theoretic models for two coordinated dual-channel delivery models, one with implementation of the OOPO strategy and the other without the implementation. We derive analytically a feasible range of the cooperative price such that both the manufacturer and the retailer increase their respective profits. Further, as the manufacturer often adopts a uniform pricing policy to attract customers, we analytically drive the feasibility of a uniform pricing policy and examine its impacts on the profits of both sides. Next, we numerically examine the impact of commodity lead-time and e-channel preference on the profits. We are the first that apply a game-theoretic approach to analyze the decisions of both sides when implementing the OOPO strategy. In addition, we specify the notion of cooperation to not only delivery channel coordination but also commodity pricing coordination, which is more appealing.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the game-theoretic models to investigate the implementability of the OOPO strategy. In this section, we derive analytical results on the feasible range of the cooperative price and further specify the range within which uniform pricing between the two channels can be established. Section 4 reports numerical experiments to examine the impact of various model parameters on the feasible range of the cooperative service fee and both stakeholders profits. Section 5 draws conclusions and outlines future research.

2. Literature review

Three areas are closely related to our dual-channel pricing research. We first review the literature on time-sensitive dual-channel supply chain as delivery lead-time sensitivity is the main focus of this paper. We next review the literature on channel coordination concerning lead time. Finally, we review the literature on uniform pricing between online and offline channels.

2.1. Time sensitivity in dual-channel supply chains

Research that concerns time sensitivity in dual-channel supply chains has achieved fruitful results. For example, Tasy *et al.* pointed out that time sensitivity is an important factor when assessing strategic advantage of the supply chain [24]. The delivery lead time strongly influences the pricing strategies of the manufacturer and the retailers. Webster *et al.* introduced a demand function to analyze how quoted lead time significantly affects customer preference [26]. Ray *et al.* explicitly modeled the relationship between price and delivery lead time, and the authors investigated the capital investment strategy of a single firm for optimal delivery lead time, which is constrained by the service level [20]. Liu *et al.* considered pricing and lead-time decisions, and the authors showed that inefficiency in a decentralized supply chain is strongly affected by the market and operational factors [15]. Chen *et al.* studied the problem of optimizing delivery lead-time for the direct channel and wholesale price for a traditional retailer, who in turn sets the service level for the indirect channel [4].

Hua *et al.* examined the optimal decisions on delivery lead-time and retail prices both in centralized and decentralized dual-channel supply chains [9]. Hong *et al.* focused on pricing and lead time competition in a duopoly industry consisting of two large rms and several small rms [7]. Xu *et al.* investigated how pricing and delivery lead-time decisions affect channel configuration under either manufacturer-owned or decentralized mode [30]. Li *et al.* studied the optimal decisions on promised delivery lead time and pricing for a risk-averse firm [13]. Li *et al.* studied decisions related to dual-channel supply chains with retailers as dominant firms in the supply chains [14]. Hua *et al.* [9] and Li *et al.* [14] are the most related to our paper. Similar to our works, the authors presented game-theoretic models for time-sensitive dual-channel supply chains and investigated the impacts of retail price and commodity lead-time on stakeholders' profits. However, our paper extends their research to study the impact of implementing O2O cooperation on time-sensitive dual-channel supply chains. Our work will increase the potential to address practical challenges of Chinese e-commerce enterprises.

2.2. Supply chain coordination concerning lead time

There is extensive work on delivery lead time in the supply chain coordination literature. Chen *et al.* studied the coordination of a supply chain with long lead time and demand information updating [3]. Pekgun *et al.* studied the problem of coordinating the production and marketing departments of a firm where the production department determines the lead time and the marketing department determines the retail price [18]. Leng *et al.* proposed game-theoretic models for lead-time reduction and developed a profit-sharing contract [12]. Hu *et al.* solved the lead-time hedging problem between the manufacturing and sales departments of a firm, and proposed a coordination scheme with an internal price charged by the manufacturing department to the sales department [8]. Xiao *et al.* explored coordination in a supply chain *via* a revenue-sharing contract, on which the manufacturer specifies the standard on the lead time [29]. Boute *et al.* studied the coordination between a retailer making inventory decisions and a supplier making lead-time decisions for make-to-order commodities [2]. Zhu *et al.* concluded that revenue-sharing and two-part tariff contracts are ineffective to channel coordination; instead, a franchise contract with a contingent rebate can achieve channel coordination [32]. Xiao *et al.* assumed that the arrival rate depends on the announced delivery time and derived equilibrium solutions for a supply chain with an all-unit quantity discount contract [28]. Zhai *et al.* developed a production lead-time hedging coordination strategy to enhance the on-time delivery probability of prefabs by mitigating the impacts caused by production uncertainty [31]. Uthayakumar *et al.* proposed vendor-buyer integrated approach (coordination between buyer and seller), where the demands of different customers are not identical during the lead time [25]. Although the above coordination solutions aim at achieving a win-win situation, all of them focused on single-channel or inner-organization supply chains, and thus their models cannot be applied directly to dealing with the proposed dual-channel coordination problem with online and offline retailers.

2.3. Uniform pricing

This research area focuses on same-price policy implemented between indirect and direct channels. Asheraft found that differential prices for online and offline delivery in a dual-channel supply chain may lead to customer anger, confusion, and irritation [1]. Tang *et al.* noted that since a retailer's pricing decision would inevitably have influence on demand of its conventional stores, the retailer should set the same price for different distribution channels to avoid channel conflict [22]. Neslin *et al.* suggested that multi-channel retailers charge uniform prices across different channels to avoid consumer irritation [17]. In China, the uniform retail pricing mode is also called "Suning mode". Wu *et al.* considered the price war between Suning and Jingdong as an example to analyze the price competition between a dual-channel retailer (Suning in this case) and a pure online retailer (Jingdong in this case). The authors showed the latter will gain more profit when the former has no obvious advantage on its market size [27]. Under the OOPO strategy, we are first to analyze the possibility of a same-price policy and its influence on the profits.

In summary, our paper investigates how to ensure the implementation of OOPO strategy so as to meet the targets of fast delivery and low cost. Unlike most of the previous studies focusing on the interplay between price

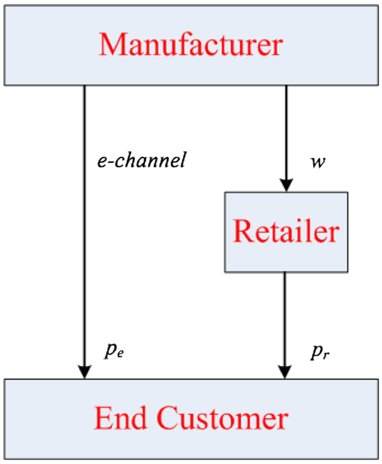

Figure 1. Current dual-channel model.

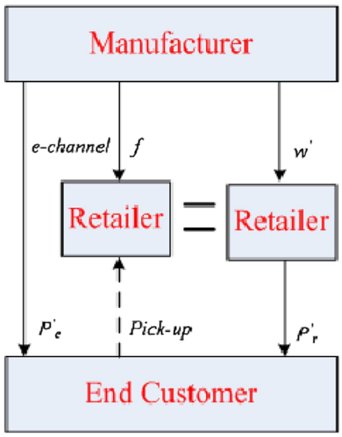

Figure 2. OOPO-based dual-channel model.

and lead-time decisions, the lead time is minimized for customers doing self-pickup at the nearest community store, and it depends only on the distance between the customers and the store. Thus the lead time becomes an exogenous factor not a decision variable in our paper. Moreover, different from other coordination strategies such as revenue-sharing and all-unit quantity discount, the OOPO strategy utilizes existing supply chain resource to minimize delivery cost. The studied strategy has yet been applied to time-sensitive commodities.

3. A Stackelberg game-theoretic model

We consider a dual-channel supply chain, composed of a manufacturer and an independent retailer (see Figs. 1 and 2).

Figure 1 presents the schematics of a current dual-channel supply chain, in which the manufacturer sells commodities to both the community store and customers. Customers may use either the e-channel or the indirect channel to purchase the goods. Figure 2 presents the schematics of a dual-channel model with implementation of the OOPO strategy. The difference between the two is the delivery mode with the e-channel. Under the

TABLE 1. Notation.

Decision variables	
w	The wholesale price
p_e	The e-channel retail price
p_r	The indirect retail price
Model parameters	
α	Lead time sensitivity of the demands in the e-channel
β	Lead time sensitivity of the demands in the indirect channel
θ	Customer preference for the e-channel
a	Base demand
b	The coefficients of price elasticity
c_1, c_2	The price sensitivity factor
c_d	The sum of the unit production cost and the least incurred logistics cost by the manufacturer through the e-channel
c_e	The total cost incurred by the manufacturer through the e-channel
c_r	The total cost incurred by the manufacturer through the indirect channel
l	The average lead time
f	The cooperative price
Other notation	
D_e	The demand *via* the e-channel
D_r	The demand *via* the indirect channel
π_m	The manufacturer's profit
π_r	The retailer's profit

OOPO strategy (Fig. 2), after ordering at an e-store run by the manufacturer, the customers pick up the orders themselves at the community store, which is the retailer of the other channel.

To ensure the implementation of the OOPO strategy, both parties must make more profits than without the implementation. It is not surprising that the manufacturer will make more profit for customer's convenience. To the community store, we consider the mechanism of receiving a cooperative price from the manufacturer for each order fulfilled. In the following, we present a Stackelberg model for each delivery model and compare the two models in terms of optimal profits of the manufacturer and the community store. Before modeling, we summarize below the notation used in our models (Tab. 1).

3.1. The dual-channel delivery model under the non-OOPO strategy

First, we model dual-channel delivery without OOPO (*i.e.*, the current dual-channel delivery model without coordination). The decision process is assumed to follow this sequence. The manufacturer, as the leader, determines wholesale price w, e-channel retail price p_e. Then the retailer, as the follower, sets its own optimal retail price p_r based on the manufacturer's decisions. We present a Stackelberg game-theoretic model in the following. The profits of the manufacturer and the retailer are specified by

$$\pi_r = (p_r - w)\, D_r, \tag{3.1}$$

$$\pi_m = (w - c_r)\, D_r + (p_e - c_d - \gamma/l)\, D_e. \tag{3.2}$$

In equation (3.2), $c_d + \gamma/l$ indicates the total cost through e-channel, in where c_d includes the unit production cost and the least incurred logistics cost when the delivery lead time is very long. And γ is a positive constant, which indicates an inverse relationship between the delivery cost and the lead time [9,30]. The reason for this expression is that the logistics cost of the manufacturer in the e-channel decreases with l. That is, when lead time l is short, the logistics cost rises sharply as l decreases, whereas when l is long, the logistics cost rises slowly as l decreases [9]. Next we present the demands of the e-channel D_e and the indirect channel D_r as,

$$D_e = a\theta - b_1 p_e + c_1 p_r - \alpha l, \tag{3.3}$$
$$D_r = (1-\theta)\, a - b_2 p_r + c_2 p_e + \beta l. \tag{3.4}$$

In equations (3.3) and (3.4), α and β are the lead time sensitivity coefficients of the demands in each channel. If the delivery lead time l increases by one unit, α units of the demand will be lost from the e-channel, of which β units of the demand will transfer to the indirect channel. Further, we assume that $\alpha > \beta$, which implies that the customers purchasing goods through the e-channel are more time-sensitive than those through the indirect channel [9, 21]; and $c_1 = c_2$, which implies the cross-price effects are symmetric. In addition, we assume that $b_1, b_2 \geq c$, so that the own price effects are greater than the cross-price effects.

We then derive optimal p_r^* by setting $\frac{\partial \pi_r}{\partial p_r} = 0$, and similarly derive optimal p_e^* and w^* by setting $\frac{\partial \pi_m}{\partial p_e} = 0$ and $\frac{\partial \pi_m}{\partial w} = 0$. Thus, we have:

$$p_e^* = \frac{a\left[c\,(1-\theta) + b_2\theta\right] - l\,(\alpha b_2 - \beta c)}{2\,(b_1 b_2 - c^2)} + \frac{c_e}{2}, \tag{3.5}$$
$$w^* = \frac{a\left[b_1\,(1-\theta) + c\theta\right] - l\,(\alpha c - \beta b_1)}{2\,(b_1 b_2 - c^2)} + \frac{c_r}{2}, \tag{3.6}$$
$$p_r^* = \frac{\left(3b_1 b_2 - c^2\right)\left[\beta l + a\,(1-\theta)\right] - 2\alpha c b_2 l + 2a b_2 c\theta}{4b_2\,(b_1 b_2 - c^2)} + \frac{c c_e}{4b_2} + \frac{c_r}{4}\cdot \tag{3.7}$$

Substituting the optimal prices obtained in (3.5–3.7) into (3.1) and (3.2), we can get the optimal profits of the retailer π_r and the manufacturer π_m under the non-OOPO strategy. See Appendix A for more derivation details.

3.2. The dual-channel delivery model under the OOPO strategy

Next, we study the coordinate dual-channel model with the implementation of OOPO strategy. For clarity, we add the superscript $'$ to the notation. The demand functions are the same as in the previous model.

$$D'_e = a\theta - b_1 p'_e + c_1 p'_r - \alpha l', \tag{3.8}$$
$$D'_r = (1-\theta)\, a - b_2 p'_r + c_2 p'_e + \beta l'. \tag{3.9}$$

Since customers pick up goods at the partnering retailer by themselves, the lead time l' represents the time consumption from the retailer to the customer. Compared to the current dual-channel model, the lead time in the coordinate model is shortened as the retailer is closer to the customers than the manufacturer, *i.e.*, $l' < l$.

Accordingly, the profits of both sides need to be updated. With a cooperative price being considered, the profits are updated as:

$$\pi'_r = (p'_r - w')D'_r + f D'_e, \tag{3.10}$$
$$\pi'_m = (w' - c_r)\, D'_r + (p'_e - c_r - f)\, D'_e. \tag{3.11}$$

In above equations, f indicates the cooperative price. We then derive the optimal prices and the corresponding profits under the OOPO strategy:

$$p_e'^* = \frac{a\left[c\,(1-\theta) + b_2\theta\right] - l'\,(\alpha b_2 - \beta c)}{2\,(b_1 b_2 - c^2)} + \frac{c_r + f}{2}, \tag{3.12}$$
$$w'^* = \frac{a\left[b_1\,(1-\theta) + c\theta\right] - l'\,(\alpha c - \beta b_1)}{2\,(b_1 b_2 - c^2)} + \frac{c_r}{2} - \frac{cf}{2b_2}, \tag{3.13}$$
$$p_r'^* = \frac{\left(3b_1 b_2 - c^2\right)\left[\beta l' + a\,(1-\theta)\right] - 2\alpha c b_2 l' + 2a b_2 c\theta}{4b_2\,(b_1 b_2 - c^2)} + \frac{(b_2 + c)\, c_r}{4b_2} + \frac{cf}{2b_2}\cdot \tag{3.14}$$

Substituting the optimal values obtained in (3.12–3.14) into (3.10) and (3.11), we can get the optimal profits of the retailer π_r' and manufacturer π_m' under the OOPO strategy (see Appendix A for more detailed derivation).

Proposition 3.1. *The retail prices $p_e'^*$, $p_r'^*$, and the whole price w'^* are linearly related to the cooperative price f. That is,*

$$\text{(a)} \quad \frac{\partial p_e'^*}{\partial f} = \frac{c_r}{2} > 0, \qquad \text{and} \quad \frac{\partial p_r'^*}{\partial f} = \frac{c}{2b_2} > 0, \tag{3.15}$$

$$\text{(b)} \quad \frac{\partial w'^*}{\partial f} = -\frac{c}{2b_2} < 0, \quad \text{and} \quad \frac{\partial w'^*}{\partial f} = -\frac{\partial p_r'^*}{\partial f}. \tag{3.16}$$

Proposition 3.1(a) indicates that the retail prices $p_e'^*$ and $p_r'^*$ increase with increasing cooperative price f. Within the feasible range of the cooperative price, the higher the price is agreed between the manufacturer and the retailer, the higher the cooperative price is, the more loss of consumers' welfare. Proposition 3.1(b) shows that for the retailer, the wholesale price changes in the opposite direction, and the magnitude of the change is the same. That is, for a given f, the retail price $p_r'^*$ increases as much as the wholesale prices w decreases.

Proposition 3.2. *The negative linear correlation is certain between the e-channel price $p_e'^*$ and the lead time l'. To the contrary, The linear relationship is uncertain between the indirect price $p_r'^*$, the whole price w'^* and the lead time l'.*

$$\text{(a)} \quad \frac{\partial p_e'^*}{\partial l'} = -\frac{(\alpha b_2 - \beta c)}{2\left(b_1 b_2 - c^2\right)} < 0, \tag{3.17}$$

$$\text{(b)} \quad \frac{\partial p_r'^*}{\partial l'} = \frac{\partial w'^*}{\partial l'} = -\frac{(\alpha c - \beta b_1)}{2\left(b_1 b_2 - c^2\right)}. \tag{3.18}$$

From (3.17), we know that the closer the customers are to the retailer, the higher e-channel price $p_e'^*$. For $p_r'^*$ and w'^*, the sign of the first derivative $-\frac{(\alpha c-\beta b_1)}{2(b_1b_2-c^2)}$ is uncertain. It is possible that, contrary to the e-channel price $p_e'^*$, the closer retailers are to the customers, the lower the retail price $p_r'^*$ and wholesale price are w'^*. In addition, by (3.18), $\frac{\partial p_r'^*}{\partial l'} = \frac{\partial w'^*}{\partial l'}$ implies that $p_r'^*$ and w'^* not only have the same magnitude of change, but also change in the same direction.

Proposition 3.3. *The retail prices $p_e'^*$ and $p_r'^*$, and the whole price $w'*$ are linearly related to the e-channel preference θ. That is,*

$$\text{(a)} \quad \frac{\partial p_e'^*}{\partial \theta} = \frac{a\left(b_2 - c\right)}{2\left(b_1 b_2 - c^2\right)} > 0, \tag{3.19}$$

$$\text{(b)} \quad \frac{\partial p_r'^*}{\partial \theta} = \frac{a\left(-3b_1 b_2 + 2b_2 c + c^2\right)}{4b_2\left(b_1 b_2 - c^2\right)} < 0, \tag{3.20}$$

$$\text{(c)} \quad \frac{\partial w'^*}{\partial \theta} = -\frac{a\left(b_1 - c\right)}{2\left(b_1 b_2 - c^2\right)} < 0. \tag{3.21}$$

Inequalities (3.19) and (3.20) imply that if the number of customers choosing a particular channel increases, the retail price of that channel increases. On the other hand, qualities (3.21) shows that if increasing customers choose the e-channel, the wholesale price falls.

3.3. Range of the cooperative price

In this section, based on the profits and the prices derived for the two models, we calculate the range of the cooperative price. First, with the no-arbitrage conditions, we have

$$p_e'^* > w'^* > c_r. \tag{3.22}$$

The OOPO strategy is implemented only when the profits of the manufacturer and the retailer increase simultaneously. Thus we have

$$\pi'_m > \pi_m. \tag{3.23}$$

$$\pi'_r > \pi_r. \tag{3.24}$$

Solving inequalities (3.26) and (3.27), respectively, the intersection of the obtained solutions R is considered the range of the cooperative price f. If $R = \phi$, the cooperative price is non-existent, so that the OOPO strategy is not invalid. With this range, the manufacturer and the retailer can accurately design a coordination scheme to achieve a win-win situation instead of pricing with blindness, which may eventually leads to loss. Since the profits $R = \phi$ and π'_r are quadratic functions of the cooperative price f, the analytical solution of the inequalities are difficult to analyze. So we will next examine the feasible range of the cooperative price numerically.

3.4. The "uniform price online and offline" policy

To avoid prices price discrimination between the two channels, the "uniform price online and offline" policy is often adopted by suppliers. In this section, we analyze the feasibility of such policy under the OOPO strategy.

At the equilibrium, *i.e.*, let $p'^*_r = p'^*_e$, then the cooperative price f^* can be computed as:

$$f^* = \frac{\begin{array}{c}\left(c^2 c_r + 2\alpha b_2 l'\right)(b_2 - c) - \beta c l' (2b_2 + c) - b_1 b_2 (b_2 c_r - c c_r - 3\beta l') \\ +a\left[3b_1 b_2 (1-\theta) - c(2b_2 + c) - \theta\left(2b_2^2 - 4b_2 c - c^2\right)\right]\end{array}}{2(b_2 - c)(b_1 b_2 - c^2)}. \tag{3.25}$$

If $f^* \in R$, the "uniform price online and offline" requirement can be met by adjusting the cooperative price. Otherwise, the policy cannot be applied. Assuming the cooperative price is valid, we discuss the changes of the cooperative price with the changes on lead time and e-channel preference.

Proposition 3.4. *Under the "uniform price online and offline" policy, the cooperative price f^* is a liner function of lead time l' and e-channel preference θ.*

$$\text{(a)} \quad \frac{\partial f^*}{\partial l'} = \frac{2b_2 (b_2 - c)(\alpha + \beta) + \beta\left(b_1 b_2 - c^2\right)}{2(b_2 - c)(b_1 b_2 - c^2)} > 0, \tag{3.26}$$

$$\text{(b)} \quad \frac{\partial f^*}{\partial \theta} = -\frac{a\left(3b_1 b_2 + 2b_2^2 - 4b_2 c - c^2\right)}{2(b_2 - c)(b_1 b_2 - c^2)} < 0. \tag{3.27}$$

Above inequalities imply that the shorter the lead time or the flexible the choice of the e-channel is, the lower the cooperative price is. If the manufacturer expects to reach an agreement on a lower cooperative price, it needs to select a retailer closer to customers as the partner or enhance the attractiveness of e-commerce.

4. Numerical studies

First of all, we examine the effect of changes in parameter values (% change) on the profits. The sensitivity analysis is performed by increasing value of each parameter by 20%, taking one parameter at a time, and keeping the remaining unchanged. Assuming $a = 50\,000$, $b_1 = b_2 = 150$, $c = 40$, $c_e = 150$, $c_r = 100$, $f = 50$, $l = 1$, $l' = 0.1$, $\alpha = 3000$, $\beta = 500$, the corresponding results are given in Table 2.

In above table ↑, ↓ and − represent increase, decrease and irrelevant respectively. From the table, we observed that (1) the profits of the manufacturer and the retailer increase with increasing a, c, β and decreasing b_1, b_2, c_r, α under both the non-OOPO and OOPO strategies; (2) when θ increases, the profit of manufacturer increases but the profit of retailer decreases under the non-OOPO strategy, whereas the profits of both parties increase with the increment of θ under the OOPO strategy; and (3) for the changing intervals, a has the most influence $b_1, b_2, c, c_e, c_r, \theta$ also have a strong influence, whereas α, β have less influence. Thus in the decision making

TABLE 2. Sensitivity analysis on the profits.

Parameter	Non-OOPO		OOPO	
	π_m	π_r	π'_m	π'_r
a	$\uparrow$ 135.0%	$\uparrow$ 81.7%	$\uparrow$ 122.2%	$\uparrow$ 55.1%
b_1,b_2	$\downarrow$ −71.2%	$\downarrow$ −54.5%	$\downarrow$ −69.4%	$\downarrow$ −42.0%
c	$\uparrow$ 33.1%	$\uparrow$ 22.0%	$\uparrow$ 29.0%	$\uparrow$ 13.1%
c_e	$\downarrow$ −33.7%	$\uparrow$ 22.0%	−	−
c_r	$\downarrow$ −14.3%	$\downarrow$ −45.4%	$\downarrow$ −36.7%	$\downarrow$ −21.7%
α	$\downarrow$ −6.9%	−	$\downarrow$ −0.7%	$\downarrow$ −0.4%
β	$\uparrow$ 0.9%	$\uparrow$ 1.7%	$\uparrow$ 0.7%	$\uparrow$ 0.4%
θ	$\uparrow$ 37.8%	$\downarrow$ −77.1%	$\uparrow$ 46.2%	$\uparrow$ 20.6%

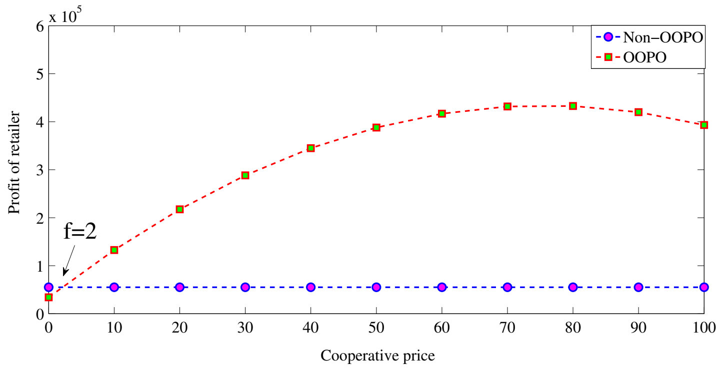

FIGURE 3. Retailer's profit with cooperative price.

context, more attention should be given to the values of parameters a, b_1, b_2, c, c_e, c_r and θ for a successful implementation of the OOPO strategy.

Next we discuss the effects of cooperative price f, lead time l, and e-channel preference θ on the profits π_m and π_r by varying $f \in [0, 100]$, $l' \in [0.1, 1]$, $\theta \in [0.5, 0.8]$ respectively. In Figures 3 and 4, the blue line is the baseline, which represents the profits without the implementation of the OOPO strategy. The red line, which represents the profits under the OOPO strategy, should be on top of the solid line in both figures, otherwise OOPO should be rejected.

From Figure 3, we observe that the profit of the retailer increases with increasing cooperative price. When $f \geq 2$, the retailer's profit under the OOPO strategy is higher than that under the non-OOPO strategy. Similarly, from Figure 4, we observe that the profit of the manufacturer decreases with increasing cooperative price. When $f \leq 62$, the profit of the manufacture with OOPO is higher than that without OOPO. Combining the above results, we conclude that $f \in [2, 62]$ is the feasible range.

Next, to investigate the relationship between the lead time and the profits under the OOPO strategy, we set $f = 50$, and vary $l' \in [0.1, 1]$. From Figure 5, we conclude that to the manufacturer, if the potential partnering retailer is far from the customers, the OOPO strategy would be abandoned. There is a threshold value for the average distance to the customers. However to the retailer, it can accept any lead time in this case (see Fig. 6).

Finally, we assume $f = 50, l = 1, l' = 0.1$ to discuss the impacts of e-channel preference θ on the profits of both parties. Figures 7 and 8 show that under the non-OOPO strategy, the profit of retailer decreases whereas the profit of manufacturer increases with increasing θ. Compared to the OOPO strategy, both profits increase with increasing θ. Therefore, the retailer should prevent customers from choosing e-channel without coordination.

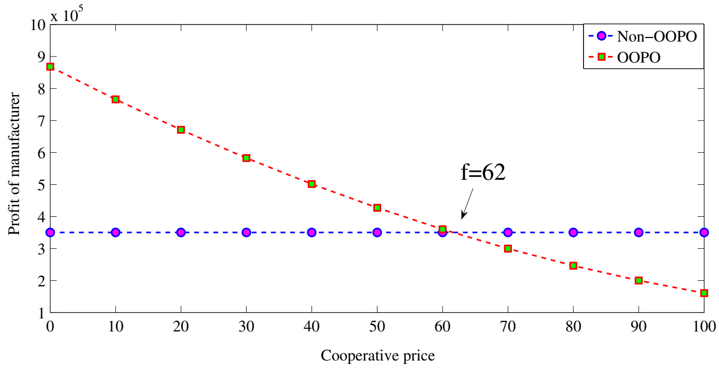

FIGURE 4. Manufacturer's profit with cooperative price.

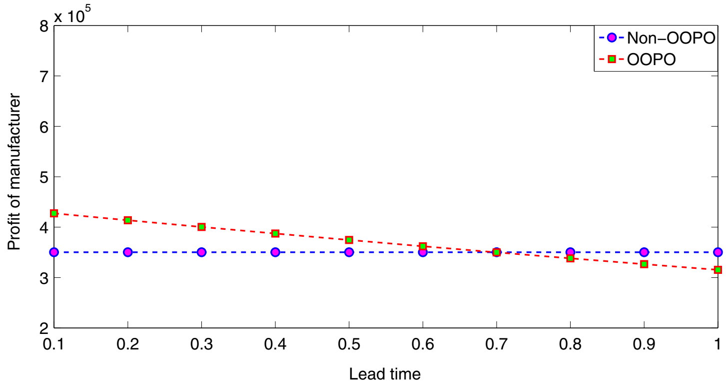

FIGURE 5. Manufacturer's profit with lead time.

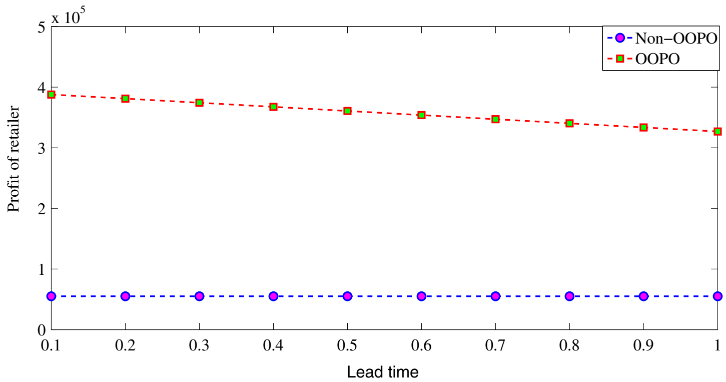

FIGURE 6. Retailer's profit with lead time.

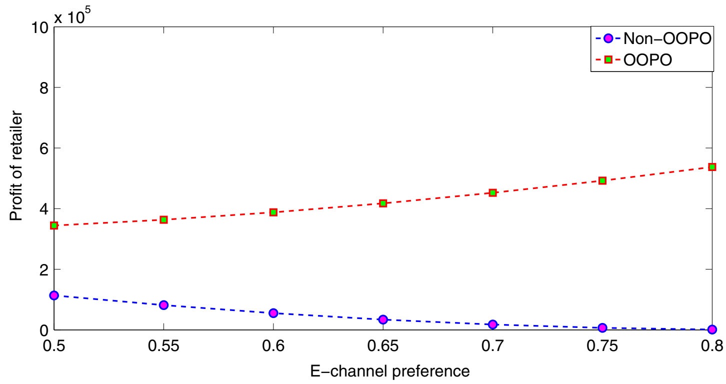

FIGURE 7. Retailer's profit with e-channel preference.

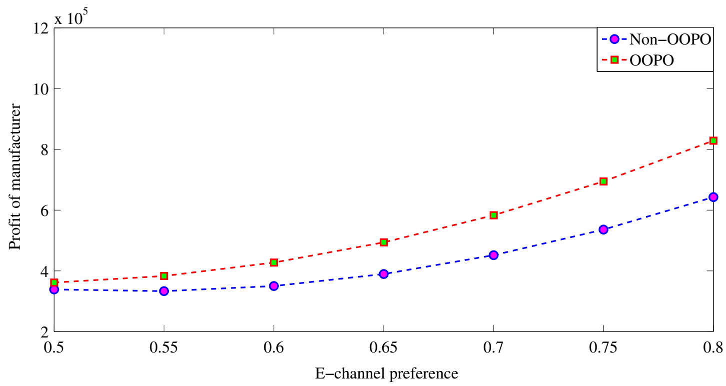

FIGURE 8. Manufacturer's profit with e-channel preference.

But with the implementation of the OOPO strategy, the retailer should adjust its marketing strategy to attract more customers to the e-channel.

5. Conclusions and future research

In order to expand the customer population size, manufacturers build their own online sales platforms. Usually, customers desire receive their online orders as soon as possible after order placement, especially for time-sensitive orders such as medicine and fresh food. On the other hand the quality of the ordered products should be guaranteed. Thus, requirements on the delivery speed and/or quality result in high logistics cost, which has prohibited the development of e-commerce around time-sensitive goods. To reduce cost and shorten lead time, manufacturers have elected to use an offline logistics system with the "Order Online, Pickup Offline" strategy. It seems to be effective and brings win-win outcome to both manufacturers and retailers. But in real life, this new business model is far from being profitable. The crucial question is how to design a cooperative strategy to ensure the acceptance of the OOPO strategy by both parties of the supply chain.

From a theoretical viewpoint, this paper introduces a cooperative price to ensure the feasibility of the online-offline coordination. That is, manufacturer pays a cooperative service fee to retailer after each self-pickup. We establish a manufacturer's time-sensitive dual-channel model with the cooperative service fee. We derive an analytic expression for the feasible range of cooperative price. Further, we study the feasibility of the "uniform prices online and offline" policy under the OOPO strategy.

As for the managerial implications, we make the following remarks. If the range of cooperative price is not empty, implementation of the OOPO strategy is feasible.. With this in mind, the manufacturer and the retailer can effective negotiate an OOPO coordination scheme to achieve a win-win situation instead of pricing with irrationality, which may eventually lead to profit loss. With numerical experiments, we also find that (1) both the manufacturer and the retailer prefer to be closer to the customers for more profit; and (2) the manufacturer intends to attract more customers to the e-channel whereas the retailer cannot always be assumed to dislike e-commerce.

There are several interesting topics for future research. First, many 3rd-party e-commerce platforms, such as Taobao and Suning, will have adopted the OOPO strategy in near future. As a result, how will these 3rd-party platforms, which have become dominant players, compete and negotiate the cooperative price among them? Second, if the retailer considers additional cross-selling when customers come to pick up ordered goods, what should the cooperative price be?

Appendix A.

The retailer and manufacturer profits without the implementation of the OOPO strategy are given as:

$$\pi_r = \frac{\left[a(1-\theta) + cc_e - b_2 c_r + \beta l\right]^2}{16 b_2}, \tag{A.1}$$

$$\pi_m = \frac{\begin{array}{l} 2b_1^2 b_2^2 c_e^2 + c^4 c_e^2 + 2b_2 c^3 c_e c_r - b_2^2 c^2 c_r^2 - 4\alpha b_2 c^2 c_e l \\ + 2\beta c^3 c_e l + 2b_2 \beta c^2 c_r l + 2\alpha^2 b_2^2 l^2 - 4\alpha b_2 \beta c l^2 + \beta^2 c^2 l^2 \\ + b_1 b_2 \left[-3c^2 c_e^2 + b_2^2 c_r^2 + 4\alpha b_2 c_e l - 2b_2 \beta c_r l + \beta^2 l^2 - 2cc_e\left(b_2 c_r + \beta l\right)\right] \\ + a^2 \left[b_1 b_2 (1-\theta)^2 + c^2 (1-\theta)^2 + 4b_2 c(1-\theta)\theta + 2b_2^2 \theta^2\right] \\ + 2a \left[\begin{array}{l} c^3 c_e (1-\theta) - 2\alpha b_2^2 l\theta + 2b_2 c l(\alpha\theta - \alpha + \beta\theta) - c^2 \beta l(1-\theta) \\ -c^2 b_2 (c_r - c_r\theta + 2c_e\theta) - (b_1 b_2 \beta l - cc_e - b_2 c_r)(1-\theta) + 2b_2 c_e \theta \end{array}\right] \end{array}}{8b_2\left(b_1 b_2 - c^2\right)}. \tag{A.2}$$

where $c_e = c_d + \gamma/l$.

With implementation of the OOPO strategy, the retailer and manufacturer profits are given as:

$$\pi_r' = \frac{\begin{array}{l} (b_2 - c)^2 c_r^2 + 8f(c_r + f)\left(c^2 - b_1 b_2\right) + 2\beta c l'(c_r + 4f) + \beta^2 l'^2 - 2b_2 l'(\beta c_r + 4\alpha f) \\ + a^2 (1-\theta)^2 + 2a\left[(cc_r + 4cf - \beta l')(1-\theta) + b_2 (c_r - c_r\theta - 4f\theta)\right] \end{array}}{16 b_2}, \tag{A.3}$$

$$\pi_m' = \frac{\begin{array}{l} \left(-b_2^2 + 2b_2 c + c^2\right) c^2 c_r^2 + 2c^4 f(2c_r + f) + 2b_1^2 b_2^2 (c_r + f)^2 - 2b_2 c^2 c_r l'(2\alpha - \beta) \\ + 2\beta c^3 c_r l' - 4c^2 f l'(\alpha b_2 - \beta c) + l'^2 \left(2\alpha^2 b_2^2 - 4\alpha b_2 \beta c + \beta^2 c^2 + b_1 b_2 \beta^2\right) \\ + b_1 b_2 \left[\begin{array}{l} b_2^2 c_r^2 - c^2\left(3c_r^2 + 8c_r f + 4f^2\right) - 2\beta c l'(c_r + 2f) \\ -2b_2\left(cc_r^2 + \beta c_r l' - 2\alpha c_r l' - 2\alpha f l'\right) \end{array}\right] \\ \times a^2 \left[\left(b_1 b_2 + c^2\right)(1-\theta)^2 + 4b_2 c(1-\theta)\theta + 2b_2^2\theta^2\right] \\ + 2a \left[\begin{array}{l} \left(c^2 - b_1 b_2\right)(cc_r + 2cf + \beta l')(1-\theta) - 2\alpha b_2^2 l'\theta \\ -\left(c^2 - b_1 b_2\right) b_2 (c_r + c_r\theta + 2f\theta) + 2\alpha b_2 c l'(1-\theta) + \beta b_2 c\theta_2 \end{array}\right] \end{array}}{8b_2\left(b_1 b_2 - c^2\right)}. \tag{A.4}$$

Acknowledgements. This work was supported by the National Natural Science Foundation of China (Grant No. 71661147004, 71671039), the Key R & D Plans of Jiangsu Province, China (No. BE2017156).

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