International Journal of Innovative Computing, Information and Control
Volume **16**, Number **4**, August **2020**

ICIC International ©2020 ISSN 1349-4198
pp. 1165–1181

A MODEL OF REFUNDABLE ORDER CANCELLATION PROBLEM WITH FULFILLMENT COST

Yi Zhang[1], Xiangpei Hu[1], Yonggang Li[1,*] and Ying Gao[2]

[1]Institute of Systems Engineering
[2]School of Software Technology
Dalian University of Technology
No. 2, Linggong Road, Dalian 116023, P. R. China
[*]Corresponding author: lygdlut@foxmail.com

Received February 2020; revised June 2020

Abstract. *This paper addresses a refundable order cancellation problem from the observation of online grocery retail business in China, characterized by the fulfillment cost consisting of both physical losses caused by deteriorations in order fulfillment process and expenses spent on operational activities associated with the cancelled orders, which is a considerable sunk cost. In consideration of this fulfillment cost, we formulate a revenue management model by determining the refund rate and the hassle cost to optimize refund policies with the goal of maximizing the retailer's profit. Then, we conduct model specification and yield several main results. Finally, numerical experiments are performed on randomly generated data and the implications of numerical results are discussed. We show both theoretically and experimentally that offering partial refund is always the superior policy rather than imposing hassles of cancelling on consumers. The proposed model can expand to be implemented in revenue management for extensive emerging on-demand instant service systems, and we provide managerial insights to practitioners at managing order cancellations with fulfillment costs on physical operations.*

Keywords: Order cancellation, Fulfillment cost, Revenue management, Online grocery retailing

1. Introduction.

Today, the online grocery retailing, which is distinguished for its at-once response to consumers' demands, e.g., One-Hour Delivery of Missfresh.com, Pre-Agreed Delivery of Freshhema.com at a daily basis, is greatly favored by the consumers [1]. However, consumers may face consumption uncertainties such as new alternatives, changed mind, and unexpected events after placing a purchase order [2]. These occurrences take place from time to time; thus consumers may prefer to cancel their orders before the pre-agreed delivery time. Retailers commonly have concerns about negative impact that these cancellations have on the revenue, as they will disrupt the original order fulfillment operations, resulting in deterioration losses and waste of costs. Consequently, in real life, it tends to cost consumers pretty many efforts in terms of communications and requests of a cancellation. It is reported that about a quarter of online grocery retail disputes in China are over order cancellation [3], which suggests a ubiquitous lack of reasonable and effective refund and cancellation policy. And with the explosive growth of online grocery retail sales (CNY 300 billion sales in 2019 and an expected annual growth rate of 30-40% in the next three years [4]), apparently, retailers are facing a rising number of order cancellation requests, having this refundable order cancellation problem a crucial issue at present.

DOI: 10.24507/ijicic.16.04.1165

From our observation of online grocery retails in China, two features of such type of service systems are identified. First, orders are fulfilled timely order-by-order with instant responsiveness. A cancellation means a termination of an on-going service. Second, order fulfillments are supported by costly physical operations, such as picking, packaging and shipping throughout the entire order fulfillment process. Each cancelled order is associated with a fulfillment cost which has a negative impact on the retailer's revenue. A system with these two features is regarded as an on-demand instant service system, where an order cancellation is always associated with a fulfillment cost. Existing literature is mostly backgrounded on capacity-constrained service system, and Xie and Gerstner [5] believe that refund should be offered for cancellations in the advance selling. However, with a fulfillment cost, the order cancellation problem for an on-demand instant service system has not been extensively studied, and it is challenging not only for the decision on the refund, but also for the uncertain potential cancellations. In this paper, we term the hassle cost to indicate the price that a consumer affords to request for a cancellation. Cancellation restrictions [6], terms and conditions [7] are the specific forms of the hassle cost imposed on consumers. High refund is favorable to consumers and will increase the consumers' willingness to pay, whereas the hassle cost plays a part in reducing potential cancellations while may decrease the willingness to pay to some extent. The decisions on the refund and the hassle cost will influence the consumers and subsequently function on the revenue of the retailer.

Motivated by the current practices and the theoretical gap in the literature, we attempt to make cancellation policy for the refundable order cancellation problem with a fulfillment cost on each cancellation. So, several interesting research questions arise: What is the optimal refund rate to online grocery retailer? How does imposing a certain amount of hassles on the consumer affect the retailer's revenue? How can the retailer adjust the participation of potential customers by the decisions of the refund rate and the hassle cost?

In this paper, we devote to modeling this refundable order cancellation problem with fulfillment cost aiming to optimize the retailer's profit. We formulate a revenue management model that involves both the refund rate and the hassle cost, and specialize the model under a uniform distribution of cancellation probability to generate analytical results of refund and cancellation policy. The results show that offering partial refund without imposing any hassles of cancelling on consumers is always a superior policy, where the profit advantage is owing to more order placements from consumers under a larger acceptable range of cancellation probabilities, and stems from retaining the nonrefundable portion of the sales price. Specially, the full refund and generous cancellation policy, under which consumers can cancel their previous orders freely, should be adopted when the fulfillment cost is a trivial matter, such as in the contexts of most conventional e-commerce retailing.

It is worth noting that the order cancellation under discussion typically refers to the time period before the delivery moment, as shown in Figure 1. It is different from product returns. Return management programs [8,9] often serve as insurance against dissatisfaction or poor fit. In this paper, we focus on the scenario when consumers have unexpected occurrences before the ordered items are delivered. Ignoring cancellation request may lead to the situation of loaded consumer complaints and mislead order cancellations into product returns with much higher loss due to deterioration and degradation.

The remaining parts of the paper are organized as follows. In the next section, we review the related literature. The model for refundable order cancellation with fulfillment cost is presented in Section 3. We analyze the model specification results in Section 4, and conduct numerical experiments to illustrate implications in Section 5. We conclude in Section 6 with research limitations and future research directions.

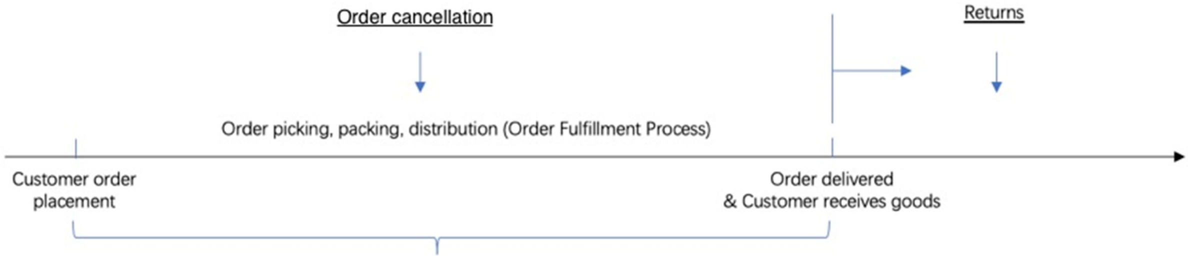

Figure 1. Order cancellation and order fulfillment process

2. **Literature Review.** Research in the context of online grocery retailing is relatively recent, primarily focusing on several topics, such as channel choices [10,11], business model [12,13], and distribution strategy [14-16]. To our knowledge, there is very limited research on order cancellation problem in online grocery retailing. Most existing literature that accounts for order cancellations focuses on revenue management (RM) for capacity-constrained service systems, such as airlines, hotels and car rentals [17-20]. The general idea to deal with cancellations for these systems is to utilize the limited capacity so as to maximize the expected revenue [21]. Order cancellations are regarded as chances to enhance revenue by multi-selling the released resource units [22,23], and gain additional profit potential from the uncertain customer valuations that evolve over time [24-26]. Basically, an order means to have the designated capacity reserved or occupied, so cancelling an order means cancelling the reservation and does not involve the fulfillment cost upon order processing operations. Unfortunately, this is not the case of on-demand instant service systems. In the context of online grocery retailing, an order will initiate a physical operation process with fulfillment cost. Even if the demand is substantial, order cancellation needs to be treated deliberately because each cancelled order incurs a considerable "sunk" fulfillment cost. This suggests a new and unexplored issue in RM.

Many studies employ pricing strategies into revenue management with order cancellations. In [22,23], dynamic pricing models are formulated with full refund upon cancellation, and the freed item from the cancelled order can be resold during the remaining sales period. Fan and Chen [27] consider a refundable fare issued on the cancelled order, and draw the optimal pricing strategy for a make-to-order firm aiming to maximize the expected profit. Li et al. [28] investigate the optimal joint inventory and pricing strategy with consideration of order cancellation and refund options, and further explore the impact of the refund policy on the market growth and the customers' order cancellation behavior. For more related work on pricing models of revenue management, we refer readers to [29]. This stream of research takes advantage of pricing strategy as a means to adjust the match between demand and supply to improve revenue.

Our study follows this trend but from a different perspective. We devote on refund policy under the theoretical framework of revenue management assuming the price is exogenously given. This assumption holds in practice since in online grocery retail the sales period is typically very short, mostly at a daily basis, and there is very limited space to dynamically adjust the price in a day. We employ the refund and cancellation policy to achieve trade-off between cost and benefit. The existing literature in marketing science regards refund as a strategy to improve revenue [5]. Ringbom and Shy [30,31] study the effects of different refund policies. In markets with multiple parties, the equilibrium choice of policies is examined [32,33]. In terms of the fulfillment cost, we endogenously solve for the participation rates of consumers, which can be adjusted by the refund rate and the hassle cost.

Our work contributes to the literature of revenue management for implementation beyond capacity-constrained service systems to on-demand instant service systems, and provides an economic theory that takes advantage of order cancellations especially with fulfillment cost. Moreover, it is of great significance that the proposed model can be extended to manage order cancellations for contemporary online-to-offline e-commerce platforms which also provide on-demand services to customers, like Didi Ride and Eleme Takeaway.

3. **Problem Statement and Revenue Model.**

3.1. **Problem statement.**

Consider an online grocery retail business where a consumer arrives with expected valuation v (willingness-to-pay) and places an order, and then the retailer responds instantly to carry out a series of physical operations, such as picking, packaging, and shipping, to fulfill the order within the pre-agreed delivery time slot. The fulfillment cost w consists of the operation costs plus deterioration damage if exists. The selling price is p. Assume that the price is exogenously given and is relatively stable over a daily sales horizon. Such an assumption is consistent with the actual situation in retailers. Inherently, the relation $v > p$ always holds since a consumer only buys if her willingness-to-pay exceeds the sales price. Note that the payment is due immediately, while consumptions occur until later that consumers receive the goods. During the time period before delivery, consumers have the option of canceling orders. Suppose potential consumers vary in their cancellation probabilities. Let θ denote the cancellation probability, following the distribution function $F(\cdot)$ and the density function $f(\cdot)$. If a consumer cancels her order, the retailer terminates the operation process of the cancelled order and issues a refund rp for the cancellation, where r is the refund rate and $r \in (0, 1]$. Namely, the consumer will be refunded with a proportion of the sales price. The rest part $(1-r)p$ is retained by the retailer, at the very least as a compensation for the loss resulting from order cancellations. We use h to measure the hassles that a consumer endures to notify the retailer about her cancellation and withdraw her order, where $h \geq 0$. Following Xie and Gerstner [5], the hassle cost directly reflects the process inconvenience of cancelling and refunding. Here, we assume that consumers have identical perceptive value on hassles. Suppose the resales of the cancelled units are always possible in the selling horizon, and the decisions are simply without involving the purchase cost nor the inventory cost, which are omitted in this paper for simplicity. The decisions of the retailer are twofold, which are the refund rate r and the hassle cost h for those who cancel their orders.

The sequence of the events is as follows:

- The retailer claims the price p, the refund rate r, and the cancellation conditions and procedures that are equivalent to the hassle cost h;
- A consumer decides whether to place an order based on her cancellation probability;
- The retailer carries out order fulfillment operations;
- The retailer terminates the operational process corresponding to a cancellation, and issues the refund with the refund rate r.

3.2. **The consumer's side.**

The consumer's utility is depicted as follows,

$$CU = (1-\theta)(v-p) + \theta(rp - p - h) \tag{1}$$

In Equation (1) above, CU represents the expected utility of a consumer with cancellation probability θ. The first part of Equation (1) is the utility when the consumer keeps the purchase order, and the second part is the utility when she cancels her order. The consumer makes her purchase only if she gets nonnegative utility, that is, $CU \geq 0$. When a consumer's cancellation probability $\theta = 0$, she will keep the order without cancelling it until delivery.

Let $\hat{\theta}$ be the threshold cancellation probability of the consumer who is indifferent between order placement or not. From (1), $\hat{\theta}$ is derived by $CU = 0$,

$$\hat{\theta} = \frac{v - p}{v - rp + h} \tag{2}$$

Here, $\hat{\theta}$ is the threshold of acceptable order cancellation probability, which is determined by the retailer's decisions on the refund rate r and the hassle cost h. The retailer will serve the consumers whose cancellation probability θ indexed in the range of $\left[0, \hat{\theta}\right]$.

Lemma 3.1. *$\hat{\theta}$ increases in r and decreases in h.*

Proof: From Equation (2) we conclude that,

$$\frac{\partial \hat{\theta}}{\partial r} = \frac{p(v-p)}{(v - rp + h)^2}, \quad \frac{\partial \hat{\theta}}{\partial h} = -\frac{v-p}{(v - rp + h)^2}$$

It is easy to observe that $\frac{\partial \hat{\theta}}{\partial r} > 0$ and $\frac{\partial \hat{\theta}}{\partial h} < 0$. □

Lemma 3.1 tells that the retailer targets potential consumers by settling the refund rate and the hassle cost. By promising a higher refund rate, the retailer can capture more consumers with a larger range of cancellation probabilities. However, since concerning about the negative effect of excessive cancellations, the retailer would struggle to keep the amount of cancellations within an acceptable range, thereby setting certain hassles for cancellation requests. This intuitionally motivates most practitioners who adopt the cancellation policy of full refund with quite high hassle cost in the model.

3.3. **The retailer's revenue.** Here we describe the retailer's model and explore refund decisions to optimize the revenue. From the retailer's perspective, the unit profit $G(\theta)$ from a consumer who places order is,

$$G(\theta) = p - w - \theta rp \tag{3}$$

The retailer gains a revenue p for a purchase order from a consumer with cancellation probability of θ, while paying the fulfillment cost w and the refund portion θrp. Recall (2), the cancellation probability θ of the consumer belongs to the acceptable cancellation probability range of $\left[0, \hat{\theta}\right]$. Consequently, the expected profit Π of the retailer is defined as the integral of $G(\theta)$,

$$\Pi = \int_0^{\hat{\theta}} G(\theta) dF(\theta) = \int_0^{\hat{\theta}} (p - w - \theta rp) dF(\theta) \tag{4}$$

Note that $p - w \geq 0$ always holds as the retailer runs operations for nonnegative revenue. The objective of the retailer is to maximize his expected profit Π.

4. **Model Specification and Main Results.** Previous studies [30] and [31], have investigated the refund rate in their revenue models for order cancellations. While in our model, to deal with this order cancellation problem with fulfillment cost, there is an additional hassle cost in the cancellation policy. In this section, we intend to explore the optimal decision of the two variables respectively, i.e., the refund rate and the hassle cost.

Suppose that the cancellation probability θ follows uniform distribution over a unit interval, $\theta \sim U[0,1]$. Substituting $\hat{\theta} = \frac{v-p}{v-rp+h}$ into Equation (4), we have

$$\begin{aligned}\Pi &= \int_0^{\frac{v-p}{v-rp+h}} (p-w-\theta rp) f(\theta) d\theta \\ &= \frac{(p-v)\left(-2hp+p^2r-2pv+prv+2hw-2prw+2vw\right)}{2(h-pr+v)^2}\end{aligned} \tag{5}$$

Equation (5) is the specific representation of the retailer's expected profit, which is the integral of the profit function $G(\theta)$ over the range of acceptable cancellation probability $\left[0, \hat{\theta}\right]$. Given the values of the parameters v, p, w, the retailer's expected profit is determined by the decisions on the refund rate r and the hassle cost h. Next, we will carry on the optimization analysis to these two decisions respectively.

4.1. Refund over an arbitrary feasible hassle cost.

Lemma 4.1. *Given a hassle cost h, the optimal refund rate $r^* = \frac{(h+v)(3p-v-2w)}{p(p+v-2w)}$ that maximizes the expected profit Π, where $0 \le w < \frac{1}{2}(3p-v)$.*

Proof: For a given hassle cost, taking the first and second derivatives of the retailer's profit Π with respect to r,

$$\Pi_r = \frac{\partial \Pi}{\partial r} = \frac{p(p-v)[-(h+v)(3p-v-2w)+rp(p+v-2w)]}{2(h-pr+v)^3} \tag{6}$$

And

$$\Pi_{rr} = \frac{\partial^2 \Pi}{\partial r^2} = \frac{p^2(p-v)\big(p^2r+p(-4+r)v-2prw+2v(v+w)+2h(-2p+v+w)\big)}{(h-pr+v)^4} \tag{7}$$

Let r^* denote the optimal refund rate corresponding to a feasible hassle cost. When $\Pi_r(r^*)=0$, we obtain the profit-maximizing refund rate r^*,

$$r^* = \frac{(h+v)(3p-v-2w)}{p(p+v-2w)} \tag{8}$$

Substituting (8) into (7),

$$\Pi_{rr}\left(r^*\right) = -\frac{p^2(p+v-2w)^4}{16(p-v)^2(h+v)^3} < 0$$

As $r^* = \frac{(h+v)(3p-v-2w)}{p(p+v-2w)} \in (0,1]$, $\Pi_r\left(r^*\right)=0$ and $\Pi_{rr}\left(r^*\right)<0$, the expected profit $\Pi\left(r^*\right)$ is the maximum value. In addition, the fulfillment cost w satisfies $0 \le w < \frac{1}{2}(3p-v)$ since $r^* \in (0,1]$. □

Proposition 4.1. $\frac{dr^*}{dh} > 0$*, for all $r \in (0,1]$.*

Proof: According to Equation (8), the first deviation of r^* on h is $\frac{dr^*}{dh} = \frac{3p-v-2w}{p(p+v-2w)}$. It is easy to observe that $p(p+v-2w)>0$. From Lemma 4.1, we know that $3p-v-2w>0$. Therefore, $\frac{dr^*}{dh} = \frac{3p-v-2w}{p(p+v-2w)} > 0$, where $r \in (0,1]$. □

Proposition 4.1 indicates that r^* is increasing in h, which means that if the hassle cost is in a quite high level, consumers should be provided a high refund for their order cancellations.

Proposition 4.2. *The policy of partial refund with free hassle cost dominates that of full refund with high hassle cost.*

Proof: We perform comparative static analysis on two policies of full refund and free hassle as follows. Observe the two cases respectively.

Case 1. The policy that the retailer offers full refund for cancellations.

If $r^*_{full} = 1$, according to Equation (8), the default value of the hassle cost is,

$$h \geq H = \frac{(v-p)(v-p+2w)}{3p-v-2w} \tag{9}$$

Suppose H is the lower bound of the hassle cost. In this case, the retailer offers full refund to consumers, who would afford a quite high cancelling hassle of a minimum value H. Thus, substituting $(1, H)$ into (2) and (5), we can obtain the acceptable order cancellation probability $\hat{\theta}\left(r^*_{full}, H\right)$ and the expected profit $\Pi\left(r^*_{full}, H\right)$,

$$\hat{\theta}\left(r^*_{full}, H\right) = \frac{3p-v-2w}{2p}, \quad \Pi\left(r^*_{full}, H\right) = \frac{(3p-v-2w)(p+v-2w)}{8p} \tag{10}$$

Case 2. The policy that the retailer sets free hassle cost of cancelling.

When $h_{hassle\text{-}free} = 0$, then

$$r^*_{hassle\text{-}free} = \frac{v(3p-v-2w)}{p(p+v-2w)} \tag{11}$$

$$\because p(p+v-2w) - v(3p-v-2w) = (v-p)(v-p+2w) > 0$$

$$\therefore r^*_{hassle\text{-}free} = \frac{v(3p-v-2w)}{p(p+v-2w)} < 1$$

In this case, the retailer places no cancelling hassle cost to consumers, while offers partial refund for the cancellations due to the fact that the optimal refund rate is strictly a fraction. Thus, the acceptable cancellation probability $\hat{\theta}\left(r^*_{hassle\text{-}free}, 0\right)$ and the expected profit $\Pi\left(r^*_{hassle\text{-}free}, 0\right)$ are as follows,

$$\hat{\theta}\left(r^*_{hassle\text{-}free}, 0\right) = \frac{p+v-2w}{2v}, \quad \Pi\left(r^*_{hassle\text{-}free}, 0\right) = \frac{(p+v-2w)^2}{8v} \tag{12}$$

Subsequently, compare the results of the two cases above.

$$\Delta\hat{\theta} = \hat{\theta}\left(r^*_{full}, H\right) - \hat{\theta}\left(r^*_{hassle\text{-}free}, 0\right) = -\frac{(v-p)(v-p+2w)}{2pv} < 0$$

$$\Delta\Pi = \Pi\left(r^*_{full}, H\right) - \Pi\left(r^*_{hassle\text{-}free}, 0\right) = -\frac{(v-p)(v-p+2w)(p+v-2w)}{8pv} < 0$$

Therefore, $\hat{\theta}\left(r^*_{hassle\text{-}free}, 0\right) > \hat{\theta}\left(r^*_{full}, H\right)$ and $\Pi\left(r^*_{hassle\text{-}free}, 0\right) > \Pi\left(r^*_{full}, H\right)$.

Specifically, both the acceptable order cancellation probability and the expected profit on the policy $\left(r^*_{hassle\text{-}free}, 0\right)$ dominates those on $\left(r^*_{full}, H\right)$. □

4.2. **Hassle cost over an arbitrary feasible refund rate.** Now take Π in Equation (5) as a function of the variable h ($h \geq 0$) over an arbitrary refund rate. Hence, the first deviation of the expected profit Π on h is,

$$\Pi_h = \frac{\partial \Pi}{\partial h} = -\frac{(p-v)(-hp-pv+prv+hw-prw+vw)}{(h-pr+v)^3}$$

Let $\Pi_h = 0$, the optimal hassle cost of cancelling h^* is,

$$h^* = \frac{-pv+prv-prw+vw}{p-w} \tag{13}$$

Proposition 4.3. $\frac{dh^*}{dr} > 0$*, for all* $r \in \left[\frac{v(p-w)}{p(v-w)}, 1\right]$.

Proof: According to Equation (13),

a) Since $h^* \geq 0$, it is easy to observe $r \geq \frac{v(p-w)}{p(v-w)} > 0$. Therefore, $\frac{v(p-w)}{p(v-w)} \leq r \leq 1$.

b) As $v > p > w \geq 0$, the first deviation $\frac{dh^*}{dr} = \frac{p(v-w)}{p-w} > 0$. □

Proposition 4.3 indicates that h^* is increasing in r, which implies a homogeneity with Proposition 4.1 of high refund, high hassle cost, and vice versa.

Proposition 4.4. *The policy of free hassle cost with partial refund dominates that of high hassle cost with full refund.*

Proof: Similar to Proposition 4.2, comparative static analysis is performed as follows.

Case 3. The retailer promises to offer full refund for cancellations. Substituting $r'_{full} = 1$ in Equation (13), the hassle cost is

$$h \geq H' = \frac{w(v-p)}{p-w} \tag{14}$$

Let H' denote the lower bound of the hassle cost when full refund is provided. In this case, the acceptable order cancellation probability $\hat{\theta}\left(r'_{full}, H'\right)$ and the expected profit $\Pi\left(r'_{full}, H'\right)$ are,

$$\hat{\theta}\left(r'_{full}, H'\right) = 1 - \frac{w}{p}, \quad \Pi\left(r'_{full}, H'\right) = \frac{(p-w)^2}{2p} \tag{15}$$

Case 4. Suppose $h^* = 0$, the default refund rate should be,

$$r'_{hassle\text{-}free} = \frac{v(p-w)}{p(v-w)} \tag{16}$$

Under the situation that the fulfillment cost is considerable costly ($w \neq 0$), namely $w > 0$, we can see that $r'_{hassle\text{-}free} < 1$ according to Proposition 4.3, which implies a strict partial refund. In this case, the acceptable order cancellation probability $\hat{\theta}\left(r'_{hassle\text{-}free}, 0\right)$ and the expected profit $\Pi\left(r'_{hassle\text{-}free}, 0\right)$ are,

$$\hat{\theta}\left(r'_{hassle\text{-}free}, 0\right) = 1 - \frac{w}{v}, \quad \Pi\left(r'_{hassle\text{-}free}, 0\right) = -\frac{(v-w)(-p+w)}{2v} \tag{17}$$

Now compare the results of Case 3 and Case 4 above.

$$\Delta\hat{\theta}' = \hat{\theta}\left(r'_{full}, H'\right) - \hat{\theta}\left(r'_{hassle\text{-}free}, 0\right) = -\frac{(v-p)w}{pv} < 0$$

$$\Delta\Pi' = \Pi\left(r'_{full}, H'\right) - \Pi\left(r'_{hassle\text{-}free}, 0\right) = -\frac{(v-p)(p-w)w}{2pv} < 0$$

Consequently, $\hat{\theta}\left(r'_{hassle\text{-}free}, 0\right) > \hat{\theta}\left(r'_{full}, H'\right)$ and $\Pi\left(r'_{hassle\text{-}free}, 0\right) > \Pi\left(r'_{full}, H'\right)$. Both the acceptable order cancellation probability and the expected profit on the policy $\left(r'_{hassle\text{-}free}, 0\right)$ dominates those on $\left(r'_{full}, H'\right)$. □

Corollary 4.1. *Suppose $h^* = 0$, if $w = 0$, then $r'_{hassle\text{-}free} = 1$.*

Proof: The proof is shown in Equation (16). □

Corollary 4.1 demonstrates the context that the fulfillment cost is negligible, and then the policy of full refund without hassle cost is available. An example in practice is JD.COM, the largest B2B online retailer in China, who operates logistics in batches with substantial efficiency and economy of scale, and the fulfillment cost on each order is trivial. In such circumstance, the model proposed in this paper degenerates and covers the general online retail business.

As shown in Proposition 4.1 and Proposition 4.3, the refund rate and the hassle cost are positively correlated to each other. A high refund rate is always in accompany with a relative high hassle cost for consumers. The results of Proposition 4.2 and Proposition 4.4 respectively spot a consistent evidence that the profit advantage holds the policy of partial refund without cancellation hassles, rather than the policy of full refund with high hassle cost. The profit advantage lies in the enlarged service range of consumers associated with the raised acceptable range of order cancellation probability, as well as the extra revenue from the retained part of the price.

In summary, the theoretical results suggest that the retailer should offer partial refund to consumers, and eliminate hassles of cancelling (to simplify the cancelling process and conditions as much as possible), rather than promise full refund yet impose hassles (strict cancellation conditions) when consumers request for cancellations and refunds. Specially, when the order fulfillment cost is a trivial matter, for example, the retailer of conventional online retail business deliberately holds back orders for batch processing, a refund and cancellation policy of full refund and zero hassles should be adopted.

5. **Numerical Study.** To verify the theoretical results, we conduct numerical experiments with randomly generated data for explicit illustration. 30 samples (see Table 1) of uniformly distributed consumer cancellation probability are randomly generated in the interval $[0, 1]$.

Table 1. Sample data

Consumer #	OCP θ	Consumer #	OCP θ	Consumer #	OCP θ
1	0.049	11	0.399	21	0.642
2	0.093	12	0.431	22	0.649
3	0.132	13	0.456	23	0.665
4	0.143	14	0.465	24	0.665
5	0.221	15	0.480	25	0.714
6	0.282	16	0.503	26	0.736
7	0.304	17	0.547	27	0.742
8	0.343	18	0.559	28	0.929
9	0.381	19	0.625	29	0.932
10	0.391	20	0.630	30	0.993

OCP, Order Cancellation Probability.

5.1. **Implications.** Under the parameter settings based on online grocery retail business practices in China, we apply the proposed model and discuss the implications of the numerical results.

Based on the existing practices of online grocery retail business in China, the average sale is around CNY 100 per order, and the fulfillment cost is about CNY 10 per order. The consumer's valuation (willingness to pay) of the online purchase order must be higher than the sales price, assuming CNY 150. That is, in the context of online grocery retailing, the values of the parameters are set as $p = 100$, $w = 10$, and $v = 150$.

Now, Equations (9) to (12) above are applied to calculating the results of Case 1 and Case 2, to determine the optimal refund rate given an arbitrary feasible hassle cost, as shown in Table 2. The results of Case 1 exhibit that when the default value of h is 26.92, the consumer should be fully refunded. And in this situation, the range of consumers served by the retailer is those whose cancellation probability is below 0.65,

TABLE 2. Numerical results of Case 1 and Case 2

	r^*	h	$\hat{\theta}$	Π
Case 1	1.00	26.92	0.65	37.38
Case 2 △	0.85	0	0.77	44.08

The notation △ denotes the superior case (policy).

and the expected profit in this case is 37.38. Case 2 demonstrates that the optimal refund rate should be set to 0.85 when the hassle cost imposed on the consumer is zero, that is, the consumer can cancel the order freely but only be partially refunded at the refund rate 0.85 (a partial refund at 85% of the sales price) for the cancellation. In this situation, the retailer's optimal customer service range is below 0.77 with an expected profit of 44.08. Note that a larger value of h is an equivalence of complicated cancellation procedures and terms, which represents a strict cancellation policy; and zero hassle cost means consumers can cancel the previous orders freely, which represents a generous cancellation policy. Therefore, Case 1 comes up with a "full refund + strict cancellation" policy, while Case 2 with a "partial refund + generous cancellation" policy. Comparing the two cases under different policies, the latter is more advantageous for retailers.

Likewise, Equations (14) to (17) are applied to calculating the results of Case 3 and Case 4, to determine the optimal hassle cost over an arbitrary refund rate, as shown in Table 3. The results show that in Case 3, when the full refund is promised to the consumer, the hassle cost of 5.56 should be imposed on the consumer's cancellation of the order. In this situation, the retailer serves consumers whose cancellation probability is up to 0.9, and the expected profit is 40.5. And in Case 4, when the provided refund rate for consumers is 0.96 (a partial refund at 96% of the sales price), the hassle cost imposed on consumers is zero (free cancellation), where the retailer serves consumers whose cancellation probability is up to 0.93, and the expected profit is 42. Case 3 comes up with a "full refund + strict cancellation" policy, while Case 4 with a "partial refund + generous cancellation" policy. Also, the latter is more advantageous for the retailer.

TABLE 3. Numerical results of Case 3 and Case 4

	r	h^*	$\hat{\theta}$	Π
Case 3	1.00	5.56	0.90	40.50
Case 4 △	0.96	0	0.93	42.00

The notation △ denotes the superior case (policy).

Furthermore, according to Equation (1) and Equation (3), we calculate the expected customer utility $CU(\theta)$ under the four cases (shown in Appendix, Table A1). Consumers with positive expected utility will place orders. We refer to the proportion of consumers who make purchase as the participation rate. In Case 1, eight consumers will not place orders because they have negative expected utilities, and the participation rate is 73.3%. In Case 2 and Case 3, three consumers will not place orders, and the participation rate is 90%. In Case 4, only one consumer will not make purchase, and the participation rate is up to 96.7%. Combining with the results of Table 2 and Table 3, a larger cancellation probability range of the served consumers does not necessarily imply a higher profit. For the same service level with equal consumer participation rate, it is more effective to charge consumers a cancellation fee than to impose hassles of cancelling. The retailer determines the service range of consumers by adjusting the refund rate and the hassle cost.

The above results comprehensively reflect the following implications.

- The "partial refund + generous cancellation" policy is always superior to the "full refund + strict cancellation" policy. The former one not only leads to a larger service range (i.e., a larger target market), but also has a higher profit advantage.
- On condition that the retailer promises a full refund to consumers, the optimal hassle cost should be set to $h^* = 5.56$, as shown in Case 3. When the hassle cost is higher than 5.56, for example, the situation of Case 1, the revenue will continue to decline. This is because due to excessive cancellation hassles, consumers who were willing to purchase no longer place orders, and the retailer's target market is narrowed, resulting in the loss of some profitable consumers.
- Under the premise that the retailer permits consumers to cancel orders freely, consumers should be refunded at the optimal refund rate $r^* = 0.85$, as that in Case 2. Despite a higher refund rate increases the service range and enlarges the target market, as in Case 4, the retailer ultimately suffers a diminished profit. This is partly because of the direct revenue loss caused by more paybacks, and partly due to the loss of fulfillment costs on cancelled orders placed preciously by consumers who have relatively high cancellation probabilities.

5.2. **Sensitivity analysis.** We now examine the performance of the model under varying parameters, and explore the policy effects of cancellation and refund policies on various online business practices.

5.2.1. *Robustness on multiple settings of parameters.* Here, we examine the performance of the model on several different settings of parameters and show the robustness of our research results. Different from the parameter setting at the beginning, which represents the scenario of online grocery retailing, we present two other settings of parameters that represent the scenarios of mobile cab-hailing and online ordering of takeaways for instant delivery, two typical on-demand services with fulfillment cost in our daily life. For the first scenario (mobile cab-hailing), the consumers' valuation $v = 40$, the price for each order $p = 30$, and the fulfillment cost $w = 3$. For the second scenario (online ordering of takeaways for instant delivery), same price but the consumers' valuation and the fulfillment cost are relatively larger, which are $v = 60$, $p = 30$, and $w = 10$. The overall numerical results (see in Appendix, Table A2 and Table A3) are very encouraging, which draw the same conclusions as the previous parameter setting. The three scenarios all demonstrate the superiority of the "partial refund + generous cancellation" policy.

5.2.2. *Policy effects.* We examine the policy effects under varying parameters to generate managerial insights to practitioners. Here, we review the results of the superior policy under generous cancellation with partial refund, as listed in Table 4.

TABLE 4. Varying parameters under the superior policy

Context	v	p	w	r^*	h	$\hat{\theta}$	Π	Served consumers	Participation rate
I. Online grocery retailing	150	100	10	0.85	0	0.77	44.08	27	90%
II. Mobile cab-hailing	40	30	3	0.92	0	0.80	12.80	27	90%
III. Takeaways delivery	60	30	10	0.29	0	0.58	10.21	18	60%

We can see that the refund rate $r^* = 0.29$ and the acceptable cancellation probability $\hat{\theta} = 0.58$ in the third scenario are much lower than that in the other two scenarios. This reflects that the business with higher fulfillment cost on each order should set a lower threshold of acceptable cancellation probability and only offers consumers relatively low refund. This is also consistent with our intuitive understanding. Therefore, in practical businesses like online ordering of takeaways for instant delivery, the business operator should make best effort on delivery efficiency to capture more consumers at a relatively low cancellation likelihood.

In addition, for conventional e-commerce retail business whose order fulfillment cycle is usually a couple of days, the fulfillment cost on a single order is negligible due to the cost scale effect of order batch processing, so $w = 0$. In such a scenario, we can find that the optimal policy is generous cancellation with full refund, i.e., $r^* = 1$ and $h^* = 0$, as shown in Table 5. In other words, consumers are free to cancel their orders and get a full refund, which is in line with the case in practice. This indicates that the proposed model can degenerate into order cancellation problem of the conventional e-commerce retailing, which is a special case when the fulfillment cost is zero.

Table 5. Results under trivial fulfillment cost ($w = 0$)

Context	v	p	w	r^*	h^*	$\hat{\theta}$	Π	Served consumers	Participation rate
Business 1	150	100	0	1	0	1	50	30	100%
Business 2	40	30	0	1	0	1	15	30	100%
Business 3	60	30	0	1	0	1	15	30	100%

6. **Conclusions.** In the context of online grocery retailing, we study the problem of refundable order cancellations with order fulfillment cost and develop a revenue management model to explore refund and cancellation policies aiming at optimizing the retailer's revenue. In our model, we not only consider the refund for consumers, but also specially take the hassle cost of cancelling into account according to the observation of the business practice. Refund policies are respectively investigated in model specifications with uniform distribution of cancellation probabilities. The results show that retailers should diminish the hassle cost of cancelling and provide consumers with partial refund, which is equivalent to charging consumers a cancellation fee. The profit advantage of this partial refund policy is attributed to more purchase order placed by consumers who have relatively high cancellation probabilities, and the non-refundable portion retained by the retailer as the compensation for loss on the fulfillment cost. The model is developed in the context of online grocery retailing, but it can be extended to other on-demand service systems with very similar features.

This paper makes a preliminary study on the distinctive revenue management problem with fulfillment cost from a novel perspective. For analytical simplicity, we use uniform distribution in the current model specification, and find some meaningful results. Richer results are anticipated under more general formulations, which is our next important work. In this research, the optimized solutions are acquired by separate examinations on the twofold variables, the refund rate and the hassle cost of cancelling. We expect that there are still opportunities for improvement by making joint decisions. Due to the indefinite concavity of function structures, it is tentatively intractable to derive analytical joint optimal solution to the proposed model. The joint optimization approach is another recent research pursuit. In addition, incorporating consumers choice behavior of cancellations may be a useful extension. An underlying assumption of our model is that consumers have undifferentiated awareness and preferences. In practice, consumers might have different perceptions to refunds and hassles, and the fulfillment costs associated with early and late cancellations can be different. In such event, it is a promising research direction to develop time-dependent hierarchical refund and cancellation policy.

Acknowledgment. This work is supported by Science Fund for Creative Research Groups of National Natural Science Foundation of China (NSFC) (71421001) and the program of NSFC (71971040). We also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

REFERENCES

[1] J. E. Scott and C. H. Scott, Online grocery order fulfillment tradeoffs, *Proc. of the 41st Annual Hawaii International Conference on System Sciences*, Waikoloa, HI, 2008.
[2] G. E. Montague, The problem of "cancellation", in *Business Cycles and Unemployment*, Cambridge MA, National Bureau of Economic Research (NBER), Inc., 1923.
[3] Z. D. Qin, Chaos of fresh e-commerce, *Computer & Network*, vol.14, pp.9-11, 2019.
[4] iReserach Consulting Group, *Research Report of China's Fresh Food E-Commerce Industry*, 2019, https://www.iresearch.com.cn/Detail/report?id=3400&isfree=0, Accessed on 30 Jan 2020.
[5] J. Xie and E. Gerstner, Service escape: Profiting from customer cancellations, *Marketing Science*, vol.26, no.1, pp.18-30, 2007.
[6] F. Hoffmann, R. Inderst and S. Turlo, *Regulating Cancellation Rights with Consumer Experimentation*, http://dx.doi.org/10.2139/ssrn.3360918, 2018.
[7] R. Inderst and M. Ottaviani, Sales talk, cancellation terms and the role of consumer protection, *Review of Economic Studies*, vol.80, no.3, pp.1002-1026, 2013.
[8] L. Hsiao and Y. J. Chen, Returns policy and quality risk in e-business, *Production and Operations Management*, vol.21, no.3, pp.489-503, 2012.
[9] F. J. Röllecke, A. Huchzermeier and D. Schröder, Returning customers: The hidden strategic opportunity of returns management, *California Management Review*, vol.60, no.2, pp.176-203, 2018.
[10] E. Huyghe, J. Verstraeten, M. Geuens and A. Van Kerckhove, Clicks as a healthy alternative to bricks: How online grocery shopping reduces vice purchases, *Journal of Marketing Research*, vol.54, no.1, pp.1-13, 2017.
[11] E. Suel and J. W. Polak, Development of joint models for channel, store, and travel mode choice: Grocery shopping in London, *Transportation Research Part A: Policy and Practice*, vol.99, pp.147-162, 2017.
[12] B. He, X. Gan and K. Yuan, Entry of online presale of fresh produce: A competitive analysis, *European Journal of Operational Research*, vol.272, no.1, pp.339-351, 2019.
[13] E. Belavina, K. Girotra and A. Kabra, Online grocery retail: Revenue models and environmental impact, *Management Science*, vol.63, no.6, pp.1781-1799, 2017.
[14] J. Wollenburg, A. H. Hbner and H. Kuhn, *Conceptual Framework for Order Fulfillment and Delivery in Online Grocery Retailing*, https://doi.org/10.2139/ssrn.2497000, 2014.
[15] J. Acimovic and S. C. Graves, Making better fulfillment decisions on the fly in an online retail environment, *Manufacturing and Service Operations Management*, vol.17, no.1, pp.34-51, 2015.
[16] Y. Zhang, M. Huang, X. Hu and L. Sun, Package consolidation approach to the split-order fulfillment problem of online supermarkets, *Journal of the Operational Research Society*, vol.69, no.1, pp.127-141, 2018.
[17] S. El-Haber and M. El-Taha, Dynamic two-leg airline seat inventory control with overbooking, cancellations and no-shows, *Journal of Revenue and Pricing Management*, vol.3, no.2, pp.143-170, 2004.
[18] M. G. Yoon, H. Y. Lee and Y. S. Song, Dynamic pricing & capacity assignment problem with cancellation and mark-up policies in airlines, *Asia Pacific Management Review*, vol.22, no.2, pp.97-103, 2017.
[19] J. J. G. Dai, A. J. Kleywegt and Y. B. Xiao, Network revenue management with cancellations and no-shows, *Production and Operations Management*, vol.28, no.2, pp.292-318, 2019.
[20] Y. F. He, P. P. Wen, Y. Q. Lan and Z. W. Miao, Hotel cancellation strategies under online advanced booking, *2018 IEEE International Conference on Industrial Engineering and Engineering Management*, Bangkok, Thailand, pp.1632-1636, 2018.
[21] K. T. Talluri and G. J. Van Ryzin, *The Theory and Practice of Revenue Management*, Springer Science + Business Media, Inc., New York, 2004.
[22] K. A. An, *Dynamic Pricing with Early Cancellation and Resale*, Master Thesis, Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, 2003.

[23] M. L. Fang, *Dynamic Pricing in Continuous Time with Cancellation and Refund Policies*, Master Thesis, Department of Industrial and System Engineering, State University of New York at Buffalo, 2007.

[24] Z. Peng and Y. Xiong, Value uncertain in advance selling: The impact of offering refunds for cancellations, *Proc. of 2008 IEEE International Conference on Service Operations and Logistics, and Informatics (IEEE/SOLI 2008)*, pp.64-68, 2008.

[25] G. Gallego and Ö. Şahin, Revenue management with partially refundable fares, *Operations Research*, vol.58, no.4, pp.817-833, 2010.

[26] X. Zhao and Z. Pang, *Profiting from Demand Uncertainty: Pricing Strategies in Advance Selling*, http://dx.doi.org/10.2139/ssrn.1866765, 2011.

[27] L. F. Fan and X. Chen, Pricing policy in make to order firms with order cancellation, *Chinese Journal of Management*, vol.9, no.5, pp.729-734, 2012.

[28] Y. Li, Y. Sun, Y. Zhang and X. Hu, Online grocery retailing for fresh products with order cancellation and refund options, *Journal of Supply Chain and Operations Management*, vol.16, no.1, pp.1-16, 2018.

[29] G. Gallego and H. Topaloglu, *Revenue Management and Pricing Analytics*, Springer, New York, 2019.

[30] S. Ringbom and O. Shy, Advance booking, reservations and refunds, *Hanken School of Economics*, 2002.

[31] S. Ringbom and O. Shy, Advance booking, cancellations, and partial refunds, *Economics Bulletin*, vol.13, no.1, pp.1-7, 2004.

[32] Y. Wang, T. Li and W. Su, Research on the bi-level programming of underground logistics project based on public-private partnership mode, *ICIC Express Letters*, vol.13, no.6, pp.505-511, 2019.

[33] L. Guo, Service cancellation and competitive refund policy, *Marketing Science*, vol.28, no.5, pp.901-917, 2009.

Appendix.

TABLE A1. Numerical results I

$v = 150$, $p = 100$, $w = 10$				
Case	Case 1	Case 2 △	Case 3	Case 4 △
Policy	r^* h $\hat{\theta}$ Π 1 26.92 0.65 37.38	r^* h $\hat{\theta}$ Π 0.85 0 0.77 44.08	r h^* $\hat{\theta}$ Π 1 5.56 0.90 40.50	r h^* $\hat{\theta}$ Π 0.96 0 0.93 42.00
θ	$CU(\theta)$	$CU(\theta)$	$CU(\theta)$	$CU(\theta)$
0.049	46.24	46.81	47.28	47.38
0.093	42.85	43.94	44.84	45.02
0.132	39.81	41.36	42.64	42.91
0.143	39.00	40.67	42.05	42.34
0.221	32.99	35.58	37.71	38.15
0.282	28.32	31.62	34.35	34.90
0.304	26.62	30.18	33.12	33.72
0.343	23.65	27.66	30.97	31.65
0.381	20.68	25.14	28.82	29.58
0.391	19.94	24.51	28.29	29.07
0.399	19.31	23.98	27.84	28.63
0.431	16.87	21.91	26.07	26.93
0.456	14.93	20.27	24.67	25.58
0.465	14.25	19.69	24.18	25.10
0.480	13.07	18.69	23.33	24.28
0.503	11.32	17.21	22.06	23.06
0.547	7.94	14.34	19.62	20.71
0.559	7.02	13.56	18.96	20.07
0.625	1.92	9.24	15.28	16.52
0.630	1.55	8.93	15.01	16.26
0.642	0.58	8.10	14.31	15.58
0.649	0.08	7.68	13.95	15.24
0.665	−1.14	6.65	13.07	14.39
0.665	−1.17	6.62	13.05	14.37
0.714	−4.96	3.40	10.31	11.72
0.736	−6.63	1.99	9.10	10.56
0.742	−7.09	1.60	8.77	10.24
0.929	−21.43	−10.56	−1.59	0.25
0.932	−21.69	−10.78	−1.78	0.07
0.993	−26.42	−14.79	−5.19	−3.22

r, θ, and $\hat{\theta}$ are ratio or probability calculated in decimals; v, p, w, h, Π, and $CU(\theta)$ are measured in monetary unit CNY. The notation denotes the superior case (policy).

TABLE A2. Numerical results II

$v = 40$, $p = 30$, $w = 3$																
Case	Case 1				Case 2 △				Case 3				Case 4 △			
Policy	r^*	h	$\hat{\theta}$	Π	r^*	h	$\hat{\theta}$	Π	r	h^*	$\hat{\theta}$	Π	r	h^*	$\hat{\theta}$	Π
	1	3.64	0.73	11.73	0.92	0	0.80	12.80	1	1.11	0.90	12.15	0.97	0	0.93	12.49
θ	$CU(\theta)$				$CU(\theta)$				$CU(\theta)$				$CU(\theta)$			
0.049	9.33				9.39				9.46				9.47			
0.093	8.73				8.84				8.97				9.00			
0.132	8.19				8.34				8.53				8.57			
0.143	8.05				8.21				8.41				8.45			
0.221	6.98				7.24				7.54				7.61			
0.282	6.16				6.48				6.87				6.95			
0.304	5.86				6.20				6.62				6.71			
0.343	5.33				5.72				6.19				6.30			
0.381	4.80				5.23				5.76				5.88			
0.391	4.67				5.12				5.66				5.78			
0.399	4.56				5.01				5.57				5.69			
0.431	4.13				4.62				5.21				5.34			
0.456	3.78				4.30				4.93				5.07			
0.465	3.66				4.19				4.84				4.98			
0.480	3.45				4.00				4.67				4.81			
0.503	3.14				3.71				4.41				4.56			
0.547	2.54				3.16				3.92				4.09			
0.559	2.38				3.02				3.79				3.96			
0.625	1.48				2.19				3.06				3.24			
0.630	1.41				2.13				3.00				3.19			
0.642	1.24				1.97				2.86				3.05			
0.649	1.15				1.89				2.79				2.98			
0.665	0.94				1.69				2.61				2.81			
0.665	0.93				1.69				2.61				2.81			
0.714	0.26				1.07				2.06				2.28			
0.736	−0.04				0.80				1.82				2.04			
0.742	−0.12				0.72				1.75				1.98			
0.929	−2.66				−1.61				−0.32				−0.04			
0.932	−2.71				−1.65				−0.36				−0.08			
0.993	−3.55				−2.42				−1.04				−0.74			

r, θ, and $\hat{\theta}$ are ratio or probability calculated in decimals; v, p, w, h, Π, and $CU(\theta)$ are measured in monetary unit CNY. The notation denotes the superior case (policy).

TABLE A3. Numerical results III

$v = 60$, $p = 30$, $w = 10$				
Case	Case 1	Case 2 △	Case 3	Case 4 △
Policy	r^* h $\hat{\theta}$ Π 1 150 0.17 2.92	r^* h $\hat{\theta}$ Π 0.29 0 0.58 10.21	r h^* $\hat{\theta}$ Π 1 15 0.67 6.67	r h^* $\hat{\theta}$ Π 0.80 0 0.83 8.33
θ	$CU(\theta)$	$CU(\theta)$	$CU(\theta)$	$CU(\theta)$
0.049	21.19	27.48	27.80	28.24
0.093	13.27	25.22	25.82	26.65
0.132	6.16	23.19	24.04	25.23
0.143	4.26	22.64	23.56	24.85
0.221	−9.81	18.63	20.05	22.04
0.282	−20.72	15.51	17.32	19.86
0.304	−24.70	14.37	16.33	19.06
0.343	−31.66	12.38	14.59	17.67
0.381	−38.62	10.39	12.85	16.28
0.391	−40.34	9.90	12.42	15.93
0.399	−41.81	9.48	12.05	15.64
0.431	−47.53	7.85	10.62	14.49
0.456	−52.06	6.55	9.48	13.59
0.465	−53.66	6.10	9.09	13.27
0.480	−56.42	5.31	8.39	12.72
0.503	−60.51	4.14	7.37	11.90
0.547	−68.42	1.88	5.39	10.32
0.559	−70.56	1.27	4.86	9.89
0.625	−82.50	−2.14	1.87	7.50
0.630	−83.36	−2.39	1.66	7.33
0.642	−85.64	−3.04	1.09	6.87
0.649	−86.81	−3.37	0.80	6.64
0.665	−89.66	−4.19	0.09	6.07
0.665	−89.73	−4.21	0.07	6.05
0.714	−98.61	−6.75	−2.15	4.28
0.736	−102.51	−7.86	−3.13	3.50
0.742	−103.59	−8.17	−3.40	3.28
0.929	−137.15	−17.76	−11.79	−3.43
0.932	−137.77	−17.93	−11.94	−3.55
0.993	−148.83	−21.09	−14.71	−5.77

r, θ, and $\hat{\theta}$ are ratio or probability calculated in decimals; v, p, w, h, Π, and $CU(\theta)$ are measured in monetary unit CNY. The notation denotes the superior case (policy).