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# Study on inventory and transportation integrated optimization of online shopping supply chains based on shared-savings contracts

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**Abstract.** Inventory and transportation integrated optimization can help to reduce the logistics costs and improve the logistics efficiency, and realize the optimal benefit of the whole online shopping supply chain. The members of the online shopping supply chain tend to carry out the joint optimization of inventory and transportation and have a long-term cooperation with others. The shared savings contracts can form an effective intrinsic motivation mechanism, which can encourage the online shop and the logistics service providers to work together to save the logistics costs. Based on e-commerce supply chain as the research object, this paper design a sharing contract and build a joint optimization model of inventory and transportation. We prove that inventory and transportation dynamic joint optimization can make the supply chain collaboration effectively and achieve the maximum profits under this sharing contract.

**Key words.** Shared-Savings contract, online shopping supply chain, inventory and transportation, joint optimization.

## 1. Introduction

With the rapid development of e-commerce, online shopping has become an important channel on people's daily consumption, which plays an important role in stimulating domestic demand and promoting economic growth. According to the

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*2015 annual China e-commerce market data monitoring report* (hereinafter referred to as the *report*), the transactions size of China online retail market reaches RMB 38285 billion in 2015 which increases 35.7 percent; the transactions size of China online retail market accounts for 12.7 percent of the total retail sales of social consumer goods in 2015 which increases 2.1 percent, compared with 10.6 percent in the first half of 2014;In 2015, the users of China online shopping are 460 million, which have an increase of 21 percent. *Report* also shows that the revenue of express delivery in China reaches RMB 276 billion which increases 35 percent, but it increases slower in 2015 compared with 2014. In conclusion, the profits of express industry declined while the development speed of online shopping accelerated.

In the online shopping link, the costs of inventory and transportation are the main components of the total costs, accounting for more than 80 percent. So it not only has important theoretical value to implement a dynamic joint optimization between inventory and transportation, but also has a great practical significance to find the optimal solution. In this paper, we study on inventory and transportation integrated optimization of online shopping supply chain based on shared-savings contracts. On the basis of the inventory and transportation joint optimization, online retailers and expresses sign a shared savings contract. The contract is that the expresses share sales revenue of online retailers according to a certain proportion after reducing the offer of unit product logistics service, which encourage both sides in a concerted effort to reduce the logistics cost, and increase the profits.

Foreign scholars have made some research on the Inventory and transportation integrated optimization. Herron studied and pointed out the importance of the joint optimization of inventory and transportation, and the economic benefits brought by the joint optimization[1]. Federgruen and Zipkin described the problem by introducing the model into the joint optimization of inventory and transportation[2]. Burns and Hall used the analytical method to study the inventory and transportation problem of certain demand[3]. Liu and Chen studied the influence of integrated optimization of inventory and transportation by pricing strategy under the case of supply chain management[4]. Leandro et al. studied the integration of inventory and transportation under the condition of vendor managed inventory, transfer and direct delivery[5]. In China, the research on the joint optimization of inventory and transportation started late and had less achievement. Liu studied the two level non-integrated supply chains of a single retailer and a single supplier, and pointed out that the profits of the supply chain increases when the retailer assumes a part of the transportation costs[6]. Liu and Xie studied the integration of inventory and transportation in the vendor managed inventory model[7]. Liu studied three types of inventory and transportation optimization model, and introduced the fuzzy simulation and ant colony algorithm and solved it[8]. Tang constructed a rolling planning period of inventory and transportation integrated optimization model based on a specific supply chain logistics network, and proved that the model is a NPC problem[9]. Xu constructed a VIM-TLP inventory and transportation integration model based on the fixed partition strategy and the whole period strategy, and made a research on how to make a strategy between the inventory and transportation in the model of VIM-TLP[10]. Li pointed out that information sharing is good for the development of inventory transportation optimal strategy, and enhances the competitiveness of the whole supply chain system. He further pointed out that under the shared savings contracts, the optimal profit of inventory and transportation integrated optimization is greater than the decentralized decision model's optimal profit.Scholars have conducted a lot of researches on joint optimization of inventory and transportation, but they did not introduce the online shopping supply chain and the shared Savings Contract. In modern society, the problem that online retailer supplier and express delivery can't collaborate effectively is more and more outstanding. So this paper makes a research on the joint optimization of inventory transportation based on the shared savings contract, and explores the online shopping supply chain of the participating parties to have an effective cooperation mechanism and facilitate ITIO joint optimization of online retailers and express.

## 2. Assumptions and conditions of the model

**Hypothesis 1:** The online shopping supply chain is made up of an online retailer and an express, the express provides logistics services for an online retailer. They both are completely rational, and the risk appetite is neutral.

**Hypothesis 2:** The online retailer has the right to decide the price, and can provide products according to market demand. There is a functional relationship between the market demand D for online retailer and the price $P$and the effort level $x$of express delivery:$D(P,x) = a - bP + Lx$.And the coefficients need to satisfy that:$a$, $b$and$L > 0$;$p \geq 0$;$0 < x < 1$, where$P$and$x$are the decision variables,$L$ is a sensitivity coefficient of market demand to effort level $x$ of express delivery.

**Hypothesis 3:** Express's inventory is zero and has the dominant position in the supply chain. Suppliers are always able to provide the proper amount of goods to the online retailer at the same price. Namely the situation of shortage does not exist and the online retailer and express completely know the information of demand.

**Hypothesis 4:** The unit purchasing cost and service cost of online retailer are$C_{L1}C_{L2}$. The cost of unit product logistics services that the express provides for online retailer is$C_K$, and quotes $p_K$ to online retailer. Express charge by piece, and its effort cost function is $G(x) = \delta x^2$,$C_{L1}C_{L2}$??$C_K$and$p_K$are all constants and greater than zero, where$p_K \geq C_K$.

**Hypothesis 5:** In order to save the transportation costs, express and online retailer make the level of effort respectively are$e_K, e_L$, where$0 \leq e_K, e_L \leq 1$.Both sides work together to save the cost of transportation are$\Delta c_K(e_K, e_L)$. Moreover, as a result of efforts, the costs of express delivery and online retailer are required to pay$C_K(e_K)$, $C_L(e_L)$ respectively.

Online retailer and express can maximize their profits when they make decisions respectively. Joint optimization can make the whole supply chain achieve profit maximization. To motivate online retailer and express work together to save logistics costs, we can sign such a contract which the express share sales revenue of online retailer according to a certain proportion after reducing the offer of unit product logistics service.

# 3. Study on the model of inventory and transportation integrated optimization of online shopping supply chains based on shared-savings contracts

## 3.1. *Analysis on the benefit of joint optimization of inventory and transportation*

Joint optimization of inventory and transportation ($ITIO$) refers to a situation that online retailer and express jointly consider inventory costs and transportation costs to achieve overall profit maximization. Joint optimization of inventory and transportation is an effective means of supply chain integration, which can effectively solve the "Trade off" phenomenon of online retailers and express benefits, and improve the competitiveness and efficiency of the whole supply chain.

The total profit function of the online shopping supply chain when $ITIO$ is as follows:

$$\pi(P,x) = PD(P,x) - (C_{L1} + C_{L2} + C_K)D(P,x) - G(x) \tag{1}$$

The upper formula is simplified and can be expressed as:

$$\pi(P,x) = (P - r_2)(a - bP + Lx) - \delta x^2 \tag{2}$$

Where $r_2 = C_{L1} + C_{L2} + C_K$. In order to maximize the overall profits of ITIO, we need to find the solution of formula (2), which need to meet $\frac{\partial \pi(P,x)}{\partial P} = 0 \frac{\partial \pi(P,x)}{\partial x} = 0 AC - B^2 > 0 A < 0$ where$A = \frac{\partial^2 \pi(P,x)}{\partial P^2}, C = \frac{\partial^2 \pi(P,x)}{\partial x^2}, B = \frac{\partial^2 \pi(P,x)}{\partial P \partial x}$. Solving the first order partial derivative of P??x in this formula and make it be zero, the solution is as follows:

$$x_2 = \frac{(a - br_2)L}{4\delta b - L^2} \tag{3}$$

$$P_2 = \frac{2\delta(a - br_2)}{4b\delta - L^2} + r_2 \tag{4}$$

Where$A = 2b > 0, C = 2\varepsilon > 0, B = -L/2b < 0$, namely$AC - B^2 > 0$,We know that the optimal solution is significant when the supply chain gets the maximum profits. Here we note $\pi_{ITIO}$as the maximum profits for the joint optimization of inventory and transportation. Taking the solution value of Px into the formula (**??**), $\pi_{ITIO}$can be obtained as:

$$\pi_{ITIO} = \frac{\left(8b\delta^2 - \delta L^2\right)(a - br_2)^2}{(4b\delta - L^2)^2} \tag{5}$$

In$ITIO$, from the above formula we know that the greater the$r_2$, the less the supply chain profit under the joint optimization. That is, the higher cost of online retailer and express, the lower the overall profit;$\delta$ grow faster than the growth rate of $\pi_{ITIO}$ , namely the growth rate of the cost of the express to pay is faster than the profit of the supply chain to get; The greater the $L$, the greater the $\pi_{ITIO}$.It shows that the greater the degree of efforts of express , the greater demand for online retailer, and thus lead to greater profits of $ITIO$.

### 3.2. The income distribution model of each decision subject under the shared Savings Contract

*3.2.1. Shared Savings Contract* As the express pursues the maximization of its own interests, the unit product logistics service price will be higher than the cost of logistics, which will lead to an increase in the marginal cost of the unit product of online retailer and thus making a loss of the best overall profits. In order to solve this problem, express and online retailer can reach an agreement to apply the savings contract theory to the $ITIO$ by signing such a contract which the express share sales revenue of online retailer according to a certain proportion after reducing the offer of unit product logistics service. The transfer payment of online retailer pay to express can be expressed as: $T(C_{CF}, p_K, \theta) = C_{CF} + p_K Q + (1-\theta) pQ$, where$C_{CF}$shows that the fixed part of service fee that the online retailer pay to express will not change with the number of transport products, and$C_{CF} \geq 0$. Assuming $C_{LF}$means the cost of express pay for getting fixed income$C_{CF}$, it does not change with the number of transport products and$C_{CF} \geq C_{LF} \geq 0$;$1-\theta$is the proportion that the express share the revenue of online retail sale. If$\theta = 0$, online retailer will transfers all its incomes to express. Obviously, this is a contradiction with the assumption that online retailer is rational; If$\theta \neq 0$, online retailer will obtain all the incomes, and then express will don't have the intrinsic motivation to reduce the quotation of unit product logistics service. So, it should be satisfied with$0 < \theta < 1$.

Then, the profit function of express, online retailer and the whole supply chain are respectively as follows:

$$\pi_K(p_K, e_K, e_L) = C_{CF} + [p_K - c_K + (1-\theta)\Delta c_K(e_K, e_L)]Q - C_{LF} - C_K(e_K) \quad (6)$$

$$\pi_L(\mathrm{p}, e_K, e_L) = [p - c_{L1} - p_K + \theta \Delta c_K(e_K, e_L)]Q - C_{CF} - C_L(e_L) \quad (7)$$

$$\pi_T(\mathrm{p}, e_K, e_L) = [p - c_{L1} - c_K + \Delta c_K(e_K, e_L)]Q - C_{LF} - C_L(e_L) - C_K(e_K) \quad (8)$$

Among them, the formula (6),(7) indicate the profit function of two sides after shared saving. The formula (8) indicates the profit function of the whole supply chain after shared sharing.

*3.2.2. The nature of the shared Savings Contract* As we can know according to assumes that online retailer has price decision-making power. With implementing the joint optimization of inventory and transportation, the degree of efforts of express and online retailer are expressed as$e^*_{KT} e^*_{LT}$, and $e^*_K \in [0, e^*_{KT}), e^*_L \in [0, e^*_{LT})$.

Here we prove that the necessary conditions of formula (8) have the optimal solution in the range on $e_K \in [0,1]$when online retailer has the price decision right is as follow:

$$\left(\partial \Delta c_K(e^*_{KT}, e^*_{LT}) / \partial e^*_{KT}\right) Q = dC_K / d(e^*_{KT}) \quad (9)$$

Supposing that $dC_K/d(e_K^*) = dC_K/d(e_{KT}^*)$, the $C_K(e_K)$ is a monotonically increasing concave function on $e_K \in [0,1]$,which can be derived as $e_K^* = e_{KT}^*$,and the $\Delta c_K(e_K, e_L)$ is a monotonically increasing convex function, which can be derived as $\left(\partial\Delta c_K(e_K^*, e_L^*)/\partial e_K^*\right) = \left(\partial\Delta c_K(e_{KT}^*, e_{LT}^*)/\partial e_{KT}^*\right)$. Assuming that at , we can conclude that $(1-\theta)\left(\partial\Delta c_K(e_K^*, e_L^*)/\partial e_K^*\right)Q = \left(\partial\Delta c_K(e_{KT}^*, e_{LT}^*)/\partial e_{KT}^*\right)Q$. According to $D(P,x) = a - bP + Lx$ we can know that if $P$ and $x$are changeless, the $Q$ is the same, then $\theta = 1$can be deduced, which is contradictory to $0 < \theta < 1$, so $e_K^* \neq e_{KT}^*$ can be concluded. It is easy to know that formula(8) is the convex function in the interval of$e_K \in [0,1]$, and can get the maximum value at $e_K^* = e_{KT}^*$. By the nature of formula (8) on the interval of $e_K \in [0,1]$, where $e_K^1 \in [0e_{KT}^*]e_K^2 \in [e_{KT}^*1]$, making $\pi_T e_K^1 = \pi_T e_K^2$ set up. And because the express is rational, its efforts will be in the range of $[0e_{KT}^*]$. According to $e_K^* \neq e_{KT}^*$, we can conclude $e_K^* = [0e_{KT}^*]$.

The above analysis show that under the constraint of the shared savings contract, if the online retailer's product prices are constant, the optimal efforts of express and online retailer in the inventory and transportation integrated optimization is better than that under the general pattern.

## 4. Conclusions

In this paper, we build a model of the joint optimization of inventory and transportation at first, and find the maximum total profit of the supply chain system; Then, a joint optimization model of inventory and transportation based on the shared savings contract is established to encourage both parties to work together to save the logistics costs so that increasing the profits of online retailer and express delivery. We analysis the nature of shared savings contract, and find that participation's profits increasing when the shared savings contract allows online retailer and express to share the increase of revenue which is from the transportation costs saving. This shows that the shared savings contract can make the parties involved which can benefit from the transportation cost saving, and effectively improve the performance of the whole supply chain system of inventory and transportation integrated optimization. It can effectively solve the problem of *trade off* in the joint optimization of inventory and transportation, making online retailer cooperate with express to reduce transport costs and inventory costs, so that both sides are willing to adopt inventory and transportation joint optimization strategy. Therefore, based on the shared savings contract, through implementing the joint optimization of inventory and transportation, the supply chain parties can fully and effectively have a cooperation to achieve a win-win situation.

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