Analysis of Uncertainty Influence on an E-tailer with a Threshold Policy and Alternative E-fulfillment Options

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Abstract: - Drop shipping is very popular on the Internet. E-tailers use this service to fulfill customer demand. This study analyzes a supply chain consisting of a supplier and an e-tailer. The e-tailer uses a private inventory and drop shipping option for e-fulfillment, whereas the supplier provides replenishing and drop shipping service with limited capability for the e-tailer. The e-tailer selects a threshold policy in the private inventory and provides two different priorities to customer demand, namely, high priority demand and low priority demand. This paper designs a general framework to obtain the optimal threshold of the private inventory for the e-tailer to achieve his average profit maximization. We also analyze the impact of different uncertainties and proportion variability of high priority demand on the optimal threshold in different scenarios through Monte Carlo simulation. The results can provide a significant guideline for the e-tailers who adopt drop shipping as an alternative e-fulfillment option, especially when they face complex operating environments.

Key-Words: - Uncertainty, Threshold Policy, E-fulfillment, Lead Time, Drop Shipping, Inventory, Alternative

1 Introduction

China's E-commerce Report (2012) predicted that Chinese e-commerce will continue to grow rapidly in the next 5 to 10 years [1]. The largest advantage of e-commerce is that the exchanges of information, capital, and ownership are rapid and efficient. On the one hand, e-commerce has become more prosperous in China and provides convenience to people. On the other hand, e-commerce activities are only completely finished after physical goods have been delivered to customers through logistics. Therefore, logistics is the foundation of e-commerce, which directly affects its development. The growth rate of Chinese e-commerce in recent years is approximately 200% to 300%, whereas the growth rate of logistics is only approximately 40%. Logistics grow rapidly, but it cannot meet the requirements of e-commerce. Logistics has been the "bottleneck" of Chinese e-commerce, especially during holidays when many logistics companies experience the "warehouse explosion" phenomenon [2].

Threshold policy is the approach to apply an inventory rationing strategy to the inventory system. The concept of inventory rationing comes from revenue management theory. The main idea of inventory rationing is to retain a certain amount of inventory to meet expected demand from high margin customers. Revenue management theory has received considerable attention from the field of service operations, which includes hotel, car rental, and airline businesses [3, 4, 5]. These services should be sold within a limited time because they suffer from the natural ease of corrosion or limited time. Inventory rationing strategy has also been used in durable goods, such as consumer electronics goods, CDs, and books [6, 7, 8]. Inventory decisions with drop shipping in e-commerce are similar to the traditional supply chain [9, 10, 11]. Such as Chiu (2007) [12] considered the optimal lot-size problem for an EMQ model which had constrained backlog level and designed different situations to examine this optimal policy, Chiu et al. (2008) [13] analyzed the optimal run time for an EMQ model with more constraint in operational parameters and derived the optimal replenishment policy to minimizes the overall costs, Cheng et al. (2010) [14] considered a machine breakdown factor and examined the optimal replenishment policy for an imperfect EPQ model based on Chiu's work (2003) [15]. Drop shipping has previously been used by catalog

companies in marketing and achieved much success after expanding to e-commerce. The advantage of drop shipping is clear, it helps the e-tailer avoid a large investment on an inventory system and bear little inventory risk [16]. Drop shipping brings more customers and increases the sales volume of the supplier [17]. For example, eBags uses drop shipping to sell bags of more than 200 brands and 12,000 product types, but it has almost zero inventory. The e-tailers of Taobao, eBay, and Amazon also use drop shipping to fulfill customer demand [18].

This study is motivated by a real problem in e-commerce. An e-tailer adopts drop shipping as an alternative option to ensure the stability of e-fulfillment. He uses a mixture of the private inventory and drop shipping to meet customer demand. The e-tailer also uses a threshold policy to service two different types of customer demand. The e-tailer obtains different margins from the two types of customer demand with different e-fulfillment options. The margin from fulfilling high priority demand with the same product is higher than low priority demand, whereas the margin from satisfying the same customer demand by drop shipping is lower than private inventory. The two types of customer demand have different influences on the e-tailer after analyzing the e-tailer's operating environment, and the uncertainties of customer demand and lead time affect the e-tailer's threshold policy and inventory operation.

We outline the e-tailer's operation process as follows based on the analysis of the e-tailer who uses both a threshold policy and alternative e-fulfillment options on the Internet. If the inventory position of the private inventory is above the threshold value, then both types of customer demand are met. When the inventory position reaches or becomes less than the threshold value, only the high priority demand is fulfilled by the private inventory, whereas the low priority demand is satisfied by drop shipping. If the private inventory runs out of stock, then the e-tailer uses drop shipping to meet all customer demand. Researchers analyzed several scenarios of an e-tailer adopting the threshold policy in e-commerce. For example, Aganso et al. (2006) [7] studied an e-tailer in a B2C mode that used a threshold-based inventory rationing strategy to improve his profit. The e-tailer used the drop shipping option for e-fulfillment by selling books, CDs, and other durable goods. Liu and Wang (2008) [18] modeled a maximized

revenue problem of an e-tailer who chose a private inventory and drop shipping to fulfill orders. This e-tailer selected a threshold-based inventory rationing strategy between high and low priority demands. They analyzed the impacts of system parameters on the e-tailer and compared the optimal costs with and without an inventory rationing strategy and found that the threshold-based inventory rationing strategy had clear cost-saving effects.

The remainder of this paper is organized as follows. Section 2 outlines the whole process of deriving the optimal threshold of the e-tailer in details, which includes the introduction of notations and parameters in our model, the operation process of the e-tailer and the general framework to obtain the optimal threshold for the e-tailer. Section 3 presents a numerical analysis to illustrate results of the proportion of high priority demand, uncertainties of customer demand and lead time impacts on the optimal threshold and inventory system. Finally, Section 4 presents our conclusion and discusses future possible extensions.

2 Model Formulation

The e-tailer runs the Economic Order Quantity inventory system and uses the (R, Q) policy to replenish products from the supplier. When the private inventory stock is insufficient to fulfill all customer demand, the e-tailer sends drop shipping requests to the supplier who will deliver goods to the remaining customers directly with a limited drop shipping ability.

2.1 Notations and Parameters

The notations and parameters in our model are shown in Table 1.

2.2 Hybrid scheduling method with mixed e-fulfillment options

Figure 1 shows that in every scheduling unit, the operation process of the e-tailer who uses a threshold policy and alternative e-fulfillment options to fulfill customer demand consists of six stages.

Stage 1: The customers shopping on the Internet and the e-tailer obtains the total customer demand D_t at the beginning of t.

Stage 2: The e-tailer verifies the priority of customer demand and sends two classes of demand

Table 1: Notations and parameters

t	Scheduling unit, which can be viewed as a minute, an hour, a day, or longer. $t \in T, nt = T, n = 1, 2, \mathrm{L}, N.$, where T is the total scheduling period, and N is the maximum number of units in T.
i	Classes of customer demand, $i \in I = \{1, 2\}$, where $i = 1$ represents high priority demand and $i = 2$ represents low priority demand.
D_t	Total customer demand per scheduling unit t, which includes two classes of customer demand and a nonnegative random variable with mean $E[D_t]$ and variance $V[D_t]$.
$D_{t,i}$	Demand of class i per t.
hp	Proportion of high priority demand.
$D_{t,i}^{inv}$	Demand of class i fulfilled by the private inventory per t.
$D_{t,i}^{ds}$	Demand of class i sent to the supplier by the e-tailer for drop shipping per t.
$D_{t,i}^{ds*}$	Demand of class i which is fulfilled by drop shipping per t.
$d_{t,i}^{ds}$	Demand of class i that is backordered by the supplier per t and causes penalty costs.
pc_i	Penalty cost per unit demand of class i and $pc_1 > pc_2$.
$sl_{t,i}$	Service level of the supplier's drop shipping for the class i demand per t and $sl_{t,1} \geq sl_{t,2}$.
mar_i^{inv}	Unit margin from fulfilling the class i demand by the private inventory and $mar_1^{inv} > mar_2^{inv}$.
mar_i^{ds}	Unit margin from satisfying the class i demand by drop shipping, $mar_1^{ds} > mar_2^{ds}$, and

	$mar_i^{inv} > mar_i^{ds}, i \in I = \{1, 2\}$.
L_t	Replenishment lead time is a nonnegative random variable with mean $E[L_t]$ and variance $V[L_t]$.
R	Stock reorder point.
h	Holding cost per unit stock per time.
k	Ordering cost per replenishment.
Q	Order lot size.
P_t	Inventory position per t.
X_t	On hand stock per t.
O_t	Units on order per t.
fa_t	Flag of arriving an order per t. If an order arrives in t, then $fa_t = 1$. Otherwise, $fa_t = 0$ represents no orders.
fp_t	Label of placing an order per t. If the e-tailer places an order in t, then $fp_t = 1$. Otherwise, $fp_t = 0$ represents no orders.
C	Threshold value.

to the private inventory. D_t is divided into two different classes. $D_{t,i}, i \in \{1, 2\}$ is based on the delivery time requested by customers. $D_{t,1}$ is the demand that requests for a short delivery time, and the e-tailer sets a higher price for this demand type. The e-tailer obtains more margin from $D_{t,1}$, whose orders may be delivered by air. This demand type is denoted as the high priority demand. $D_{t,1} = hp \times D_t$. $D_{t,2}$ is the other type of demand, whose products can be shipped by vehicles. This demand type is denoted as the low priority demand and $D_{t,2} = (1 - hp) \times D_t$.
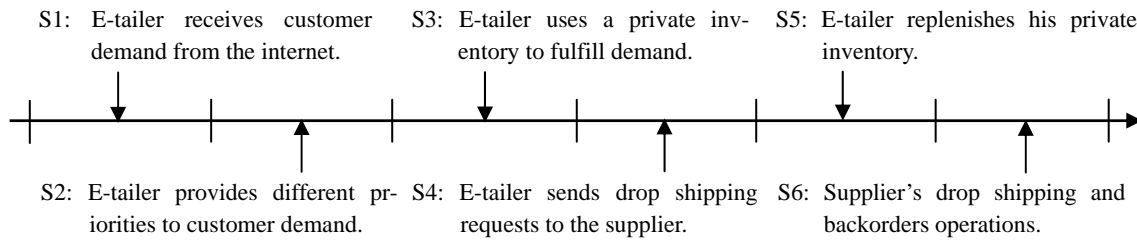
S1: E-tailer receives customer demand from the internet.

S3: E-tailer uses a private inventory to fulfill demand.

S5: E-tailer replenishes his private inventory.

S2: E-tailer provides different priorities to customer demand.

S4: E-tailer sends drop shipping requests to the supplier.

S6: Supplier's drop shipping and backorders operations.

Fig.1: Operation processes of the e-tailer with a mixture strategy

Stage 3: The e-tailer uses the private inventory to fulfill two demand types and delivers products to customers based on the threshold policy and different priorities of customer demand. The main operation of this stage is to compute $D_{t,i}^{inv}$, $i \in \{1, 2\}$. Based on e-fulfillment rules of the e-tailer, the high priority demand should be satisfied first if the private inventory has enough stocks. If X_t is insufficient to fulfill all the high priority demand, the stock left in the private inventory will all be used to fulfill high priority demand. The remaining demand will be sent to the supplier for drop shipping. If the stocks are sufficient, then all of the high priority demand will be satisfied by the private inventory. The high priority demand fulfilled by the private inventory is as Equation (1).

$$D_{t,1}^{inv} = (D_{t,1} \wedge X_t). \qquad (1)$$

Where $Z = (X \wedge Y)$ shows that Z is the minimum of X and Y. If some stocks remain after fulfilling the high priority demand, then the remaining stock in the private inventory will be used to satisfy the low priority demand when X_t is above the threshold value C. If the stock is sufficient, all of the low priority demand will be fulfilled by the private inventory. By contrast, if the stock is insufficient, some of the low priority demand can be satisfied by the private inventory. The remainder of the low priority demand will be sent to

the supplier for drop shipping. If X_t reaches or becomes less than the threshold value C at the beginning of t, then the private inventory stock will be reserved for the high priority demand in the future. All of the low priority demand will be sent to the supplier for drop shipping, thus the low priority demand fulfilled by the private inventory is zero. The low priority demand satisfied by the private inventory is shown in Equation (2).

$$D_{t,2}^{inv} = \begin{cases} [D_{t,2} \wedge (X_t - D_{t,1}^{inv})^+], & X_t > C \\ 0, & X_t \leq C \end{cases}. \qquad (2)$$

Where $Z = (X - Y)^+$ shows that Z is the maximum of $X - Y$ and 0.

Stage 4: After using private inventory to fulfill two types of customer demand, the e-tailer sends the remaining demand to the supplier for drop shipping. The remaining customer demand can be computed by Equation (3).

$$D_{t,i}^{ds} = D_{t,i} - D_{t,i}^{inv}, \quad i \in \{1, 2\}. \qquad (3)$$

Stage 5: If P_t is below R at the end of t, then the e-tailer has to replenish orders from the supplier and places an order of Q. Equations (4), (5), (6) and (7) are calculated to obtain P_t, X_t, R, and Q as follows:

$$P_t = X_t - \sum_{i=1}^{2} D_{t,i}^{inv}, \quad i \in \{1, 2\}. \qquad (4)$$

$$X_t = P_{t-1} + fa_t \times Q. \tag{5}$$

$fa_t = 1$ shows that an order arrives in t and the order lot size is Q in Equation (5). Otherwise, $fa_t = 0$ represents zero orders.

$$R = E[D_L] + \gamma \times \delta(D_L). \tag{6}$$

where $\quad E[D_L] = E[D_t] \times E[L_t]. \quad$ and

$$\delta(D_L) = \sqrt{\sum_{i=1}^{2} E[L_t] \times V[D_{t,i}] + [E[D_{t,i}]]^2 \times V[L_t]}. \; \gamma$$

is a safety factor [7] in Equation (6).

$$Q = \sqrt{\frac{2k \times E[D_L]}{h}}. \tag{7}$$

Stage 6: Given that the drop shipping capability of the supplier is limited, the e-tailer bears the risk of backorders. The two types of customer demand that are backordered are shown in Equation (8). We assume that the backorders in $t-1$ will be filled in t. The two types of customer demand that are fulfilled by the supplier with drop shipping are computed in Equation (9).

$$d_{t,i}^{ds} = [1 - sl_{t,i}] \times D_{t,i}^{ds}, \quad i \in \{1, 2\}. \tag{8}$$

$$D_{t,i}^{ds*} = \begin{cases} sl_{t,i} \times D_{t,i}^{ds} & 0 < t < 2 \\ sl_{t,i} \times D_{t,i}^{ds} + d_{t-1,i}^{ds} & t \geq 2 \end{cases}. \tag{9}$$

After six stages of the scheduling operations of the e-tailer, we obtain the profit function of the e-tailer in t as shown in Equation (10).

$$\pi_t = \sum_{i=1}^{2} mar_i^{inv} \times D_{t,i}^{inv} + \sum_{i=1}^{2} mar_i^{ds} \times D_{t,i}^{ds*} -$$

$$h \times X_t - \sum_{i=1}^{2} pc_i \times d_{t,i}^{ds} - k \times fp_t. \tag{10}$$

Equation (10) has five parts, The first part, $\sum_{i=1}^{2} mar_i^{inv} \times D_{t,i}^{inv}$, is the margin of fulfilling customer demand with the private inventory. The second part, $\sum_{i=1}^{2} mar_i^{ds} \times D_{t,i}^{ds*}$, is the profit of satisfying customer demand with the supplier's drop shipping. The third part, $h \times X_t$, is the holding cost. The fourth part, $\sum_{i=1}^{2} pc_i \times d_{t,i}^{ds}$, is the penalty cost caused by unfilled demand in drop shipping. The last part is the replenishment cost. Equation (10) shows that the profit function of the e-tailer in t is organized by summing all of the profit from selling products to customer demand minus the holding, penalty and replenishment costs.

2.3 General framework to obtain the optimal threshold.

Based on the six stages of the e-tailer's e-fulfillment operation in Section 2.2, the searching process of the optimal threshold can be derived by the exhaustion method under uncertainties of customer demand and lead time (Figure 2).

First, we initialize the searching operation environment, which includes setting values to the total number of t, the length of warming up period, the number of experiments, hp, h, k, mar_i^{inv}, mar_i^{ds}, $sl_{t,i}$ and $pc_{t,i}$, $i \in \{1, 2\}$, setting zero to P_t, X_t, fa_t, fp_t, π_t, $D_{t,i}$, $D_{t,i}^{inv}$, $D_{t,i}^{ds}$, P_t, $D_{t,i}^{ds*}$ and $d_{t,i}^{ds}$, $i \in \{1, 2\}$, and selecting the distribution functions for D_t and L. We then examine all values in interval $[1, R]$ with the exhaustion method after selecting

one value as threshold. The e-tailer begins to satisfy customer demand with the threshold policy and two different e-fulfilment options. The simulation process of the e-tailer is based on the six stages in t, which includes computing $D_{t,i}$, $D_{t,i}^{inv}$, $D_{t,i}^{ds}$, P_t, $D_{t,i}^{ds*}$, $d_{t,i}^{ds}$ and replenishing operation. We then acquire the e-tailer's profits for the current threshold in t and turn to the next scheduling unit $t+1$. After the e-tailer processes all scheduling units, we then obtain his average profits for the current threshold. Finally, we can obtain the maximum average profit and optimal threshold after examining all integers in the interval $[1, R]$.
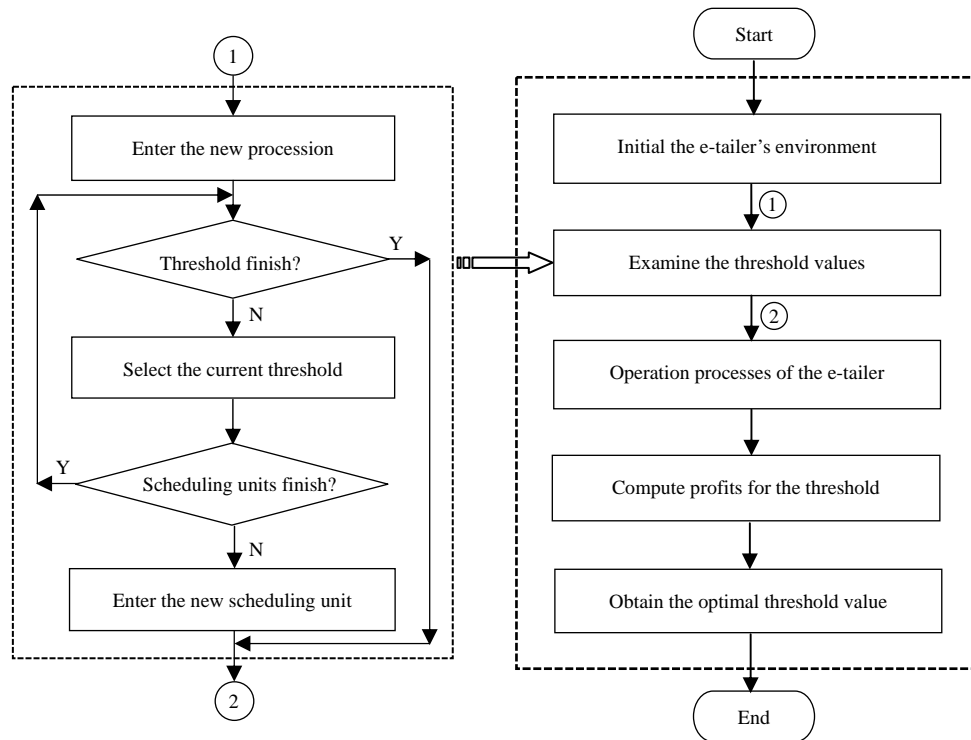
Fig.2: General framework to obtain the optimal threshold value

3 Simulation Analysis

The computer used in the simulation experiments is an HP 6530s (CPU: Intel Core 2 Duo T5670 1.8 GHz, RAM: 2G, HDD: 320G) with the simulation software Matlab R2008a. Approximately 1200 scheduling units were set, whose top 10% of the total units acted as the training data. The lead time is generated by the uniform distribution of 300 units, whose top 10% was also treated as the training data. Customer demand and lead time were randomly generated based on their distribution functions. Every simulation cycle ran 100 times.

We analyzed the impacts of customer demand uncertainty, the variability of the proportion of high priority demand and lead time uncertainty on threshold policy, maximum average profit, and inventory operation in this section. The inventory operation variables contain the order times, average inventory position, R, Q, and inventory cycle. We use the same values of six parameters in [7] because we have the similar operational environment, which are $mar_1^{inv} = \$16$, $mar_2^{inv} = \$7$, $mar_1^{ds} = \$5$, $mar_2^{ds} = \$3$, $h = \$0.2$ and $k = \$1000$. We assume that customer demand and lead time follow uniform distribution, $E[D_t]$ and $E[L_t]$ are

constants, but the corresponding $CV[D_t]$ and $CV[L_t]$ are dynamically changing at this point.

3.1 Impact of customer demand uncertainty

$CV[D_t]$ changes, whereas customer demand expectation remains the same. $E[D_t] = 1000$, and the coefficients of variation $CV[D_t] \in [0, 0.6]$; the proportion of high priority demand is 0.3; the distribution function of lead time is $U(8,12)$, and $E[L_t] = 10$. If customer demand is lower than before, then more products will be left in the private inventory and the inventory holding cost will increase. The private inventory may be out of stock when facing a sudden increase in customer demand. The e-tailer can no longer earn more profits. The impacts of customer demand uncertainty on maximum average profit, the optimal threshold, order times, average inventory position, inventory cycle, stock reorder point and order lot size are shown in Figure 3, Figure 4 and Figure 5, respectively.
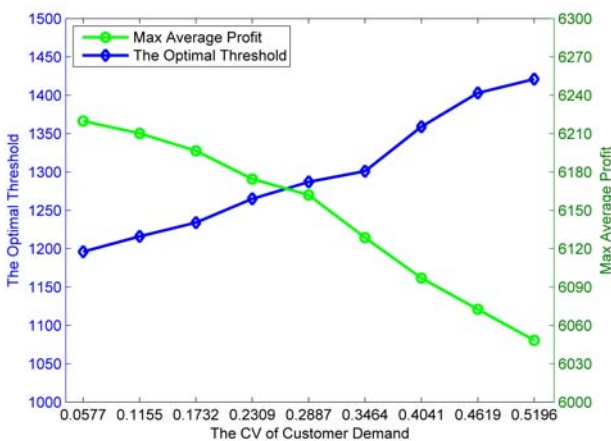
Fig.3: Effect of customer demand uncertainty on max average profit and the optimal threshold

Figure 3 shows that the optimal threshold of the private inventory increases with the increasing

$CV[D_t]$, whereas the maximum average profit gradually decreases. Thus, the increase in the customer demand uncertainty has a negative effect on the profit level of the e-tailer. The e-tailer should adjust the threshold value to a higher level in response to the customer demand uncertainty of this condition. A higher threshold value level requests more goods to be stored in the private inventory, which will cause more inventory holding costs for the e-tailer. The e-tailer should devote his appropriate attentions and efforts in maintaining a stable customer groups in actual operations to decrease the adverse effect of customer demand uncertainty. This condition is the reason many commercial activities provide more privileges for old customers. The e-tailer should focus more on repeat customers.
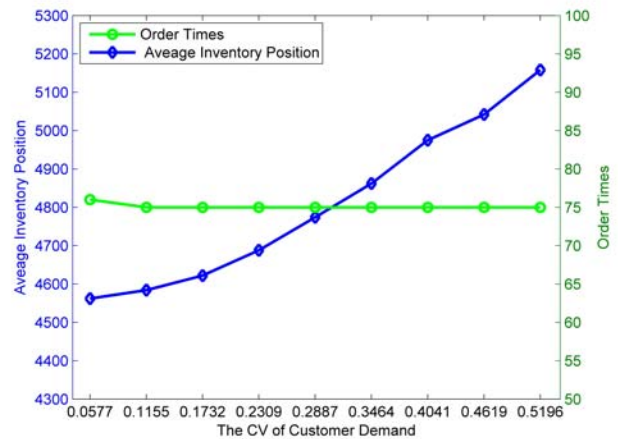

Fig.4: Effect of customer demand uncertainty on order times and average inventory position

The average inventory position increases with the increasing uncertainty of customer demand, but it does not have any effect on the order times (Figure 4). The e-tailer should improve the threshold value of his private inventory to achieve more profit. A Higher threshold value level means that the private inventory should retain more stock for the high priority demand in the future. The average inventory position will then become higher. This phenomenon is consistent with the results shown in Figure 3. When the customer demand uncertainty has clear changes, the e-tailer should arrange human, material, and financial resources in the inventory holding

operations to secure the private inventory. The e-tailer ensures the normal operations of the private inventory in this scenario to decrease the adverse effect caused by the rising inventory position.
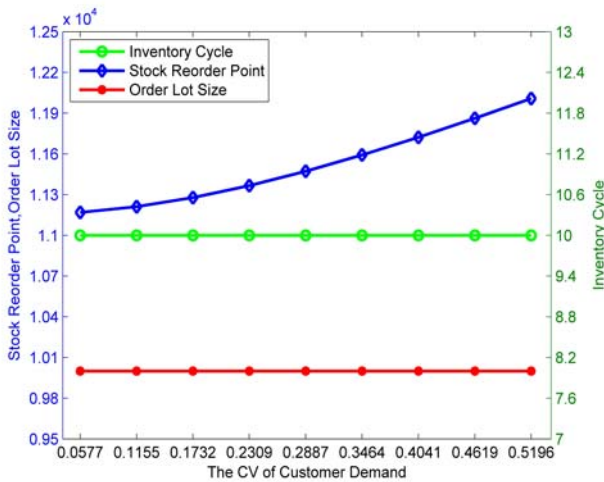

Fig.5: Effect of customer demand uncertainty on inventory cycle, stock reorder point and order lot size

Figure 5 shows that the stock reorder point depicts a rising trend along with the increasing of customer demand uncertainty, but few changes are observed in the order lot size and inventory cycle. The rising stock reorder point will cause more goods to remain in the private inventory and average inventory position to rise. These results are similar to those in Figure 3. Improving the average inventory position in actual operation forces the e-tailer to prioritize the inventory operation and maintain the current state of the ordering process. By summing up the above paragraphs, we can obtain proposition 1 as follows:

Proposition 1: When the expectation of customer demand is constant with the increase or decrease in $CV[D_t]$, the optimal threshold, average inventory position and stock reorder point also exhibit an increasing or decreasing trend. However, the trend of the maximum average profit displays the opposite trend. This change also has little effect on the order times, order lot size, and inventory cycle.

3.2 Impact of the variability of the proportion of high priority demand

The e-tailer faces two types of customer demand and obtains different margins from the two e-fulfillment options with the same unit of stock. Thus, changes in the two types of customer demand have an important influence on the e-tailer. When the quantity of customer demand remains unchanged, the increasing high priority demand means that the low priority demand is being reduced and vice versa. We choose $U(800,1200)$ and $U(8,12)$ as the distribution functions of customer demand and lead time in this section. When the proportion of high priority demand rises from 0.1 to 0.9, we analyze the effect of the proportion variability of the high priority demand on the e-tailer. The impacts on these operational parameters of the e-tailer are shown in Figure 6, Figure 7 and Figure 8.
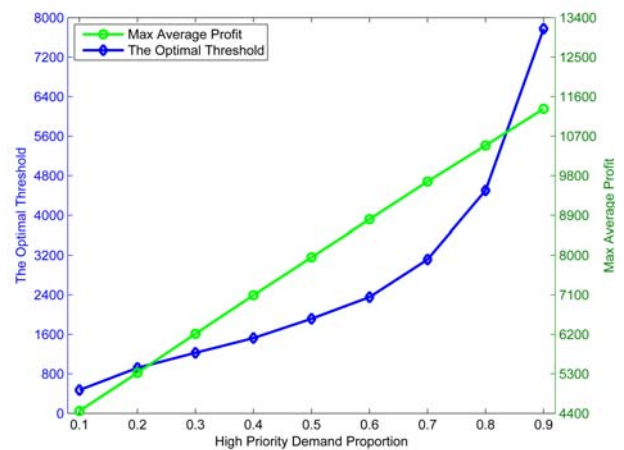

Fig.6: Effect of hp variability on max average profit and the optimal threshold

Figure 6 shows that with the increasing proportion of high priority demand, the optimal threshold and maximum average profit also rise gradually. The objective of the threshold policy is to maintain stock for the expected high priority demand to enable the e-tailer to improve the threshold value when the high priority demand increases. The maximum average profit also increases because the e-tailer obtains a higher margin from fulfilling the high priority demand using the private inventory than

the low priority demand with the same unit of product. This result is valuable to the e-tailer. For example, when the debt crisis adversely affects the global economy, the unemployment rate in many countries is high, and the salary level of workers decreases. This situation means that the proportion of high priority demand is less than before, so the e-tailer obtains less profit with a higher threshold value. Given that reserving more stocks cannot expect more high priority demand in the future and inventory holding costs will increase, the optimal threshold should be set to a low level in this condition. Conversely, when the world economy is recovering and developing, the employment rate and income level rise, as well as the proportion of high priority demand increases. Thus, the threshold value can be reset to a high level.
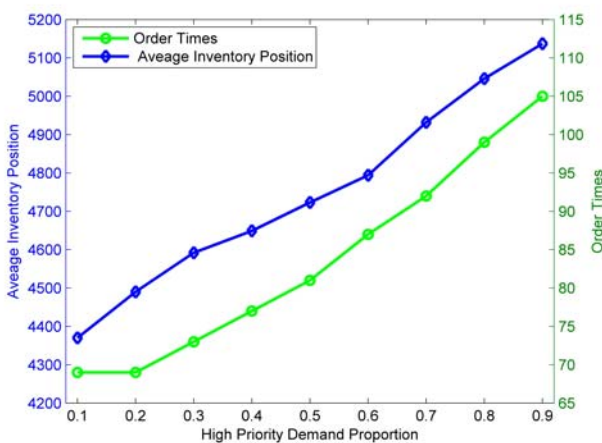

Fig.7: Effect of *hp* variability on order times and average inventory position

Given the customer demand and lead time, both average inventory position and order times show a growth trend with the increasing proportion of high profit demand (Figure 7). Figure 6 shows the e-tailer will improve the optimal threshold when the proportion of high priority demand increases. Thus, the e-tailer requires more stock reserved in the private inventory and more order times for replenishment. With the increasing order times, the amount of products stored in the private inventory also increases, so the average inventory position has an upward trend. The e-tailer should focus on inventory ordering and stock operation when social

wages are rising because more high priority demand is expected in e-commerce.

Figure 8 shows that the proportion variability of high priority demand has little impact on the stock reorder point, order lot size, and inventory cycle when customer demand and lead time are provided. The increase or decrease of the proportion of high priority demand has little effect on the e-tailer's inventory operation. Thus, the e-tailer should mainly focus on other aspects and arrange few additional resources to these inventory operations.
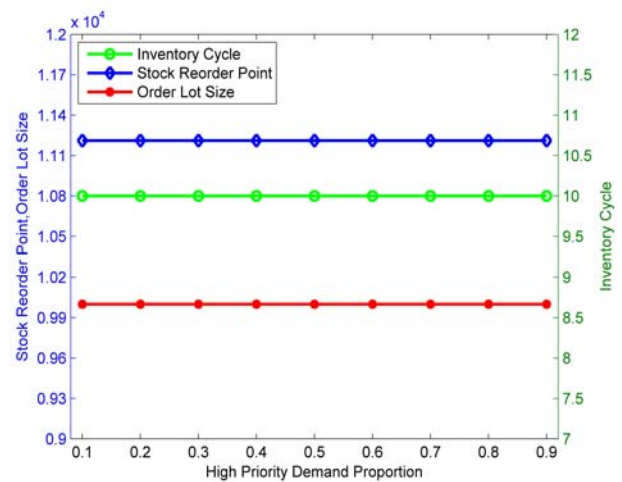

Fig.8: Effect of *hp* variability on inventory cycle, stock reorder point and order lot size

Proposition 2: With the increase or decrease in the proportion of high priority demand, the optimal threshold, maximum average profit, average inventory position, and order times increase or decrease. However, this change has little impact on the stock reorder point, order lot size, and inventory cycle.

3.3 Impact of lead time uncertainty

Lead time has a direct impact on the private inventory of the e-tailer. When lead time is shortened, more stocks will be left in the private inventory and the inventory holding cost will increase. If lead time is lengthened, then the inventory position drops and the private inventory will not have enough stock to fulfill all customer demand.

The distribution function of customer demand at this point is $U(800,1200)$, the proportion of high

priority demand is 0.3, the lead time follows a uniform distribution with $E[L_t] = 10$, and the coefficients of variation are $CV[L_t] \in [0, 0.6]$. The impacts of lead time uncertainty on the environment variables of the e-tailer are shown in Figure 9, Figure 10 and Figure 11.
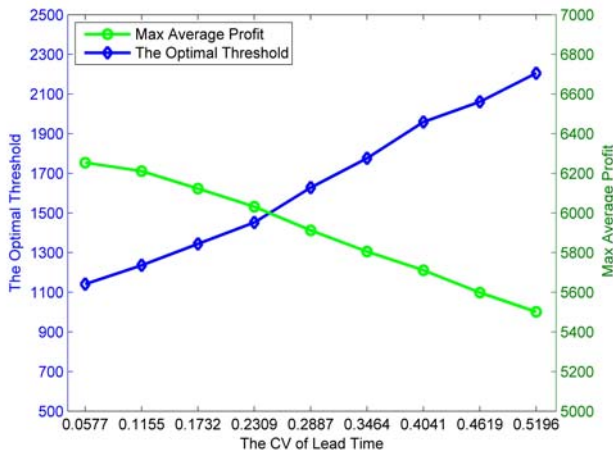

Fig.9: Effect of lead time uncertainty on max average profit and the optimal threshold

Figure 9 shows that the lead time uncertainty has a negative impact on the maximum average profit of the e-tailer. With $CV[L_t]$ increasing from 0.0577 to 0.5196, the maximum average profit decreases gradually, whereas the e-tailer needs to improve the threshold value to maximize his profit. This situation shows that the changes in lead time directly influence the quantity of the on hand stock. The increase in $CV[L_t]$ indicates that lead time changes with a larger fluctuation. If the larger fluctuation is in the increasing direction of the lead time, then the private inventory has inadequate goods to fulfill customer demand and results in depleted stocks when the lead time becomes too long. If the lead time lengthens and the stocks run out, then the e-tailer obtains a minimum profit. Given that the e-tailer earns a lower margin for fulfilling the low priority demand by drop shipping rather than his private inventory, all customer demand is satisfied by drop shipping. Conversely, if the lead time suddenly becomes too

short, it results in more stocks remaining in the private inventory. The inventory holding cost increases, so the e-tailer's profit decreases. Based on the above analysis, a significant inverse relationship is observed between $CV[L_t]$ and the e-tailer's profit. Thus, the e-tailer must strive to maintain lead time stability to obtain the minimum $CV[L_t]$ in a real environment.

Figure 10 shows that the average inventory position of the private inventory rises gradually with the increase in the lead time uncertainty. The order times remain unchanged after declining slightly in the initial stage. The e-tailer should focus more on maintaining the inventory than the ordering process when the lead time uncertainty increases.
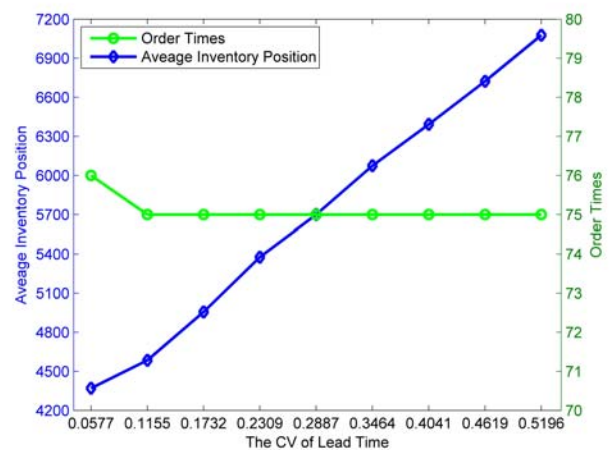

Fig.10: Effect of lead time uncertainty on order times and average inventory position

The stock reorder point of the private inventory shows a growth trend with the increasing $CV[L_t]$. However, it has little influence on the order lot size and inventory cycle. The above results are shown in Figure 11. The e-tailer in this case should improve the stock reorder point and consider nothing for the order lot size and inventory cycle. The average inventory position will also become higher with the rising stock reorder point, which is consistent with the results in Figure 9 and Figure 10. The e-tailer should then focus more on the inventory holding process.
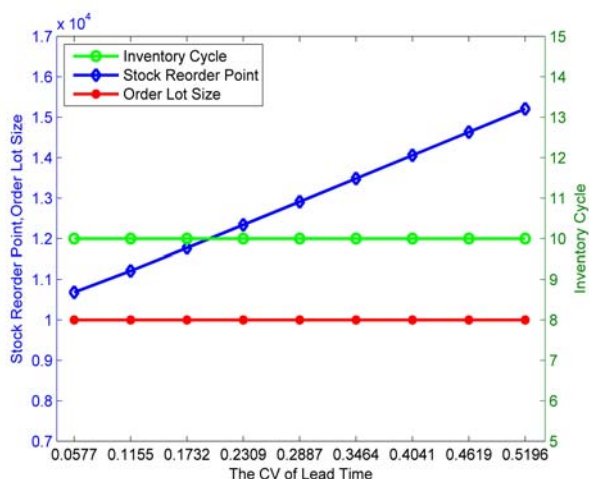
Fig.11: Effect of lead time uncertainty on inventory cycle, stock reorder point and order lot size

Proposition 3: When $CV[L_t]$ increases or decreases and its mean value remains constant, the optimal threshold, average inventory position, and stock reorder point will increase or decrease while the maximum average profit decreases. The order times, order lot size, and inventory cycle remains unchanged under these changes in lead time.

support and basis to make tactical decisions in e-commerce. These conclusions are particularly helpful to e-tailers with limited resources facing complex uncertainty environment, who should allocate resources between acquiring customers and operating private inventories.

This study has some extensions. First, deriving the mathematical model to acquire the analytical formula of the optimal threshold is valuable. Second, using real data of the customer demand and lead time in our model, the results of the optimal threshold and maximum average profit are more useful to the e-tailer. More complex scenarios exist in practical application, such as the rising customer demand and its $CV[D_t]$, decreasing lead time and its $CV[L_t]$, and changing the customer demand or lead time and its $CV[D_t]$ or $CV[L_t]$ with different directions. The analysis of these scenarios is also important for the e-tailers' e-fulfillment in e-commerce.

4 Conclusion

Chinese e-commerce will continue to flourish in 5 to 10 years given its trading volume of more than ￥8 trillion in 2012 [1]. The rapid development of e-commerce brings more opportunities and challenges to logistics, and more e-tailers strive to fulfill customer demand because e-fulfillment is important. Thus, more e-tailers use drop shipping as an alternative e-fulfillment option besides private inventory. We examine the threshold policy under the high priority demand variability, customer demand and lead time uncertainties; design the general framework to obtain the optimal threshold for the e-tailer to maximize his profit; and analyze the influence of customer demand and lead time uncertainties on the optimal threshold and average maximum profit based on the mixed e-fulfillment strategy. Finally, we obtain some beneficial conclusions in our simulation that provide the e-tailer, supplier, and middle administrative staff with

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