ORDER ALLOCATION MODEL IN LOGISTICS SERVICE SUPPLY CHAIN WITH DEMAND UPDATING AND INEQUITY AVERSION: A PERSPECTIVE OF TWO OPTION CONTRACTS COMPARISON

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Abstract. This paper considers an logistics service supply chain consisting of a logistics service integrator (LSI) and a number of functional logistics service providers (FLSPs). In the environment of demand updating, we focus on the inequity aversion among the FLSPs and introduce two option contracts (the reservation option contract and the option guarantee contract), build the multi-objective programming models, to explore effects of the inequity aversion behavior on the order allocation, and whether the two option contracts can mitigate the impact of inequity aversion on order allocation. Three important conclusions are obtained after two option contracts comparisons: first, there is an optimal update time, at which point, the order allocation results reach the optimal value and tend to be stable. Second, two option contracts both can not only increase the total performance of the supply chain, but also mitigate the impact of inequity aversion on the allocation under certain conditions. Third, when demand decreases, the reservation option contract is better than option guarantee contract, in contrast, when demand increases, option guarantee contract is better.

1. Introduction. In recent years, with the rapid development of China’s e-commerce industry, logistics service integrator (LSI) began to integrate the multiple functional logistics service providers (FLSPs), to provide customers with integrated logistics services [24]. LSI and FLSPs form the logistics service supply chain. In practice, the LSI assigns logistics service orders obtained from customer to FLSPs, and then requires FLSPs to provide the corresponding logistics service capacity to complete the logistics services. For example, Tianjin YTO Express, as the North China branch of China YTO Express, integrates 42 FLSPs in Tianjin area [27]. These FLSPs provide services such as warehousing and transportation to help Tianjin YTO Express complete the customer’s logistics service demand.
In the logistics supply chain management, the order allocation of LSI is one of the key decisions in supply chain management, how the LSI organizes order allocation is important to ensure the long-term stable operation of the logistics service supply chain [7, 24]. At the practical level, there are two concerns when making the order allocation decisions. On the one hand, fairness concerns will impact the decision-making in order allocation, the FLSPs will have the unfair feelings when their profits are lower than their competitors’ [23], which is also common in practice. For example, during the period of November 11, 2015, three FLSPs of Tianjin YTO express company announced to withdraw from the cooperation because they felt unfair to the order allocation results, which brought huge losses to Tianjin YTO express company and end customers [22]. Some other LSIs, China’s P.G. Logistic, and Tianjin port, also pay high attentions to the issue of horizontal fairness of order allocation, and encourages their FLSPs to compete fiercely to provide high-quality services.

On the other hand, demand uncertainty caused by demand updating brings a few risks to the order allocation, which leads to the decrease of FLSP’s satisfaction and the dissatisfaction of customer demand [26]. In practice, many companies adopt the option contract to respond to the adverse impact of demand updating. For example, Beijing Changjiu Logistics Co., Ltd integrates more than 200 FLSPs, which can schedule more than 20,000 vehicles, its customer demand has been fluctuating significantly since 2013. However, some FLSPs did not want to increase their investment in transport vehicles for the reason that the demand fluctuations are accompanied by risks. In response, the Changjiu Logistics Company set up a German international leasing company in January 2014, it provided option contracts to these FLSPs before the actual logistics service demand occurred, reserving part of the capacities in advance can ensure that the updated demand be met. The introduction of this option contract was approved by the FLSPs. Since October 2015, more than 100 FLSPs have reached a cooperation agreement.

As aforementioned, it is a common way to sign option agreements among the members of the supply chain. In addition, there is another option called option derivatives, which is widely applied to reduce the demand uncertainty of agricultural products, and bulk goods. Extensive articles used option derivative contract to solve the problem of price fluctuation and demand fluctuation caused by weather [29]. Logistics service is also perishable and constantly updated, in practice, in order to make a reasonable option contract, many insurance companies engaged in transport insurance business, they often cooperate with the transport companies to understand the transportation risk and transportation needs for different routes. For example, in order to reduce the freight risk, Kunming fanbang logistics co. LTD cooperates with the PICC (people’s insurance company of China), and CPIC (China Pacific insurance) to sign the insurance contract terms, which stipulate the corresponding standards of compensation for the shortage, and the compensation is undertaken by insurance company. Therefore, we also introduce the option guarantee contract.

From the perspective of theoretical research, many articles have studied order allocation, the topics include the mathematical models [37, 31, 9], the order allocation algorithm [12, 38, 28], and the coordination mechanism of order allocation [32, 15]. However, there are two shortcomings in the research progress of supply chain order allocation. On the one hand, most articles focus more on the modeling and algorithm of order allocation and less on the introduction of the contractual
approach in the model. On the other hand, the existing studies rarely consider the demand-updated environment and the inequity aversion of FLSPs at the same time. At present, only [26] has considered the combination of the two factors, and found that demand updating and FLSP’s behavior would affect the results of order allocation, but no reasonable solution mechanism was proposed. Therefore, we take [26] as the case of no option contract to discuss the influence of option contract on the inequity aversion behavior of FLSPs.

According to the practical cases and exiting studies, option contracts have been introduced to solve the problem of supply chain cooperation and risk of demand updating in the manufacturing supply chain [18, 45, 30]. However, there is a gap in the literature related to whether the option contract mechanism can solve the problem of order allocation better in the case of demand updating? Especially whether the option contract can mitigate the impact of inequity aversion behavior of the FLSPs on supply chain order allocation performance? If there are different effects of different types of option contracts? To answer these questions, we conduct the research based on demand updating and FLSP’s inequity aversion, and introduce two common option contracts in the order allocation model. The first is reserve option contract, the second is option guarantee contract. We build multi-objective order allocation decision models, to discuss the influence of inequity aversion on LSI’s utility, FLSP’s utility and the total performance of logistics service supply chain. In addition, we compare the allocation results with the most relevant article by [26], to analyze whether the option contract can mitigate the impact of inequity aversion. The main conclusions are as follows.

First, we find that two option contracts can increase the total supply chain performance, and there is an optimal update time, at which point, the order allocation results reach the optimal value and tend to be stable. Second, both options contracts can reduce the impact of inequity aversion among FLSPs on supply chain performance. Third, we find the applicable conditions of the two option contracts. Specifically, when the demand decreases, the LSI should choose the reservation option, and when the demand increases, the LSI is better to purchase the option guarantee from the outside.

This paper has two important contributions, from the theoretical perspective, we provide the contractual mechanism to solve the impacts of the demand updating and FLSP’s inequity fairness behavior, which is blank in the present research. In addition, to our best knowledge, we firstly introduce the option derivative into the logistics service supply chain management, although the option derivative has been widely studied in the agricultural industry management [6, 11]. And as aforementioned, the reservation option contract is also rarely researched in the logistics service supply chain management. Hence, this paper enriches the application and research of option contracts. From the practical perspective, this paper considers inequity aversion among FLSPs and the environment of demand updating, which are more practical, so the conclusions of this paper can be applied to solve the practical problems better. For example, according to above mentioned Changjiu Logistics Company, we suggest that when the demand increases, it is better to give the priority to the option guarantee contract, as it may obtain a better supply chain performance than the reservation option contract.

The rest of this paper is organized as follows: in Section 2, we summarize the literature review with regard to demand updating, order allocation, and the options applied in the supply chain. Section 3 offers the model description and assumptions;
in Section 4, the logistics service supply chain coordination model, considering the environment of demand updating and inequity aversion, is established, and the model’s solving method is also provided. Section 5 offers a numerical simulation and analysis, and it analyzes the impact on order allocation results of the inequity aversion, as well as the option contracts. Section 6 proposes the conclusion and prospects for future research.

2. Literature review. In this paper, we study the coordination of the option contract in the logistics service supply chain, considering the inequity aversion of FLSPs in the environment of demand updating. Therefore, in the literature review, we will focus on three aspects of research progress: demand updating, inequity aversion behavior, and the application of option contracts in the supply chain.

2.1. Order allocation under demand updating. Unstable factors in the market make demand fluctuate. This not only increases the difficulty of demand forecast, but also leads to the intensification of supply and demand imbalance [34]. Demand updating, as an important means to improve the performance of the supply chain, has aroused the concern of academia and industry. Decision makers can use the updated market demand to make better decisions.

With respect to demand updating, some scholars have studied pricing and inventory management issues in manufacturing supply chain [33, 4, 14], and supply chain contract design issues [44]. [47] extended the demand updating in some constraints. In addition, many scholars also considered the competition [2, 14, 41] and after-sales [42]. In recent years, demand updating has also been gradually applied to service capacity procurement issues in the logistics service supply chain. [27] considered a logistics service supply chain consisting of an LSI and an FLSP, and explored the conditions of repurchase contracts applied in the logistics service supply chain under demand updating and rational expectations. At the same time, [22] extended the single-cycle environment to a more complex environment. Then some behaviors are considered when studied the demand updating in logistics service supply chains, such as fairness [24], overconfidence [23], loss averse [25].

2.2. Inequity aversion behavior. In the study of behavioral operations, fairness has become an important topic, and a great number of related researches have emerged in the field of supply chains. The existing researches on fairness preference are mainly reflected in the equitable order allocation of supply chain channels [7]. Research on equity concerns mainly includes two types. On the one hand, decision makers have distributive inequity concerns, and their own utility will be affected by the benefits of other players in vertical channels [16]. On the other hand, as the service competition between competitors becomes increasingly fierce, there will be a comparison between peers due to the profit gap, thus generating peer equity concerns [7, 13]. A few articles examined both of these concerns for contract design [16, 17], and order allocation [26, 24]. [26] is highly relevant to this article, which both considered the fairness behavior and demand updating, studied the effects of two factors on order allocation. While they did not introduce a contract or explore the impact of the contract on order allocation, this study will make up for this deficiency.

2.3. Options in the supply chain. The option contract was first introduced into the apparel industry [10]. There are two types of option contracts. One is the option derivatives, which are mainly used in the agricultural product supply
chain. Many scholars use the option derivatives to transfer uncontrollable weather risk. [11] studied seasonal product retailers in the face of weather-sensitive demand, using weather call options to hedge the inventory risks of seasonal products to make optimal order and pricing decisions. [6] discussed the risk for seasonal products with a call-option contract under weather-sensitive demand to improve the performance of members in the supply chain.

Another is the option contracts, in recent years, the study of option contracts in the supply chain has been extensive. There are two aspects of literature concerning the application of option contracts. One is the supply chain pricing problem [39, 40, 46]. The other is the supply chain coordination research, which has been widely explored when considering the option contracts [36, 5, 1, 44]. In terms of order allocation, [45] introduced a two-way option contract to respond to stochastic fluctuations in risk hedging mechanisms and updating demand, presenting closed-end solutions for initial orders. [21] considered the delivery service supply chain composed of a single express service provider and single online retailer, along with the reservation option contract; they found that the option contract can effectively solve the supply and demand matching problem, realize the risk sharing between the retailer and the provider and increase the flexibility in responding to customer demands.

In the above literature, the reservation option was mainly studied in the manufacturing supply chain and agricultural industry. However, in the logistics service supply chain, research about options is very rare. There is no paper considering both options contracts studied in this paper.

2.4. Summary of the literature. From the above literature review, the existing literature has independently studied the three aspects of order allocation, inequity aversion and the option contracts under demand update. Some literature has carried out cross research on two aspects, but joint research on the three factors is still lacking. In general, the literature associated with this article is [21], [26], and [6]. The differences between these studies and this paper are shown in following Table 1.

| Research content | [21] | [26] | [6] | This paper |
|------------------|--|--|--|-------|
| Supply chain structure | A single provider and a single retailer | Logistics service supply chain with single LSI and multiple FLSPs | Agricultural product supply chain with a single manufacturer and a single retailer | Logistics service supply chain with single LSI and multiple FLSPs |
| Demand updating is considered | × | √ | × | √ |
| Option types | Reservation option | × | Derivative option | Reservation option and derivative option |
| Fairness concern is considered | × | √ | × | √ |
| Research problem | Supply chain coordination and performance management | Behavioral management in order allocation | Supply chain performance and risk management | The effect of option and behavior on the performance of order allocation |

3. Model assumptions and parameters. This paper considers a logistics service supply chain, consisting of an LSI and n FLSPs. The LSI outsources customer orders to FLSPs according to the customer’s order requirements. Before the demand updating (set as the first phase), the LSI anticipates market demand $D \sim N(\mu, \sigma^2)$,
and chooses the form of option contract. According to the description in the Introduction, we consider two forms of option contract, one is to reserve the options from FLSPs (set as the option1), and the other is to purchase the option guarantee from the financing institution (set as option2). Meanwhile, the LSI shares demand information and allocates the logistics orders to FLSPs, we call this process pre- allocation, which is not the final result of the order delivery. The order allocation is public, so FLSPs know the results of order allocation among each other, and comparing the result will generate unfair feelings in the first phrase. Customer requirements always change before they actually arrive, the LSI re-updates the demand information at the moment \( t \) (which is the lead time for the demand updating) before the requirement are realized, then the LSI gets the estimated mean of market demand distribution \( \xi \), and shares it to the FLSP, we call this period after demand updating is the second phrase. The LSI shares the updated demand information with the FLSPs and reallocates the orders, in the meantime, the LSI performs the options contract decided in the first phrase. Similar to the first phrase, the FLSPs not only have the unfair feelings, but also generate the satisfaction utility after comparing the two allocation results. Finally, the customer demand is met, LSI not only have the unfair feelings, but also generate the satisfaction utility after comparing the two allocation results. Based on the above description, we give the following three assumptions.

**Assumption1.** The updated demand \( Q \) is related to the lead time \( t \). Using the method of [7] and [26], we assume that the demand in the second period is distributed to \( Q \mid \xi \sim \mathcal{N}(\mu(\xi), \nu^2) \). \( \xi \) is the estimated mean value of the demand by the LSI according to the information, \( \mu(\xi) = \frac{\sigma^2 \mu + \tau_2^2(\xi)}{\sigma^2 + \tau_2^2(\xi)} \) is the expected mean value of the demand in the second period, and the variance is \( \nu^2 = \sigma^2 + \frac{1}{\phi(t)} = \sigma^2 + \frac{\sigma^2(\gamma k^2 t)^2}{\sigma^2 + (\gamma k^2 t)^2} \), where \( \phi(t) = \frac{1}{\sigma(t)} + \frac{1}{\tau(t)} \), and \( \tau(t) \) indicates the prediction error, which is logarithmically related to the demand update time \( t \), \( \tau(t) = \gamma k^2 t, \gamma > 0 \). Accordingly, the mean value \( \mu(\xi) \) changes with \( t \). There are two cases about the estimated mean value \( \xi \). On the one hand, the estimated mean value is larger than the mean value of the demand in the first period (that is \( \xi > \mu \)). On the other hand, the estimated mean value is smaller than the mean value of the demand in the first period (that is \( \xi < \mu \)).

**Assumption2.** In the case of reservation option contract, in the first phrase, LSI reserves \( x_{i,1} \) order quantities from FLSP \( i \) at the predetermined price \( e_i \). After demand updating, LSI pre-allocates FLSP \( x_{i,2} \) order quantities, and LSI executes the reservation contract at the executing price \( P_i \) for the order quantities \( \min(x_{i,1}, x_{i,2}) \). If \( x_{i,2} > x_{i,1} \), the excess order quantities \( x_{i,2} - x_{i,1} \) are delivered at the market price \( p_i \). In order to guarantee the rationality, we assume that \( E_i < p_i \).

**Assumption3.** In the case of option guarantee contract, LSI shares demand information with external financial institutions in order to obtain corresponding guarantees. In the first phrase, LSI buys financial guarantee according to the demand \( D \), and the insurance company decides the compensate standard \( \eta \). Then LSI updated the second demand as \( Q \), only if the demand error between two periods \( \tau(t) > \eta D \), the insurance company would compensate the LSI for the quantities \( \min(q, \tau(t)) \).

The parameters of the model are shown in following Table 2.

4. **Model building.** This section establishes the order allocation decision model of the logistics service supply chain, considering FLSP's inequity aversion and two
**Table 2 Notations**

| Notation | Description |
|----------|-------------|
| $c_{i,opp}$ | Opportunity cost of FLSP $i$ at the time $t$ |
| $C_I$ | Demand updating cost of LSI |
| $c_i$ | The cost of unit logistics capacity for FLSP $i$ |
| $d_{i,0}$ | Initial utility of FLSP $i$ |
| $d_{i,1}$ | Satisfaction utility of FLSP $i$ with the reservation option in the second stage |
| $d_{i,2}$ | Satisfaction utility of FLSP $i$ with the option guarantee in the second stage |
| $D$ | Demand in the first stage, which subjects to the normal distribution $D \sim N(\mu, \sigma^2)$ |
| $e_i$ | Option purchase price of unit logistics capacity for FLSP $i$ in reservation option contract |
| $h_i$ | Option executive price of unit logistics capacity for FLSP $i$ in reservation option contract |
| $n$ | The total number of FLSPs |
| $p_i$ | The market price at which the LSI buys the unit logistics capacity from the FLSP $i$ |
| $q$ | Option purchase quantity for LSI in option guarantee contract |
| $d_{i,2}$ | Demand in the first stage, which subjects to the normal distribution $D \sim N(\mu, \sigma^2)$ |
| $Q$ | The updated demand in the second stage, which subjects to the normal distribution $(Q | \xi) \sim N(\mu(\xi), \nu^2)$ |
| $r$ | Option purchase price of unit logistics capacity for LSI in option guarantee contract |
| $R$ | Option compensation price of unit logistics capacity for LSI in option guarantee contract |
| $v_{i,1}$ | In the first stage, profit utility of FLSP $i$ in reservation option contract |
| $v_{i,2}$ | In the second stage, profit utility of FLSP $i$ in reservation option contract |
| $w_{i,1}$ | The weight of satisfaction utility of FLSP $i$ |
| $w_{i,2}$ | The weight of profit utility of FLSP $i$ |
| $x_{i,1}$ | In the first stage, logistics service capacity provided by FLSP $i$ in reservation option contract |
| $x_{i,2}$ | In the second stage, logistics service capacity provided by FLSP $i$ in reservation option contract |
| $y_{i,1}$ | In the first stage, logistics service capacity provided by FLSP $i$ in option guarantee contract |
| $y_{i,2}$ | In the second stage, logistics service capacity provided by FLSP $i$ in option guarantee contract |
| $z_1$ | The total profit of the LSI |
| $z_2$ | The total utility of the FLSP |
| $\alpha_i$ | Advantage unfair coefficient of FLSP $i$ |
| $\beta_i$ | Disadvantage unfair coefficient of FLSP $i$ |
| $\lambda$ | Unit logistics capacity income |
| $\xi$ | Based on the demanded sample information collected in the lead time, the estimated mean of the demand (Estimated Demand Average) |
| $\tau(t)$ | Demand forecast error, reflecting the degree of deviation between demand forecast and the actual needs |
| $\theta^-_i$ | Minimum logistics capacity provided by FLSP $i$ |
| $\theta^+_i$ | Maximum logistics capacity provided by FLSP $i$ |
| $\eta$ | Compensation threshold in option guarantee |
| $TP$ | Compensation threshold in option guarantee |
| $\Delta LSI$ | Change ratio in profit of LSI |
| $\Delta FLSP$ | Change ratio in profit of FLSP |
| $\Delta TP$ | Change ratio in total performance of supply chain |
types of option contract. Section 4.1 presents the model considering the reservation option contract, and Section 4.2 depicts the model considering the option guarantee contract. According to the description in assumptions, the models is divided into two stages, the first stage is the pre-allocation model, and the second stage is the allocation model, which are all multi-objective programming models.

4.1. Reservation option contract. As mentioned in the Assumption2, when the LSI chooses the reservation option contract, the models are presented as follows.

4.1.1. Allocation model in the first stage. (1) Objective Function 1: Minimize the option purchase cost of the LSI

\[
\min z_1(x_{i,1}) = \sum_{i=1}^{n} e_i x_{i,1} \tag{4.1}
\]

(2) Objective Function 2: Maximize the utility of FLSPs

\[
\min z_2(x_{i,1}) = \sum_{i=1}^{n} [e_i x_{i,1} - \sum_{j \neq i, j=1}^{n} \alpha_i (x_{i,1} - x_{j,1})^+ - \sum_{j \neq i, j=1}^{n} \beta_i (x_{j,1} - x_{i,1})^+] - c_{i, opp} \tag{4.2}
\]

In formula (4.2), \(e_i x_{i,1}\) is the income earned from the LSI’s purchasing options. \(\sum_{j \neq i, j=1}^{n} \alpha_i (x_{i,1} - x_{j,1})^+\) is the utility with advantage unfairness, \(\sum_{j \neq i, j=1}^{n} \beta_i (x_{j,1} - x_{i,1})^+\) is the utility with disadvantage unfairness. Since there is a need to retain their own logistics services before the next demand arrival, there will be an opportunity cost \(c_{i, opp}\) of the FLSP \(i\) in the lead time.

\[
\begin{align*}
  e_i x_{i,1} - \sum_{j \neq i, j=1}^{n} \alpha_i (x_{i,1} - x_{j,1})^+ &- \sum_{j \neq i, j=1}^{n} \beta_i (x_{j,1} - x_{i,1})^+ - c_{i, opp} > 0, \\
  x_{i,1} = \mu + \Phi^{-1}(\alpha) \sigma, \\
  h_i < p_i, \\
  \theta_i^- \leq x_{i,1} \leq \theta_i^+, \\
  x_{i,1} \geq 0, i = 1, 2, 3, ..., 
\end{align*}
\tag{4.3}
\]

For the first constraint, the model must ensure that the expected utility of the FLSP \(i\) is positive. For the second constraint, the logistics service capabilities provided by the FLSPs must meet the market demand. Because the customer demand \(D\) is the random variable, which subjects to the normal distribution \(D \sim N(\mu, \sigma^2)\), the established planning model should contain the chance constraint of the random variable. In this paper, the total capacity of the logistics service provided by the FLSPs needs to satisfy the customer demand opportunity constraint, that is

\[
\text{prob}(\sum_{i=1}^{n} x_{i,1} \geq D) = \chi, \text{ where } \chi \text{ expresses the probability of satisfaction. Specifically, } \chi = 95\% \text{ indicates that the total capacity of the logistics service provided by the FLSPs can meet at least } 95\% \text{ percents of the demand level. According to} [26], \text{ we convert the indeterminate constraints into deterministic constraints, and the ability provided by FL3SPs should satisfy the condition } \sum_{i=1}^{n} x_{i,1} = \mu + \Phi^{-1}(\chi) \sigma.
\]

The fourth item of the constraints is to guarantee that the order quantity is within the FLSPs’ logistics capacity.
4.1.2. Allocation model in the second stage. In the second phase, the LSI updated the demand at time $t$, and the order allocation model is as follows:

(1) **Objective Function 1:** Minimize the option purchase cost of the LSI

\[
\min z_1(x_{i,2}) = \sum_{i=1}^{n} \left[ (\lambda - E_i)\min(x_{i,1}, x_{i,2}) + (\lambda - p_i)(x_{i,2} - x_{i,1})^+ - C_I \right]
\] (4.4)

In formula (4.4), $E_i$ is the option execution price, $p_i$ is the market price, and $\sum_{i=1}^{n} [(\lambda - E_i)\min(x_{i,1}, x_{i,2}) + (\lambda - p_i)(x_{i,2} - x_{i,1})^+ - C_I]$ is the LSI’s profit, specifically, when $x_{i,1} > x_{i,2}$, meaning that the order capacity allocated to FLSP $i$ in the first stage is greater than that in the second stage, the LSI’s revenue from the FLSP $i$ is $(\lambda - E_i)x_{i,2}$. In contrast, when $x_{i,1} < x_{i,2}$, meaning that the order quantity of FLSP $i$ in the first stage is smaller than that in the second stage, the LSI’s revenue from FLSP $i$ is $(\lambda - E_i)x_{i,1} + (\lambda - p_i)(x_{i,2} - x_{i,1})$.

(2) **Objective function 2:** maximizing the utility of the FLSPs

\[
\min z_2(x_{i,2}) = \sum_{i=1}^{n} [w_{1i}d_{i,1} + w_{2i}v_{i,1}]
\] (4.5)

In formula (4.5), there are two parts consisting of the utility of the FLSPs, the first part is the satisfaction utility. By citing [26], the utility function can be expressed as follows:

\[
d_{i,1} = \begin{cases} 
\min [d_{i,0} + \frac{x_{i,2} - x_{i,1}}{\theta_i^- - \theta_i^+}, 1], & x_{i,2} \geq x_{i,1} \\
\max [d_{i,0} + \frac{x_{i,2} - x_{i,1}}{\theta_i^- - \theta_i^+}, 0], & x_{i,2} < x_{i,1}
\end{cases}
\] (4.6)

In formula (4.6), $d_{i,1}$ is the satisfaction utility FLSP $i$, $d_{i,1} \in [0,1]$, and $d_{i,0}$ is the initial benchmark satisfaction. $[\theta_i^-, \theta_i^+]$ is the range of the logistics service capacity of FLSP $i$. When $x_{i,2} \geq x_{i,1}$, the satisfaction of FLSP $i$ increases, but it is important to ensure that its satisfaction is less than 1, when $x_{i,2} < x_{i,1}$, the satisfaction of FLSP $i$ decreases, but we have to ensure that its satisfaction is greater than 0. $\theta_i^-, \theta_i^+$, and $d_{i,0}$, can be obtained by the LSI through the survey when the FLSPs participate in the order allocation.

The second part $v_{i,1}$ is the profit utility after considering inequity aversion, Since $v_{i,1}$ of the FLSP $i$ should belong to $[0,1]$, we normalize the profit utility after considering the FLSPs’ unfair aversion, the specific expressions are as follows:

\[
v_{i,1} = \frac{E_i\min(x_{i,1}, x_{i,2}) + p_i(x_{i,2} - x_{i,1})^+}{\lambda x_{i,2}} - \sum_{j \neq i}^{n} \alpha_i(x_{i,1} - x_{j,1})^+ - \sum_{j \neq i}^{n} \beta_i(x_{j,1} - x_{i,1})^+ - c_i x_{i,2}
\] (4.7)

Where $E_i\min(x_{i,1}, x_{i,2}) + p_i(x_{i,2} - x_{i,1})^+$ is the unfair utility of the FLSP $i$, $c_i x_{i,2}$ is the cost of the FLSP $i$. The above two parts constitute the total utility of the FLSPs, we set the weight of the two parts to be $w_{1i}$, $w_{2i}$, and $w_{1i} + w_{2i} = 1$, then the total utility of FLSP $i$ is expressed as $w_{1i}d_{i,1} + w_{2i}v_{i,1}$.
(3) Constraints:
In the second stage, similar to the expression of formula (3), the constraints are listed as follows:

\[
\begin{align*}
E_i \min(x_{i,1}, x_{i,2}) + p_i(x_{i,2} - x_{i,1})^+ - \sum_{j \neq i, j = 1}^n \alpha_i(x_{i,1} - x_{j,1})^+ \\
- \sum_{j \neq i, j = 1}^n \beta_i(x_{j,1} - x_{i,1})^+ - c_i x_{i,2} > 0,
\end{align*}
\]

\[
\begin{align*}
\sum_{i = 1}^n x_{i,2} = \mu(k_i) + \Phi(\chi)\sigma, \\
\theta_i^- \leq x_{i,2} \leq \theta_i^+, \\
x_{i,2} \geq 0, i = 1, 2, 3...
\end{align*}
\]

(4.8)

4.2. The model of the option guarantee contract. Similarly, there are two stages in the allocation mode. In the first stage, the LSI allocates the order according to the predicted demand \(D\), the order quantity assigned to the FLSP \(i\) is \(y_{i,1}\), and the LSI will purchase the option quantity \(q\) from the insurance institution at the price \(r\). Since the allocation result is public, there also exists inequity aversion behavior among the FLSPs. Different from the reservation option contract, this stage aims at maximizing the profit of the LSI and maximizing the utility of the FLSPs, after considering inequity aversion. In the second stage, the LSI re-allocates the order according to the updated demand \(Q\), the order allocation amount for FLSP \(i\) becomes \(y_{i,2}\), and the supplier's satisfaction changed after comparing with the pre-assigned order quantity \(y_{i,1}\). Then, the external financial institution determines whether to compensate or not, according to whether the forecast error \(\tau(t)\) reaches the compensation threshold \(\eta D\). The unit compensation price is \(R\), and the quantity need to be compensated is \(\min(q, |Q - D|)\). This stage aims at maximizing the LSI’s profit and the utility of FLSPs. We list the specific model as follows.

4.2.1. Allocation model in the first stage. (1) Objective function 1: maximizing the LSI’s profit

\[
\text{min} z_1(y_{i,1}) = \sum_{i = 1}^n (\lambda - p_i)y_{i,1} - rp
\]

(4.9)

(2) Objective function 2: maximizing the FLSP’s utility

\[
\text{min} z_2(y_{i,1}) = \sum_{i = 1}^n [p_i y_{i,1} - \sum_{j \neq i, j = 1}^n \alpha_i(y_{i,1} - y_{j,1})^+ - \sum_{j \neq i, j = 1}^n \beta_i(y_{j,1} - y_{i,1})^+ - c_i y_{i,1}] 
\]

(4.10)

(3) Constraints:

\[
\begin{align*}
p_i y_{i,1} - \sum_{j \neq i, j = 1}^n \alpha_i(y_{i,1} - y_{j,1})^+ - \sum_{j \neq i, j = 1}^n \beta_i(y_{j,1} - y_{i,1})^+ - c_i y_{i,1} > 0, \\
\sum_{i = 1}^n y_{i,1} = \mu(k_i) + \Phi(\chi)\sigma, \\
\theta_i^- \leq y_{i,1} \leq \theta_i^+, \\
y_{i,1} \geq 0, i = 1, 2, 3...
\end{align*}
\]

(4.11)
4.2.2. **Allocation model in the second stage.** In the second stage, the LSI updated the demand at lead time $t$, and the order allocation model is as follows:

**1. Objective function 1:** maximize the LSI’s profit

$$
\begin{align*}
    \max z_1(y_{i,2}) = & \sum_{i=1}^{n} (\lambda - p_i) y_{i,2} + R_{\min}(q(t)) - r p - C_1, \tau(t) > \eta D \\
    & \sum_{i=1}^{n} (\lambda - p_i) y_{i,2} - r p, \tau(t) \leq \eta D
\end{align*}
$$

**2. Objective function 2:** maximize the FLSP’s utility

Similar to the section 4.1.2, the total utility function of FLSP $i$ is as follows:

$$
\begin{align*}
    \min z_2(y_{i,2}) = & \sum_{i=1}^{n} [w_1d_{i,2} + w_2v_{i,2}]
\end{align*}
$$

The satisfaction utility of the FLSP $i$ is:

$$
\begin{align*}
    d_{i,2} = \begin{cases} 
        \min [d_{i,0} + \frac{y_{i,2} - y_{i,1}}{\theta_i^+ - \theta_i^-}, 1], & y_{i,2} \geq y_{i,1} \\
        \max [d_{i,0} + \frac{y_{i,2} - y_{i,1}}{\theta_i^+ - \theta_i^-}, 0], & y_{i,2} < y_{i,1}
    \end{cases}
\end{align*}
$$

The profit utility of the FLSP $i$ is:

$$
\begin{align*}
    v_{i,2} = & \frac{p_i y_{i,2} - \sum_{j \neq i, j=1}^{n} \alpha_i (y_{i,1} - y_{j,1})^+ - \sum_{j \neq i, j=1}^{n} \beta_i (y_{j,1} - y_{i,1})^+ - c_i y_{i,2}}{p_i y_{i,2}}
\end{align*}
$$

**3. Constraints:**

$$
\begin{align*}
    & \sum_{i=1}^{n} y_{i,2} = \mu(k_t) + \Phi(\chi) \sigma \\\n    & \theta_i^- \leq y_{i,2} \leq \theta_i^+, \quad y_{i,2} \geq 0, \quad i = 1, 2, 3...
\end{align*}
$$

4.3. **Model solving algorithm.** Previous two-stage order allocation model studies mostly take a dynamic induction method, using the reverse order solution to obtain the optimal value [47]. In this paper, since the LSI updates the demand mainly based on the actual observed demand, rather than the predicted demand, which is common in practice, for example, TAOBAO will update the sales amount every month based on that of the last month instead of the predicted demand update information. Specifically, the LSI makes decisions about the order allocation in both the first stage and the second stage according to time, the customer’s demand in the second stage changes on the basis of the demand in the first stage, and the FLSPs will adjust their satisfaction utility in the second stage according to the allocation results in the first stage. Thus, we do not build a traditional dynamic programming model based on backward induction, we follow the decision sequence and establish a two-stage ordering model based on decision sequence [10, 20].

The models in the first stage and second stage all are multi-objective programming models, the general solution of a multi-objective programming problem is to convert it into a single-objective problem, and the ideal point method can be used. The specific steps of the ideal point method are as follows.

**Step1:** Solve the ideal point. Let the objective function of the LSI’s profit be $Z_1$, the objective function of the FLSPs’ utility be $Z_2$, and the optimal value of $Z_1$...
be $Z_1$, solved without considering the objective function $Z_2$, and the optimal value of $Z_2$ be $Z_{2}^{*}$, without considering the case of the objective function $Z_1$. Thus, the combination of the optimal solution is $Z^{*} = (Z_{1}^{*}, Z_{2}^{*})$.

Step 2: Normalize the objective function. Since $Z_1$ and $Z_2$ are not the same dimension, the value of $Z_2$ is [0, 1]. Therefore, we normalize $Z_1$ and $Z_2$:

$$Z_1' = \frac{Z_1}{Z_{1}^{*}}$$
$$Z_2' = \frac{Z_2}{Z_{2}^{*}}$$

then $Z_1'$ and $Z_2'$ belong to [0, 1].

Step 3: Build the evaluation function. Since the ideal point is generally difficult to achieve, we must seek the nearest point from $Z^{*}$ as an approximation and construct the evaluation function as follows:

$$\phi(Z) = \sqrt{\delta((Z_1/Z_1^*)^2 + (1 - \delta)((Z_2/Z_2^*)^2)}$$

In equation (4.17), $\delta$ and $1 - \delta$ are the weights for the normalized $Z_1$ and $Z_2$, respectively.

Step 4: Minimize $\phi(Z)$, that is, solve the following equation:

$$\min \phi(Z) = \sqrt{\delta((Z_1/Z_1^*)^2 + (1 - \delta)((Z_2/Z_2^*)^2)}$$

$\phi(Z)$ combines the target of LSI’s utility and FLSPs’ utility, so $\phi(Z)$ could be considered as the total performance (TP) of the supply chain.

According to the decision sequence method, we firstly use the above steps to solve optimal solution of the models in the first stage, and then substitute the allocation results into models in the second stage, and also use the above steps for solving the final optimal allocation results.

5. Numerical analysis. In this section, we use MATLAB to solve the model and conduct numerical analysis. We mainly explore the influence of the option contract on the supply chain members and the total performance of the supply chain. At the same time, we explore whether the option contract can affect the impact of inequity aversion on the supply chain. In Section 5.1, we give the basic parameters of the numerical analysis. Section 5.2 discusses the effect of inequity aversion on the order allocation. Section 5.3 discusses how the option contracts mitigate the impact of inequity aversion on the order allocation. In Section 5.4, we summarize the analysis and conclusions.

5.1. Basic parameter setting. Using arbitrary parameter settings and numerical results to prove the validity and applicability of the model are not acceptable. As discussed in the introduction, in order to compare our research results with the situation of non-option contract, we will use the exact same data setting as [26], who do not consider the factor of option contract.

We assume that there are three FLSPs, $A_1$, $A_2$ and $A_3$, providing logistics service for the LSI $B$, who allocates logistics service orders to them, $B$ predicts the demand that is subject to normal distribution $D \sim N(100, 4)$ in the first phase. $\alpha = 95$ can be obtained through market observation; the income of unit logistics capacity is $\lambda = 60$. The weight $\delta = 0.3$, and $c_I = 500$, the other relevant parameters for the logistics capacity of $A_1$, $A_2$ and $A_3$ are shown in Table 3.
Table 3 Parameter setting

| FLSP | $p_i$ | $c_i$ | $e_i$ | $b_i$ | $[\theta_i, \bar{\theta}_i]$ | $w_{1i}$ | $w_{2i}$ | $r_i$ | $d_i$ |
|------|------|------|------|------|------------------|--------|--------|-------|------|
| $A_1$ | 24   | 8    | 10   | 16   | [15, 24]         | 0.6    | 0.4    | 0.5   | 0.3  |
| $A_2$ | 15   | 5    | 6    | 10   | [20, 35]         | 0.6    | 0.4    | 0.4   | 0.35 |
| $A_3$ | 26   | 9    | 11   | 17   | [25, 45]         | 0.7    | 0.3    | 0.6   | 0.35 |

Note: (i) According to the Assumption 1, if $\xi > \mu$, we set $\xi = 120$. If $\xi < \mu$, we set $\xi = 80$. (ii) In this paper, the demand $D$ before updating is a signal, the LSI would update the information and accordingly estimate the mean value as $\xi$. Therefore, the estimated value is effected by the updated information, because the actual demand often changes fiercely, the $\xi$ may be much larger or smaller $\mu$.

5.2. The impact of inequity aversion on the allocation of orders. In order to facilitate the discussion of the effect that the inequity aversion difference on the utility of LSI and FLSPs, we set $\xi = 120$ to indicate that the demand increases, and $\xi = 80$ to indicate that the demand decreases, we discuss the following three scenarios.

scenarios 1: $\alpha_1 = \alpha_2 = \alpha_3 = 0.3$, $\beta_1 = \beta_2 = \beta_3 = 0.2$

scenarios 2: $\alpha_1 = 0.28$, $\alpha_2 = 0.18$, $\alpha_3 = 0.3$, $\beta_1 = 0.2$, $\beta_2 = 0.32$, $\beta_3 = 0.22$

scenarios 3: $\alpha_1 = 0.2$, $\alpha_2 = 0.1$, $\alpha_3 = 0.3$, $\beta_1 = 0.2$, $\beta_2 = 0.4$, $\beta_3 = 0.3$

Scenario 1 presents there is no difference of the inequity aversion, scenario 2 presents that there are small difference among the inequity aversion, and scenario 3 presents that there is big difference among the inequity aversion. Next, we analyze the impact of inequity aversion on the utility of LSI, utility of FLSPs and the supply chain performance under the two option contracts. The specific results are as follows.

5.2.1. Reservation option contract. From Fig. 1(a), we can see that when $\xi < \mu$, in the three cases, as the lead time $t$ increases, the utility of the LSI first decreases and then becomes stable, and LSI’s utility increases as the difference of inequity aversion increases. As can be seen from Fig. 1(b), in the three cases, when $\xi > \mu$, the LSI’s utility first increases and then becomes stable with the increase of the lead time $t$, and the utility of the LSI increases as the difference of inequity aversion increases. This is because the LSI is near to the market, and will be effected directly by the market demand, when the demand decreases (or increases), the LSI’s utility...
also decreases (or increases). In addition, the addition of the difference of inequity aversion will lead to the fierce competition, which is beneficial to the LSI.

As can be seen from Fig. 2(a), when \( \xi < \mu \), in the three cases, the utility of the FLSPs increases first and then stabilizes with the increase of the lead time \( t \). As the difference of inequity aversion increases, the utility of FLSPs decreases. As can be seen from Fig.2(b), when \( \xi > \mu \), in the three cases, the utility of FLSPs decreases first and then stabilizes with the increase of the lead time \( t \). This is because when the demand decreases (or increases ), the FLSP’s profit utility and satisfaction utility also decrease (or increase). In addition, as the difference of inequity aversion increases, the utility of the FLSPs decreases. This is because when the difference of inequity aversion increases, the fierce competition lead to the FLSP’s utility decrease.

From Fig.3(a), we can see that when \( \xi < \mu \), if there is no inequity aversion difference (Scenario1) or small inequity aversion difference (Scenario2), the supply chain performance decreases first with the increase of lead time \( t \), then tends to be stable, this is because when the demand decreases, the utilities of LSI and FLSP both decrease, then lead to the decrease of the supply chain total performance. In
the case of large inequity aversion difference (scenario3), the supply chain performance does not change significantly with an increase of lead time $t$, this is because the larger difference of inequity aversion can counteract the impact on the supply chain total performance of the demand change. Moreover, with the increase in the inequity aversion difference, the supply chain performance increases, this indicates that the LSI’s utility impacts the supply chain performance more than FLSP’s utility, and the larger difference of inequity is beneficial to the supply chain when adopting the reservation option contract.

From Fig. 3(b), we can see that when $\xi > \mu$, if there is no inequity aversion difference (Scenario1) or small inequity aversion difference (Scenario2), the supply chain performance increases first with the increase of lead time $t$, then tends to be stable, this is because when the demand increases, the utilities of LSI and FLSP both increase, then lead to the increase of the supply chain total performance. In the case of large inequity aversion difference (scenario3), the supply chain performance does not change significantly with an increase of lead time $t$, this is because the larger difference of inequity aversion can counteract the impact on the supply chain total performance of the demand change. Moreover, with an increase of the inequity aversion difference, the supply chain performance increases, this indicates that the LSI’s utility impacts the supply chain performance more than FLSP’s utility, and the larger difference of inequity is beneficial to the supply chain when adopting the reservation option contract.

5.2.2. Option guarantee contract. We set $r = 10$, $R = 100$, $q = 15$, $\eta = 0.1$. The other parameters are shown in Table 3. In this section, we study the impact of inequity aversion differences on order distribution under the conditions of the option guarantee contract, from three aspects of LSI’s utility, utility of FLSPs and supply chain performance. We consider two cases, whereby $\xi > \mu (\mu = 100, \xi = 120)$ and $\xi < \mu (\mu = 100, \xi = 80)$. The results are as follows.

It can be seen from Fig. 4(a) that when $\xi < \mu$, the utility of the LSI increases suddenly with the increase of the lead time $t$, and then it becomes stable. As can be seen from Fig. 4(b), when $\xi > \mu$, the utility of the LSI increases rapidly with the increase of the lead time $t$ and then becomes stable. These are similar to the Fig.1(a) and Fig.1(b). In addition, the change in the inequity aversion difference has no significant influence on the LSI’s utility, this indicates that the guaranteed
option contract can weaken the impact of the inequity aversion behavior on the utility of LSI.

As can be seen from Fig. 5(a), when $\xi < \mu$, the utility of FLSPs decreases first as the update lead time $t$ increases, then it becomes stable, and the utility decreases as the inequity aversion difference increases. As can be seen from Fig. 5(b), when $\xi > \mu$, the utility of the FLSPs increases first as the update lead time $t$ increases, then it becomes stable, and the utility of FLSPs decreases as the inequity aversion difference increases, these results are similar to the Fig.2(a) and Fig.2(b), the reason is that when the demand decreases (or increases), the FLSP’s profit utility and satisfaction utility also decrease (or increase), and when the difference of inequity aversion increases, the fierce competition leads to the FLSP’s utility decrease.

As can be seen from Fig. 6(a), when $\xi < \mu$, the supply chain performance decreases first as the lead time $t$ increases, then it becomes stable. As can be seen from Fig. 6(b), when $\xi > \mu$, the supply chain performance increases first as the lead time $t$ increases, then it tends to be stable. This is because when the demand decreases, the utilities of LSI and FLSP both decrease, which lead to the decrease of the supply chain total performance, and vice versa. Moreover, The supply chain performance decreases as the inequity aversion difference increases, this indicates that the FLSPs’ utility impacts the supply chain performance more than LSI’s
utility, and the larger difference of inequity is adverse to the supply chain when adopting the guarantee option contract.

5.3. The impact of the option Contracts on behavioral factors. This section compares this paper with the study conducted by [26], the purpose is to explore the impact of two option contracts on the inequity aversion behavior. We let [26] represent the case of no option contract (denoted by the textbf none option), and textbf Option 1 represents that the LSI reserves option from the FLSPs, and textbf Option 2 represents that the LSI purchases option from an external financial institution. We analyze the changes of LSI’s utility, FLSPs’ utility and TP of supply chain. To conduct our research, on the one hand, we use the change percentage of results between the scenario 1 and scenario 2 as the effects of small inequity aversion on order allocation, in order to easily understood, we set \( \Delta \Pi_{LSI}^{1-2} = \frac{\Pi_{scenario1}^{1} - \Pi_{scenario2}^{1}}{\Pi_{scenario1}^{1}} \) as the LSI’s utility change in small unfair aversion situation, \( \Delta U_{FLSP}^{1-2} = \frac{U_{scenario1}^{1} - U_{scenario2}^{1}}{U_{scenario1}^{1}} \) as the FLSPs’ utility change in small unfair aversion situation, and \( \Delta TP_{TP}^{1-2} = \frac{TP_{scenario1}^{1} - TP_{scenario2}^{1}}{TP_{scenario1}^{1}} \) as the TP’s change in small unfair aversion situation. On the other hand, we use the change percentage of results between the scenario 1 and scenario 3 as the effects of large unfair aversion on order allocation. Similarly, we set \( \Delta \Pi_{LSI}^{1-3}, \Delta \Pi_{FLSP}^{1-3}, \Delta \Pi_{TP}^{1-3} \) as the change in this situation.

5.3.1. Impact of options on behavioral factors in case of decreased demand. In this section, we analyze how the option contracts influence the effects of inequity aversion on order allocation when the demand decreases. We list the specific allocation data in the Appendix, in this section, we mainly use figures to clearly present the results.

1. Percentage change in LSI’s utility

\[ \Delta \Pi_{LSI}^{1-2} \text{ in the case of decreased demand} \]

\[ \Delta \Pi_{LSI}^{1-3} \text{ in the case of decreased demand} \]

It can be seen from Fig. 7(a) that when the inequity aversion difference is small, the change in the LSI’s profit under two options is less than that of the non-option contract. It also shows that the two option contracts can both reduce the impact on the LSI’s Profit. From Fig. 7(b), we can see that when the inequity aversion difference is large, the changing tendency is just similar to that in the small unfair aversion situation, it means that both option contracts can mitigate the effects of
inequity aversion on LSP’s utility. In addition, the utility change of non-option situation is generally much larger than that in the small unfair aversion situation, this also indicates that the LSI’s utility increases with the difference of inequity aversion.

2. Percentage change in utility of FLSPs

As can be seen from Fig. 8(a) and Fig. 8(b), regardless of the inequity aversion is small or large, the change of the FLSP’s utility under two options is less than that of the non-option. Thus, both option contracts can mitigate the effects of inequity aversion on FLSPs’ utility. And there is no difference of two option contracts to weaken the effects of the inequity aversion on the FLSPs’ utility.

3. Percentage change in supply chain performance

From Fig.9(a) and Fig.9(b), we can see that regardless of the inequity aversion is small or large, the change in the supply chain performance under two options is less than the change of the supply chain performance in case of non-option contracts, which shows that the two option contracts can effectively reduce the impact
of inequity aversion on supply chain performance. Furthermore, the proportion of change in the supply chain performance under reservation option contract is less than that under guarantee option contract, which means that when the demand decreases, the reservation option contract is better than the option guarantee contract to weaken the effects of the inequity aversion on total supply chain performance.

5.3.2. The impact of options on behavioral factors in the case of increased demand.

1. Percentage change in LSI’s utility

From Fig.10(a) and Fig.10(b), we can see that regardless of the inequity aversion is small or large, the change of the LSI’s utility under the reservation option contract is greater than that under the non-option contract, and then greater than that in case of the option guarantee contract. This means that option guarantee contracts can effectively reduce the impact of inequity aversion on the LSI’s utility, while reservation option contract cannot.

2. Percentage change in utility of FLSPs

From Fig.11(a), we can see that when the inequity aversion is small, the changes of the utility of FLSPs under two option contracts are smaller than that in the case
of the non-option contract, indicating that both option contracts can mitigate the effect of inequity aversion on FLSPs’ utility and the effect of two options has no significant difference. Fig.11(b) indicates that when the inequity aversion is large, the changes of the utility of FLSPs under option guarantee contract is smaller than that under non-option, and then smaller than that under reservation option contract. This means that the both option contracts can mitigate the effect of inequity aversion on FLSPs’ utility and option guarantee contract is more better.

3. Percentage change in supply chain performance

![Figure 12(a). ΔTP_{1-2} in the case of increased demand](image1)

![Figure 12(b). ΔTP_{1-3} in the case of increased demand](image2)

From Fig.12(a), we can see that when the inequity aversion difference is small, the change of the supply chain performance under the non-option contract is greater than that of the reservation option contract, indicating that the reservation option can mitigate the impact of inequity aversion on supply chain performance. From Fig.12(b), we can see that when the inequity aversion difference is large, the change of the supply chain performance under the reservation option contract is greater than that under the non-option contract and much greater than that under the option guarantee contract. This means that the option guarantee contract can significantly reduce the impact of inequity aversion on supply chain performance, while the reservation option contract cannot.

5.4. Discussion. Through the numerical analysis above, we find that inequity aversion has a certain influence on the results of order allocation, and the option contracts can mitigate the effect effectively under certain conditions. The effects of inequity aversion difference on utility of LSI, and FLSP, as well as the supply chain performance are summarized in following Table4.

From Table4, it can be concluded that there is an optimal update time t at which the order allocation results are best and stabilized, after time t, the LSI’s utility, FLSPs’ utility, and supply chain performance will not change. Also, in the case of the reservation option contract, as the inequity aversion difference increases, the LSI’s profit and the supply chain’s total performance will increase, while the FLSPs’ utility will decrease. Thirdly, in the case of the option guarantee contract, when the inequity aversion difference increases, the LSI’s profit will not change, and both the FLSPs’ utility and the supply chain’s total performance will decrease.

Combined with the analysis in section5.3 and the specific data in Appendix, we can obtain the applicable conditions for the two options contracts to reduce the
Table 4 Summary of parameter influence laws

| Dependent variable | Independent variable | Demand update time $t$ | Difference of the fairness Preference among the FLSPs $\xi$ |
|--------------------|----------------------|------------------------|------------------------|
|                    | $\xi < \mu$          | $\xi > \mu$          | $\xi < \mu$          | $\xi > \mu$          |
| Model 1            |                      |                        |                        |
| reservation option | Utility of LSI       | $\nearrow$             | $\nearrow$             | $\nearrow$             | $\nearrow$             |
|                    | Utility of FLSPs     | $\nearrow$             | $\nearrow$             | $\nearrow$             | $\nearrow$             |
|                    | total performance    | $\rightarrow$          | $\rightarrow$          | $\rightarrow$          | $\rightarrow$          |
| Model 2            |                      |                        |                        |
| Option derivatives | Utility of LSI       | $\nearrow$             | $\nearrow$             | $\nearrow$             | $\nearrow$             |
|                    | Utility of FLSPs     | $\nearrow$             | $\nearrow$             | $\nearrow$             | $\nearrow$             |
|                    | total performance    | $\rightarrow$          | $\rightarrow$          | $\rightarrow$          | $\rightarrow$          |

Note: $\nearrow$ indicates with the increase of independent variable, the value of dependent variable will increase, $\searrow$ indicates with the increase of independent variable, the value of dependent variable will decrease, $\rightarrow$ indicates with the increase of independent variable, the value of dependent variable unchanged, $\uparrow$ indicates with the increase of independent variable, the value of dependent variable will increase suddenly.

impact of inequity aversion on the results of order allocation, which are shown in table 5.

Table 5 Application conditions that option can reduce the impact on allocation of inequity aversion

| $\xi < \mu$ | Options stype | Inequity aversion difference is small | Inequity aversion difference is large |
|-------------|---------------|-------------------------------------|-------------------------------------|
|             | $\Delta U_{LSI}^{\xi}$ | $\Delta U_{FLSP}^{\xi}$ | $\Delta TP^{\xi}$ | $\Delta U_{LSI}^{\xi}$ | $\Delta U_{FLSP}^{\xi}$ | $\Delta TP^{\xi}$ |
| Option1     | $Y$           | $Y$                                  | $Y^*$                                |
| Option2     | $Y^*$         | $Y$                                  | $Y$                                  |
| $\xi > \mu$ |               |                                      |                                      |
| Option1     | $N$           | $Y$                                  | $N$                                  |
| Option2     | $Y$           | $Y^*$                                | $Y$                                  |

Note: $Y$ indicates that the option contract can weaken the impact of the inequity aversion; $Y^*$ indicates that the weakening effect is better; $N$ indicates that option contract cannot diminish the impact of the inequity aversion.

From Table 5, we can see that, whether the inequity aversion difference is small or large, when demand decreases, both option contracts can weaken the effect of inequity aversion difference on the LSI’s utility, FLSP’s utility and supply chain total performance. However, the reservation option contract is more efficient than the option guarantee contract.

In the case of the increased demand, when the inequity aversion difference is small, the reservation option contract can reduce the effect of inequity aversion on the FLSPs’ utility and the supply chain’s total performance, although it cannot mitigate the effect on the LSI’s utility. The option guarantee contract can mitigate the effect of inequity aversion on the LSI’s profit and FLSPs’ utility, but it cannot mitigate the effect on supply chain performance. When the inequity aversion difference is large, the reservation option contract can reduce the effect on the utility of FLSPs, while the option guarantee contract can mitigate the effect in three aspects of inequity aversion. Based on these results, the option guarantee contract is more efficient for mitigating the effect, and hence, it is used more widely.

6. Main conclusions and inspiration for management. In Section 6.1, we present the main conclusions of this paper. The significance to managers and researchers is offered in Section 6.2. Finally, suggestions for future research are given in Section 6.3.
6.1. Main conclusions. This paper establishes the order allocation model in an logistics service supply chain, considering two types of option contracts and the inequity aversion among FLSPs in the environment of demand updating. Also, compared with [26], we study the influence of inequity aversion on order allocation in the case of two option contracts, and we explore whether the option contract can weaken the impact of inequity aversion. From our study, we obtained the following important conclusions.

Firstly, this article found that there exists optimal update time, at which the LSI's utility, FLSPs' utility, and supply chain performance will not change. Secondly, in the case of the reservation option contract, as the inequity aversion difference increases, the LSI's profit and the supply chain's total performance will increase, while the FLSPs' utility will decrease. Meanwhile, in the case of the option guarantee contract, when the inequity aversion difference increases, the LSI's profit will not change, and both the FLSPs' utility and the supply chain's total performance will decrease. Thirdly, as the inequity aversion difference increases, the LSI's profit and supply chain performance increase and the utility of FLSPs decreases under the reservation contract. In the case of the option guarantee contract, when inequity aversion differences increase, the utility of FLSPs and supply chain performance decrease, while the LSI's profit does not change significantly. Finally, two option contracts can weaken the influence of inequity aversion on order allocation under certain conditions. In the case of decreasing demand, the reservation option contract is better, while in the case of increasing demand, the option guarantee contract is preferred.

6.2. Significance for management. This study offers many insights for management with regard to LSI and FLSPs. For LSI, there is an optimal update time, therefore, the LSI is better to update at the optimal update time. In addition, the LSI needs to judge the trends in future demand changes before deciding upon a specific option contract. When demand decreases, the LSI can choose both the two options, but it is better to choose the reservation option contract; when demand increases, it is more favorable to choose the option guarantee contract. Therefore, for the Changjiu Logistics Company mentioned in the Introduction of this paper, we suggest that, in the case of increasing demand, it is better to give the priority to the option guarantee contract, as it may obtain a better supply chain performance than the reservation options.

For FLSPs, the increase in the inequity aversion difference will decrease their utility under the two option contracts. Therefore, FLSPs should try to strengthen cooperation between each other to prevent the inequity aversion difference becoming too large. For example, in the actual logistics service supply chain coordination process, FLSPs can establish a FLSP alliance to minimize their own sensitivity to inequity aversion. In addition, the reservation option contract can reduce the effect of inequity aversion difference on utility of FLSPs, so it is beneficial for FLSPs to choose the reservation option, which is contradictory to the LSI, hence they can establish a certain contractual relationship with the LSI (such as price discount) in order to obtain higher utility.

6.3. Future research. In this paper, we use the multi-objective programming model to study the order allocation of an logistics service supply chain in the demand updating environment, considering the inequity aversion among FLSPs and the two option contracts. However, there are some shortcomings. The solution to the
model only uses a numerical analysis, which has some limitations and cannot fully represent the real situation. Therefore, the follow-up researchers can carry out empirical research to further verify the conclusions based on the results of this paper.

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Appendix. Appendix A. When demand decreases, the order allocation results in the case of non-option, option1 and option2

Table 6 Allocation data of non-option contract ([26])

| t | Scenario1 | Scenario2 | Scenario3 | Scenario1 | Scenario2 | Scenario3 | Scenario1 | Scenario2 | Scenario3 |
|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 10 | 528.280   | 564.390   | 641.890   | 0.305     | 0.306     | 0.292     | 0.191     | 0.188     | 0.182     |
| 15 | 561.290   | 596.290   | 676.780   | 0.344     | 0.340     | 0.319     | 0.217     | 0.214     | 0.207     |
| 20 | 604.580   | 642.280   | 748.980   | 0.356     | 0.355     | 0.347     | 0.224     | 0.222     | 0.215     |
| 25 | 621.360   | 660.270   | 746.250   | 0.362     | 0.359     | 0.351     | 0.228     | 0.225     | 0.218     |
| 30 | 628.930   | 668.260   | 752.570   | 0.364     | 0.359     | 0.354     | 0.229     | 0.225     | 0.219     |
| 35 | 631.240   | 671.020   | 753.180   | 0.364     | 0.359     | 0.354     | 0.229     | 0.225     | 0.219     |
| 40 | 631.240   | 671.850   | 754.020   | 0.364     | 0.363     | 0.354     | 0.229     | 0.227     | 0.219     |
| 45 | 631.240   | 671.980   | 754.380   | 0.364     | 0.363     | 0.354     | 0.229     | 0.227     | 0.219     |
| 50 | 632.240   | 672.980   | 755.380   | 0.364     | 0.363     | 0.354     | 0.229     | 0.227     | 0.219     |

Table 7 Allocation data of option1 (reservation option contract)

| t | Scenario1 | Scenario2 | Scenario3 | Scenario1 | Scenario2 | Scenario3 | Scenario1 | Scenario2 | Scenario3 |
|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 5  | 5212.604  | 5214.035  | 5219.711  | 0.390     | 0.390     | 0.390     | 0.999     | 1.000     | 1.000     |
| 10 | 4989.574  | 4991.008  | 4996.698  | 0.385     | 0.384     | 0.384     | 0.999     | 1.000     | 1.000     |
| 15 | 4820.468  | 4821.904  | 4827.605  | 0.380     | 0.380     | 0.380     | 0.999     | 0.999     | 1.000     |
| 20 | 4731.125  | 4732.563  | 4738.269  | 0.378     | 0.378     | 0.378     | 0.999     | 0.999     | 1.000     |
| 25 | 4692.747  | 4694.186  | 4699.894  | 0.377     | 0.377     | 0.377     | 0.999     | 0.999     | 1.000     |
| 30 | 4672.095  | 4673.534  | 4679.243  | 0.376     | 0.376     | 0.376     | 0.999     | 0.999     | 1.000     |
| 35 | 4677.743  | 4679.182  | 4684.891  | 0.376     | 0.376     | 0.376     | 0.999     | 0.999     | 1.000     |
| 40 | 4677.743  | 4679.182  | 4684.891  | 0.376     | 0.376     | 0.376     | 0.999     | 0.999     | 1.000     |
| 45 | 4689.226  | 4690.655  | 4670.374  | 0.376     | 0.376     | 0.376     | 0.999     | 0.999     | 1.000     |
| 50 | 4689.411  | 4690.380  | 4670.990  | 0.376     | 0.376     | 0.376     | 0.999     | 0.999     | 1.000     |

Table 8 Allocation data of option2 (option guarantee contract)

| t | Scenario1 | Scenario2 | Scenario3 | Scenario1 | Scenario2 | Scenario3 | Scenario1 | Scenario2 | Scenario3 |
|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 5  | 3513.128  | 3513.128  | 3513.127  | 1.423     | 1.423     | 1.422     | 0.994     | 0.995     | 0.996     |
| 10 | 4473.498  | 4473.498  | 4473.498  | 1.422     | 1.422     | 1.422     | 0.992     | 0.994     | 0.995     |
| 15 | 4533.986  | 4533.986  | 4533.986  | 1.422     | 1.422     | 1.422     | 0.991     | 0.993     | 0.994     |
| 20 | 4588.996  | 4588.996  | 4588.996  | 1.422     | 1.422     | 1.422     | 0.991     | 0.993     | 0.994     |
| 25 | 4726.783  | 4726.783  | 4726.783  | 1.422     | 1.422     | 1.421     | 0.991     | 0.993     | 0.994     |
| 30 | 4614.189  | 4614.189  | 4614.189  | 1.422     | 1.422     | 1.421     | 0.991     | 0.993     | 0.994     |
| 35 | 4409.448  | 4409.448  | 4409.448  | 1.422     | 1.422     | 1.421     | 0.991     | 0.993     | 0.994     |
| 40 | 4407.690  | 4407.690  | 4407.690  | 1.422     | 1.422     | 1.421     | 0.991     | 0.993     | 0.994     |
| 45 | 4407.040  | 4407.040  | 4407.040  | 1.422     | 1.422     | 1.421     | 0.991     | 0.993     | 0.994     |
| 50 | 4406.801  | 4406.801  | 4406.801  | 1.422     | 1.422     | 1.421     | 0.991     | 0.993     | 0.994     |
### Table 9 Changes in order allocation when inequity aversion difference is small

|   | $\Delta U_{LSLR}$ | $\Delta U_{LSLR}$ | $\Delta T^{\text{PPP}}$ |
|---|------------------|------------------|------------------|
|   | None option | Option 1 | Option 2 | None option | Option 1 | Option 2 | None option | Option 1 | Option 2 |
| 10 | 6.835% | 0.029% | 0.006% | 1.553% | 0.019% | 0.005% | 0.624% | 0.012% | 0.024% |
| 15 | 6.366% | 0.030% | 0.006% | 1.553% | 0.020% | 0.005% | 1.279% | 0.015% | 0.026% |
| 20 | 6.366% | 0.030% | 0.006% | 1.213% | 0.021% | 0.005% | 0.449% | 0.013% | 0.028% |
| 25 | 6.253% | 0.031% | 0.006% | 1.413% | 0.021% | 0.005% | 0.750% | 0.013% | 0.022% |
| 30 | 6.253% | 0.031% | 0.006% | 1.625% | 0.021% | 0.005% | 1.442% | 0.013% | 0.022% |
| 35 | 6.302% | 0.031% | 0.006% | 1.848% | 0.021% | 0.005% | 1.442% | 0.013% | 0.023% |
| 40 | 6.333% | 0.031% | 0.006% | 1.848% | 0.021% | 0.005% | 0.371% | 0.013% | 0.022% |
| 45 | 6.454% | 0.031% | 0.006% | 0.909% | 0.021% | 0.005% | 0.371% | 0.013% | 0.023% |
| 50 | 6.444% | 0.031% | 0.006% | 0.909% | 0.021% | 0.005% | 0.371% | 0.013% | 0.023% |

### Table 10 Changes in order allocation when inequity aversion difference is large

|   | $\Delta U_{LSLR}$ | $\Delta U_{LSLR}$ | $\Delta T^{\text{PPP}}$ |
|---|------------------|------------------|------------------|
|   | None option | Option 1 | Option 2 | None option | Option 1 | Option 2 | None option | Option 1 | Option 2 |
| 10 | 21.306% | 0.145% | 0.008% | 4.641% | 0.078% | 0.023% | 4.007% | 0.062% | 0.348% |
| 15 | 20.576% | 0.146% | 0.008% | 4.481% | 0.083% | 0.023% | 3.766% | 0.064% | 0.361% |
| 20 | 21.841% | 0.151% | 0.008% | 4.011% | 0.088% | 0.023% | 2.870% | 0.065% | 0.356% |
| 25 | 20.699% | 0.152% | 0.008% | 4.295% | 0.090% | 0.023% | 2.774% | 0.066% | 0.343% |
| 30 | 19.659% | 0.158% | 0.008% | 4.356% | 0.091% | 0.023% | 2.701% | 0.066% | 0.348% |
| 35 | 19.318% | 0.153% | 0.008% | 4.573% | 0.091% | 0.023% | 2.701% | 0.066% | 0.349% |
| 40 | 19.451% | 0.153% | 0.008% | 4.573% | 0.091% | 0.023% | 2.701% | 0.066% | 0.350% |
| 45 | 19.468% | 0.153% | 0.008% | 4.573% | 0.091% | 0.023% | 2.701% | 0.066% | 0.350% |
| 50 | 19.477% | 0.153% | 0.008% | 4.573% | 0.091% | 0.023% | 2.701% | 0.066% | 0.350% |

### Appendix B. When demand increases, the order allocation results in the case of non-option, option 1 and option 2

#### Table 11 Allocation data of none option contract ([26])

| t | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ |
|---|-----------|-----------|-----------|-----------|-----------|
| 10 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 15 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 20 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 25 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 30 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 35 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 40 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 45 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 50 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |

#### Table 12 Allocation data of option 1 (reservation option contract)

| t | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ | $\Pi_{LSLR}$ |
|---|-----------|-----------|-----------|-----------|-----------|
| 10 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 15 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 20 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 25 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 30 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 35 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 40 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 45 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
| 50 | 5043.467 | 5042.428 | 4990.278 | 0.141 | 0.148 |
### Table 13 Allocation data of $option2$ (option guarantee contract)

| $t$ | $\Pi_{LS1}$ | $\Pi_{LS2}$ | $\Pi_{LS3}$ | $U_{LR1}$ | $U_{LR2}$ | $TP$ |
|-----|-------------|-------------|-------------|----------|----------|------|
| 5   | 4123.226    | 4123.226    | 4123.226    | 1.424    | 1.424    | 1.423 |
| 10  | 5441.720    | 5441.720    | 5441.720    | 1.424    | 1.424    | 1.424 |
| 15  | 5775.426    | 5775.426    | 5775.426    | 1.424    | 1.424    | 1.424 |
| 20  | 5845.852    | 5845.852    | 5845.852    | 1.425    | 1.425    | 1.425 |
| 25  | 5876.104    | 5876.104    | 5876.104    | 1.425    | 1.425    | 1.425 |
| 30  | 5887.931    | 5887.931    | 5887.931    | 1.425    | 1.425    | 1.425 |
| 35  | 5892.383    | 5892.383    | 5892.383    | 1.425    | 1.425    | 1.425 |
| 40  | 5894.035    | 5894.035    | 5894.035    | 1.425    | 1.425    | 1.425 |
| 45  | 5894.645    | 5894.645    | 5894.645    | 1.425    | 1.425    | 1.425 |
| 50  | 5894.869    | 5894.869    | 5894.869    | 1.425    | 1.425    | 1.425 |

### Table 14 Changes in order allocation when inequity aversion difference is small

| $t$ | $\Delta \Pi_{LS1}$ | $\Delta \Pi_{LS2}$ | $\Delta \Pi_{LS3}$ | $\Delta U_{LR1}$ | $\Delta U_{LR2}$ | $\Delta TP$ |
|-----|-------------------|-------------------|-------------------|------------------|------------------|-----------|
| 10  | 0.020%            | 0.027%            | 0.006%            | 4.971%           | 0.010%           | 0.007%    |
| 15  | 0.021%            | 0.026%            | 0.006%            | 2.334%           | 0.009%           | 0.006%    |
| 20  | 0.024%            | 0.026%            | 0.006%            | 0.448%           | 0.008%           | 0.004%    |
| 25  | 0.019%            | 0.025%            | 0.006%            | 0.964%           | 0.008%           | 0.003%    |
| 30  | 0.019%            | 0.025%            | 0.006%            | 1.970%           | 0.008%           | 0.002%    |
| 35  | 0.019%            | 0.025%            | 0.006%            | 0.233%           | 0.008%           | 0.002%    |
| 40  | 0.019%            | 0.025%            | 0.006%            | 0.133%           | 0.008%           | 0.002%    |
| 45  | 0.019%            | 0.025%            | 0.006%            | 0.125%           | 0.008%           | 0.002%    |
| 50  | 0.019%            | 0.025%            | 0.006%            | 0.125%           | 0.008%           | 0.002%    |

### Table 15 Changes in order allocation when inequity aversion difference is large

| $t$ | $\Delta \Pi_{LS1}$ | $\Delta \Pi_{LS2}$ | $\Delta \Pi_{LS3}$ | $\Delta U_{LR1}$ | $\Delta U_{LR2}$ | $\Delta TP$ |
|-----|-------------------|-------------------|-------------------|------------------|------------------|-----------|
| 10  | 0.037%            | 0.131%            | 0.006%            | 2.841%           | 0.031%           | 0.036%    |
| 15  | 0.078%            | 0.127%            | 0.006%            | 1.593%           | 0.031%           | 0.029%    |
| 20  | 0.019%            | 0.126%            | 0.006%            | 2.087%           | 0.028%           | 0.018%    |
| 25  | 0.075%            | 0.125%            | 0.006%            | 2.785%           | 0.026%           | 0.013%    |
| 30  | 0.075%            | 0.125%            | 0.006%            | 0.199%           | 0.026%           | 0.011%    |
| 35  | 0.075%            | 0.124%            | 0.006%            | 0.156%           | 0.026%           | 0.011%    |
| 40  | 0.075%            | 0.124%            | 0.006%            | 0.109%           | 0.026%           | 0.010%    |
| 45  | 0.075%            | 0.124%            | 0.006%            | 0.106%           | 0.026%           | 0.010%    |
| 50  | 0.075%            | 0.124%            | 0.006%            | 0.106%           | 0.026%           | 0.010%    |

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