IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received 24 April 2023, accepted 6 May 2023, date of publication 9 May 2023, date of current version 15 May 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3274697

RESEARCH ARTICLE

Cross-Border E-Commerce Supply Chain Decision-Making Considering Out-of-Stock Aversion Risk and Waste Aversion Risk

XIN XU AND SHAOJIE ZHOU
College of Maritime Economic and Management, Dalian Maritime University (DMU), Dalian 116026, China
Corresponding author: Xin Xu (red86933563@dlmu.edu.cn)

ABSTRACT With the increase of black swan incidents, cross-border e-commerce supply chains are facing more risks. Out-of-stock aversion and waste aversion are examined as the risk preferences of cross-border e-commerce platforms and overseas warehouses based on prospect theory. A cross-border e-commerce supply chain decision making model with four different risk preference combinations is constructed under the Stackelberg game decision making model. The relationships between the risk preference coefficient and the ordering strategy for the overseas warehouse and the pricing strategy for the cross-border e-commerce platform are analyzed through the numerical analysis of an arithmetic case. The results show that: 1) the cross-border e-commerce platform at the leading position has a more prominent impact on the performance of the cross-border e-commerce supply chain; 2) when the overseas warehouse is out-of-stock averse and the cross-border e-commerce platform is waste averse, both the order quantity and pricing increase with the increase of the risk preference coefficient; when the overseas warehouse is waste averse and the cross-border e-commerce platform is out-of-stock averse, both the order quantity and pricing decrease with the increase of the risk preference coefficient; 3) when the overseas warehouse and the cross-border e-commerce platform have the same risk preference, the overseas warehouse adopts a more aggressive ordering strategy when they are more out-of-stock averse, and adopts a more conservative ordering strategy when they are more waste averse.

INDEX TERMS Cross-border e-commerce supply chain, risk preference, stackelberg game, out-of-stock aversion, waste aversion.

I. INTRODUCTION

Cross-border e-commerce is an important way and breakthrough to create new demand for foreign trade in the Internet-based economy, but cross-border e-commerce supply chains face more risks than ordinary e-commerce [1]. With increasing occurrences of black swan incidents in international trade in recent years, it is extremely important to manage risks along cross-border e-commerce supply chains. In particular, the shock caused by the COVID-19 pandemic shapes a set of unique circumstances [2]. Cross-border e-commerce supply chains have accelerated their previous trend in response to new changes and given rise to new components of the supply chain structure. The fast development of overseas warehouses is one of the main forces supporting the anti-trend growth of cross-border e-commerce during the pandemic. For example, according to the data from the General Administration of Customs of China, there were more than 2,000 overseas warehouses in China 2021, with a built-up area of over 16 million square meters, while the import and export of cross-border e-commerce in China reached about 1.92 trillion Yuan in 2021, with a year-on-year growth rate of 18.6%. The impact of COVID-19 will increase the risk of stock management for overseas warehouses, and it is expected that overseas warehouses will play an important role in future cross-border e-commerce supply chains. Schweitzer and Cachon [3] defined this risk as a combination of waste aversion risk and out-of-stock aversion risk. In this

The associate editor coordinating the review of this manuscript and approving it for publication was Daniela Cristina Momete.

context, how waste aversion risk and out-of-stock aversion risk affect the performance of the supply chain under the current cross-border e-commerce supply chain structure is an important issue facing cross-border e-commerce supply chains.

The impact of the COVID-19 pandemic on cross-border e-commerce supply chains is seen as a demand shock [4]. Many researchers [5], [6], [7], [8] have analyzed the impact of demand shock on cross-border e-commerce supply chains. These studies can be broadly divided into two categories: studies on the impact on supply chain decision making [9], [10] and studies on the impact of demand visibility and bullwhip effect on the performance of the supply chain [11], [12]. However, there are still some problems in the current research as follows: first, although some studies have examined the impact of demand uncertainty on cross-border e-commerce supply chains, there is still relatively less attention to demand. The current research area on the impact of demand risk on supply chains is mainly focused on manufacturing supply chains, while there are relatively few studies on cross-border e-commerce supply chains where manufacturing and services are integrated [13]. Secondly, the synergy between cross-border e-commerce and cross-border logistics has been neglected [14]. With the development of cross-border logistics, the structure of the cross-border e-commerce supply chain has been changing gradually, but this issue is mentioned only in a few articles [15], [16]. Finally, compared to demand risk, the internal risks of the cross-border e-commerce supply chain have received less attention. The existing studies have mainly examined the impact of demand risk on suppliers and customers [17]. However, demand risk is rarely incorporated as a risk within the cross-border e-commerce supply chain [1], [18]. In light of the characteristics of the industry, it is currently pressing to address the management of out-of-stock aversion risk and waste aversion risk along the cross-border e-commerce supply chain [3].

The synergy between cross-border e-commerce and cross-border logistics and the integrating role of cross-border e-commerce enterprises in the supply chain [19] are examined in this article. Based on the assumption that the cross-border e-commerce platform and the overseas warehouse are the decision makers of the cross-border e-commerce supply chain, and that the cross-border e-commerce platform is the leader and the overseas warehouse is the follower, a cross-border e-commerce supply chain model with four different risk preference combinations is then constructed based on prospect theory to investigate the impact of different risk preference combinations (shown in Table 1) on the performance of the cross-border e-commerce supply chain.

In summary, this article makes three main contributions:

(1) A cross-border e-commerce supply chain decision making model has been constructed to cover both cross-border e-commerce platforms and overseas warehouses, providing a certain basis for the subsequent research on cross-border e-commerce supply chains in light of the current rapid development of overseas warehouses in cross-border e-commerce supply chains;

TABLE 1. Decision maker risk preference combinations.

Decision maker preference	Out-of-stock aversion of the cross-border e-commerce platform	Waste aversion of the cross-border e-commerce platform
Out-of-stock aversion of the overseas warehouse	Out of stock - Out of stock	Out of stock - waste
Waste aversion of the Overseas warehouse	Waste - out of stock	Waste - Waste

(2) Schweitzer and Cachon classified cognitive biases in newsvendor decision making into overconfidence, underestimation of opportunity cost, risk aversion, loss aversion, out-of-stock aversion and waste aversion [3]. Among them, overconfidence, risk aversion and loss aversion are hot topics in the research on supply chain risks, while out-of-stock aversion and waste aversion have received little attention. Their article examines the impact of these two risk preferences on cross-border e-commerce supply chain decision making, to identify which one can provide a certain decision basis for cross-border e-commerce sellers to respond to safety stock, and also to enrich the research on cognitive biases in newsvendor decision making.

(3) Simultaneously, it considers the risk preferences of two decision makers, including the cross-border e-commerce platform and the overseas warehouse and follows the current research trend of comprehensively evaluating the cognitive characteristics of decision makers, which is conducive to optimizing the decisions made by each decision maker in response to different risk preferences and promoting the sustainable operation of the cross-border e-commerce supply chain.

The article is structured as follows: Section II reviews the relevant articles on supply chain decision making, supply chain decision making under risk preferences and supply chain decision making under different risk preference combinations. Section III examines and discusses the model and assumption under the four different risk preference combinations. Section IV presents the numerical analysis of a case. Section V summarizes the main findings and presents the research outlook.

II. LITERATURE REVIEW

A. STUDIES ON SUPPLY CHAIN DECISION MAKING

Studying the output and pricing decision making of supply chains allows successful firms to achieve optimal performance of the supply chain by integrating internal operations and coordinating external supply chain operations [20]. This is the reason why the search for optimal decision making by decision makers has become one of the key issues concerning the development of supply chains [21].

The current studies related to supply chain decision making can be broadly divided into two phases: early studies are mainly based on a deterministic environment and have examined pricing by news suppliers under a certain quantity of supply [22], [23], [24]. These studies present certain characteristics of the supply chain structure, but they are relatively simple. Most of the recent studies are based on uncertain environments and featured with diverse research levels. Supply chain structures are no longer limited to forward supply chains. The development of e-commerce and concepts such as recycling for remanufacturing has led to the emergence of dual-channel and closed-loop structures. Currently, the research on dual-channel and closed-loop supply chains still needs to cover a number of topics. Specifically, dual-channel supply chains need to focus on some themes such as information asymmetry, demand uncertainty, multiple retailers and multiple cycles, while new models should be developed to address a series of nascent challenges [25]. As for closed-loop supply chains, it is necessary to deal with issues such as COVID-19, environment and sustainability, where multiple objectives and multiple decision variables should be incorporated into modeling [26], [27]. In supply chains, decision makers also exhibit different behaviors, such as risk preferences [28], concerns with equity [29], altruistic preferences [30], [31]. There are other topics such as different power compositions [32] and the development of new technologies such as big data and the Internet [33], [34].

Cross-border e-commerce supply chains are somewhat similar to but also different from e-commerce supply chains. Particularly, cross-border e-commerce supply chains are more concerned with the cognitive characteristics of supply chain members such as consumer behavioral preferences and decision maker risk preferences [35], [36]. However, the current research on cross-border e-commerce supply chains is mainly concentrated on channel competition, information asymmetry, manufacturer or supplier encroachment, advertising, online markets, supply chain coordination, etc., resulting in the unavailability of sufficient understanding of the cognitive characteristics of supply chain members [37].

B. STUDIES ON SUPPLY CHAIN DECISION MAKING UNDER RISK PREFERENCES

Supply chain decision making under risk preferences is a key topic in the management of supply chain risks [38] and requires further research in this field [39]. Risks appear in many forms and need to be assessed according to their specific source [13]. This article focuses on the incorporation of demand risk into the endogenous risks of the supply chain. There are some existing studies on how to reduce the impact of endogenous risk manifestations, such as loss aversion and risk aversion [40], [41], [42], [43]. These studies all confirm the idea that risk manifestations lead to higher costs.

However, in addition to loss aversion and risk aversion, there are many kinds of endogenous risks within supply chains, which are related to the characteristics of the industry [44]. The corresponding other types of endogenous risks are comparatively under-researched.

In response to the newsvendor issue, Schweitzer and Cachon classified cognitive biases in newsvendor decision making into overconfidence, underestimation of opportunity cost, risk aversion, loss aversion, out-of-stock aversion and waste aversion [3]. Since each type of risk may lead to different problems in the supply chain, it is necessary to scrutinize each risk. However, it is clear that there is insufficient research on out-of-stock aversion risk and waste aversion risk.

C. STUDIES ON SUPPLY CHAIN DECISION MAKING UNDER DIFFERENT RISK PREFERENCE COMBINATIONS

All the participants in the supply chain are stakeholders. Hence, the risk assessment of the supply chain should be conducted based on the cognitive characteristics of stakeholders [13].

Nevertheless, most of the existing studies on risk preferences have only considered the cognitive characteristics of a single type of decision makers. To be specific, some scholars [45], [46] have discussed only the risk preferences of suppliers, while some scholars [47], [48] have analyzed only the risk preferences of retailers. A small number of studies have comprehensively considered the cognitive characteristics of all decision makers in the supply chain. Chen and Xiao [49] investigated the decision making and coordination mechanism for a supply chain consisting of a risk-neutral manufacturer and a loss-averse retailer. Choi et al. [50] examined decision making for a supply chain consisting of a risk-averse manufacturer and two risk-averse retailers.

Under situations where only a single decision maker has a risk preference, there is generally a lower stock when the decision maker is more risk averse. However, if multiple decision makers have risk preferences, what impact will their interactions have on supply chain decision making? This is still a blank in the current research on supply chain risks.

III. PROBLEM DESCRIPTION AND MODEL BUILDING

A. NOTATIONS

To facilitate understanding, Table 2 lists the symbols used in this article and their respective meanings. Furthermore, we make several assumptions, including $p_j > c_{jm}$, $p_m > p_j + c_{jm}$, $c_{jm} + \omega_m^+ + \omega_j^+ > v > c_{jm}$, $p_j > b$, to ensure the profitability of both the cross-border e-commerce platform and the overseas warehouse, as well as the willingness of the platform to repurchase products.

B. ASSUMPTIONS

In order to establish the model more effectively, this article makes certain simplifications to the complex real-world situation and proposes some assumptions based on reality and logic thinking.

Assumption 1: the cross-border e-commerce platform and the overseas warehouse are completely rational, and the

TABLE 2. Notations.

Notations	Contents
j, m	j represents the cross-border e-commerce platform; m represents the overseas warehouse
n	n represents different risk preference combinations, $n \in \{1,2,3,4\}$
p_j	Price of products per unit sold by the cross-border e-commerce platform to the overseas warehouse
p_m	Price of products per unit sold by the overseas warehouse to customers
c_{jm}	Cost of transactions per unit between j and m
Q	Quantity of sales from the cross-border e-commerce platform to the overseas warehouse
v	Residual value of products remaining after sales per unit
b	Repurchase price of products remaining per unit
ω_i^+	Stock-up cost for $i, i \in \{j, m\}$ per unit
ω_i^-	Out-of-stock cost for i, $i \in \{j, m\}$ per unit
x	Random demand in the consumer market
$f(x)$	Probability density function of random demand x
$F(x)$	Distribution Function of Random Demand x
μ	Mean of random demand x
$S(Q)$	Expected transaction quantity
$L(Q)$	Expected stock quantity
$W(Q)$	Expected out-of-stock quantity
$\Pi_{jm}(Q)$	Expected profit of the entire supply chain
$\Pi_i(Q)$	Expected profit of i, $i \in \{j, m\}$
$U_{in}(\Pi_i(Q))$	Utility function of i under different risk preference combinations, $i \in \{j, m\}, n \in \{1,2,3,4\}$
Q^*	Order quantity to achieve optimal performance across the entire supply chain network
Q_{in}	Supply quantity for i under different risk preference combinations, $i \in \{j, m\}, n \in \{1,2,3,4\}$
p_{in}	Market price for i under different risk preference combinations, $i \in \{j, m\}, n \in \{1,2,3,4\}$
α_n	Risk preference coefficient of the overseas warehouse under different risk preference combinations, $n \in \{1,2,3,4\}$
β_n	Risk preference coefficient of the cross-border e-commerce platform under different risk preference combinations, $n \in \{1,2,3,4\}$

decision-making information is completely symmetrical for both parties.

Assumption 2: There is only one product of the same quality circulating in the supply chain.

Assumption 3: All the products sold on the cross-border e-commerce platform are manufactured goods, regardless of how they are produced and manufactured.

Assumption 4: Only the transaction cost is considered in transactions between the supply chain decision makers.

Assumption 5: The price is determined by the decision makers, without considering the functional relationship between price and demand.

Assumption 6: The cross-border e-commerce platform and the overseas warehouse are independent decision-making enterprises, rather than subject to Amazon's one-stop operation.

C. PROBLEM DESCRIPTION

This article examines a two-layer supply chain consisting of a single cross-border e-commerce platform (j) and a single overseas warehouse (m). In view of the dominant position of cross-border e-commerce platforms in the market and the control of information, Stackelberg game is utilized to reflect their leadership status. As buyers and sellers in the cross-border e-commerce supply chain are located in different territories while overseas warehouses are generally located in the same territory with consumers, it is easier to collet demand information. The game steps in this study are as follows: (1) The overseas warehouse provides the collected demand information to the cross-border e-commerce platform, which then determines its own price and supply quantity based on customer need. (2) The overseas warehouse determines its order quantity based on the price and supply quantity determined by the cross-border e-commerce platform. (3) The cross-border e-commerce platform dynamically adjusts its price and supply quantity based on its order quantity to maximize profits. (4) The above steps are repeated until coordination is achieved in the supply chain.

Decision makers in the supply chain tend to anchor a reference point and make insufficient adjustment to simplify the decision making process [3]. Therefore, the model in this article is established in the following way: (1) The optimal order quantity Q^* under centralized decision making is analyzed and used as the anchor point for coordination in the supply chain; (2) The supply quantity for the cross-border e-commerce platform and the order quantity for the overseas warehouse under decentralized decision making are calculated under four risk preference combinations; (3) To achieve supply chain coordination, the cross-border e-commerce platform ultimately adjusts the supply quantity according to the optimal order quantity under centralized decision making and thereby determines the final price; However, there are some problems in the establishment of this model with regard to the losses of decentralized decision making compared to centralized decision making and the impossibility to reach the level of centralized decision making without external forces [51]. Song and Hu [52] have revealed the coordinating effect of repurchase contracts on supply chains with risk preferences. Accordingly, this article can introduce repurchase contracts to better coordinate the supply chain.

There are currently two solutions to the problem of modelling supply chains under uncertain demand. One is to introduce random variables and the other is to introduce a linear demand function. This article refers to the study by Yu et al. [53], where it is assumed that the market is open without any upper bound on the market demand. Demand $x \in [0, +\infty)$ is treated as a continuous random variable. Its probability density function is $f(x)$, and its cumulative distribution function is $F(x)$. It has inverse distribution, denoted by $F^{-1}(x)$. Random variables are important factors in generating risks. There are a number of methods to measure supply chain risks in academia, such as mean-variance model, value-at-risk (VaR) model and conditional value-at-risk (CVaR) model. Some scholars have used mean-variance model to measure the risk profit for risk takers [54], [55]. However, this method cannot directly reflect market fluctuations. To solve this problem, some scholars have introduced VaR and CVaR models [56],

[57], [58]. Compared to VaR, CVaR has advantages including monotonicity and ease of computation. These models are anchored in the utility function and describe the interaction between uncertainty and risk attitudes. However, Cao et al. [59] used 'utility=economic payoff + psychological satisfaction' to integrate economic benefits and loss aversion utility, suggested that the choice of the anchor point is not fixed and proposed a parameter to describe the degree of risk aversion. A higher parameter means that the decision maker is more risk averse. When the parameter is equal to 0, the decision maker is risk neutral. Compared to other risk measures, this method is simpler and can more intuitively reflect the impact of risk preference on pricing decision making. Similarly, we use this formula to calculate the utility of the cross-border e-commerce platform and the overseas warehouse.

D. MODEL BUILDING

It is assumed that the subscripts j, m denote the parameters relevant to the cross-border e-commerce platform and the overseas warehouse respectively; p_j is the price sold by the cross-border e-commerce platform to the overseas warehouse; p_m is the price sold by the overseas warehouse to consumers; c_{jm} is the transaction cost of products per unit; v refers to the residual value of products remaining after sales per unit; b is the agreed-upon repurchase price of remaining products per unit, and satisfies the basic requirements outlined in the repurchase contract. Q is the order quantity of transactions between the cross-border e-commerce platform and the overseas warehouse; ω^+ is the cost per unit of stock; ω^- is the cost per unit of out-of-stock; x is the stochastic demand in the consumer market; $f(x)$ and $F(x)$ are the probability density function and distribution function of the stochastic demand x respectively; μ is the mean value of the demand; $S(Q)$ denotes the expected number of transactions; $L(Q)$ denotes the expected quantity of stock; $W(Q)$ is the expected quantity of out-of-stock.

$$\begin{aligned} S(Q) &= Emin(x, Q) = Q - \int_0^Q (Q-x)\, dF(x) \\ L(Q) &= E(Q-x)^+ = Q - S(Q) = \int_0^Q (Q-x)\, dF(x) \\ W(Q) &= E(x-Q)^+ = \mu - S(Q) = \int_Q^\infty (x-Q)\, dF(x) \end{aligned} \tag{1}$$

(1) Coordination model of cross-border e-commerce supply chain under centralized decision making

Supply chain network equilibrium is to view the whole supply chain as an integrated large size enterprise and aims to optimize the performance of the whole supply chain network. Therefore, $\Pi_{jm}(Q)$, $\Pi_j(Q)$ and $\Pi_m(Q)$ are set here to denote the expected profit of the supply chain, the cross-border e-commerce platform and the overseas warehouse respectively. Then, the expected profit of the overseas warehouse is expressed as:

$$\begin{aligned} \Pi_m(Q) &= p_m S(Q) + bL(Q) \\ &\quad - p_j Q - \omega_m^+ L(Q) - \omega_m^- W(Q) \\ &= \left(p_m + \omega_m^+ + \omega_m^- - b\right) S(Q) \\ &\quad + \left(b - p_j - \omega_m^+\right) Q - \omega_m^- \mu \end{aligned} \tag{2}$$

The expected profit of the cross-border e-commerce platform is expressed as:

$$\begin{aligned} \Pi_j(Q) &= p_j Q + (v-b) L(Q) \\ &\quad - c_{jm} Q - \omega_j^+ L(Q) - \omega_j^- W(Q) \\ &= \left(p_j - c_{jm} - \omega_j^+ + v - b\right) Q \\ &\quad + \left(b - v + \omega_j^+ + \omega_j^-\right) S(Q) - \omega_j^- \mu \end{aligned} \tag{3}$$

The expected profit of the supply chain as a whole is expressed as:

$$\begin{aligned} \Pi_{jm}(Q) &= \Pi_j(Q) + \Pi_m(Q) \\ &= \left(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v\right) S(Q) \\ &\quad - \left(c_{jm} + \omega_j^+ + \omega_m^+ - v\right) Q - \omega_j^- \mu - \omega_m^- \mu \end{aligned} \tag{4}$$

According to Leibniz's law, $\Pi_{jm}(Q)$ is a concave function on Q. To achieve the maximum value of $\Pi_{jm}(Q)$, it is necessary to make its first-order derivative $d\Pi_{jm}(Q)/dQ$=0, so that the optimal order quantity Q of the supply chain is expressed as:

$$Q^* = F^{-1}\left(\frac{p_m + \omega_m^- - c_{jm} + \omega_j^-}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v}\right) \tag{5}$$

The next step of model construction is to analyze decision making under four different preference combinations:

(2) The overseas warehouse has the risk preference of out-of-stock aversion, and the cross-border e-commerce platform also has the risk preference of out-of-stock aversion.

It is assumed that α_1 and β_1 are the risk preference coefficient per unit of product for the overseas warehouse's out-of-stock aversion and the risk preference coefficient per unit of product for the cross-border e-commerce platform's out-of-stock aversion respectively. When α_1 and β_1 are larger, the degree of aversion is higher. Meanwhile, it is assumed that $U_{m1}(\Pi_m(Q))$ and $U_{j1}(\Pi_j(Q))$ are respectively the utility functions for the overseas warehouse and the cross-border e-commerce platform with the risk preference of out-of-stock aversion. Thus, the obtained expected utility functions for the overseas warehouse and the cross-border e-commerce platform can be expressed as follows:

$$\begin{aligned} &E\left(U_{m1}\left(\Pi_m(Q)\right)\right) \\ &\quad = p_m S(Q) + bL(Q) - p_j Q \\ &\qquad - \omega_m^+ L(Q) - \omega_m^- W(Q) - \alpha_1 \int_Q^\infty (x-Q) f(x)\, dx \\ &\quad = \left(p_m + \omega_m^+ + \omega_m^- - b\right) S(Q) + \left(\mathrm{b} - p_j - \omega_m^+\right) Q \\ &\qquad - \omega_m^- \mu - \alpha_1 \int_Q^\infty (x-Q) f(x)\, dx \end{aligned} \tag{6}$$

$$\begin{aligned} &E\left(U_{j1}\left(\Pi_j(Q)\right)\right) \\ &\quad = p_j Q + (v-b) L(Q) - c_{jm} Q \end{aligned}$$

$$
\begin{aligned}
&- \omega_j^+ L(Q) - \omega_j^- W(Q) - \beta_1 \int_Q^\infty (x-Q) f(x)\,dx \\
&= \left(p_j^- - c_{jm} - \omega_j^+ + v - b\right) Q \\
&\quad + \left(b - v + \omega_j^+ + \omega_j^-\right) S(Q) \\
&\quad - \omega_j^- \mu - \beta_1 \int_Q^\infty (x-Q) f(x)\,dx
\end{aligned} \tag{7}
$$

Proposition 1: According to Leibniz's law, $E(U_{m1}(\Pi_m(Q)))$ is a concave function on Q. To achieve the maximum value of $E(U_{m1}(\Pi_m(Q)))$, it is necessary to make its first-order derivative $dE(U_{m1}(\Pi_m(Q)))/dQ=0$ and its second-order derivative $d^2E(U_{m1}(\Pi_m(Q)))/dQ^2<0$. Thus:

$$
Q_{m1} = F^{-1}\left(\frac{p_m + \omega_m^+ + \alpha_1 - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_1 - b}\right) \tag{8}
$$

In the same way, the following equation can be obtained:

$$
Q_{j1} = F^{-1}\left(\frac{p_j + \omega_j^- + \beta_1 - c_{jm}}{\omega_j^+ + \omega_j^- + \beta_1 + b - v}\right) \tag{9}
$$

The necessary condition to achieve supply chain equilibrium is $Q_{j1} = Q^*$. This equation can be used to get:

$$
\begin{aligned}
p_{j1} = &\frac{\left(p_m + \omega_m^- - c_{jm} + \omega_j^-\right)\left(\omega_j^+ + \omega_j^- + b - v\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\
&- \frac{\left(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v\right)\left(\omega_j^- - c_{jm}\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\
&- \frac{\left(c_{jm} + \omega_m^+ + \omega_j^+ - v\right)\beta_1}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v}
\end{aligned} \tag{10}
$$

Lemma 1: In Proposition 1, Q_{m1} is positively correlated with α_1; p_{j1} is negatively correlated with β_1; the degree of correlation is jointly determined by p_m, c_{jm}, ω_m^+, ω_m^-, ω_j^+ and ω_j^+.

As can be seen from Lemma 1, when the overseas warehouse has the preference of out-of-stock aversion and the cross-border e-commerce platform has the preference of out-of-stock aversion, the optimal order quantity for the overseas warehouse keeps increasing while the selling price for the cross-border e-commerce platform keeps decreasing as the aversion coefficient increases.

(3) The overseas warehouse has the risk preference of out-of-stock aversion, while the cross-border e-commerce platform has the risk preference of waste aversion.

It is assumed that α_2 and β_2 are the risk preference coefficient per unit of product for the overseas warehouse's out-of-stock aversion and the risk preference coefficient per unit of product for the cross-border e-commerce platform's waste aversion respectively. When α_2 and β_2 are higher, the degree of aversion is higher. Meanwhile, it is assumed that $U_{m2}(\Pi_m(Q))$ and $U_{j2}(\Pi_j(Q))$ are respectively the utility functions for the overseas warehouse with the risk preference of out-of-stock aversion and for cross-border e-commerce platform with the risk preference of waste aversion. Thus, the obtained expected utility functions for the overseas warehouse and the cross-border e-commerce platform can be expressed as:

$$
\begin{aligned}
&E\left(U_{m2}\left(\Pi_m(Q)\right)\right) \\
&\quad = p_m S(Q) + bL(Q) - p_j Q \\
&\quad\quad - \omega_m^+ L(Q) - \omega_m^- W(Q) - \alpha_2 \int_Q^\infty (x-Q) f(x)\,dx \\
&\quad = \left(p_m + \omega_m^+ + \omega_m^- - b\right) S(Q) + \left(b - p_j - \omega_m^+\right) Q \\
&\quad\quad - \omega_m^- \mu - \alpha_2 \int_Q^\infty (x-Q) f(x)\,dx
\end{aligned} \tag{11}
$$

$$
\begin{aligned}
&E\left(U_{j2}\left(\Pi_j(Q)\right)\right) \\
&\quad = p_j Q + (v-b) L(Q) - c_{jm} Q \\
&\quad\quad - \omega_j^+ L(Q) - \omega_j^- W(Q) - \beta_2 \int_Q^\infty (x-Q) f(x)\,dx \\
&\quad = \left(p_j^- - c_{jm} - \omega_j^+ + v - b\right) Q \\
&\quad\quad + \left(b - v + \omega_j^+ + \omega_j^-\right) S(Q) \\
&\quad\quad - \omega_j^- \mu - \beta_2 \int_0^Q (Q-x) f(x)\,dx
\end{aligned} \tag{12}
$$

Proposition 2: According to Leibniz's law, $E(U_{m2}(\Pi_m(Q)))$ is a concave function on Q. To achieve the maximum value of $E(U_{m2}(\Pi_m(Q)))$, it is necessary to make its first-order derivative $dE(U_{m2}(\Pi_m(Q)))/dQ=0$ and its second-order derivative $d^2E(U_{m2}(\Pi_m(Q)))/dQ^2<0$. Thus:

$$
Q_{m2} = F^{-1}\left(\frac{p_m + \omega_m^+ + \alpha_2 - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_2 - b}\right) \tag{13}
$$

In the same way, the following equation can be obtained:

$$
Q_{j2} = F^{-1}\left(\frac{p_j + \omega_j^- - c_{jm}}{b - v + \omega_j^+ + \omega_j^- + \beta_2}\right) \tag{14}
$$

The necessary condition to achieve supply chain equilibrium is $Q_{j2} = Q^*$. This equation can be used to get:

$$
\begin{aligned}
p_{j2} = &\frac{\left(p_m + \omega_m^- - c_{jm} + \omega_j^-\right)\left(\omega_j^+ + \omega_j^- + b - v\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\
&+ \frac{\left(c_{jm} - \omega_j^-\right)\left(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\
&+ \frac{\beta_2(p_m + \omega_m^- - c_{jm} + \omega_j^-)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v}
\end{aligned} \tag{15}
$$

Lemma 2: In Proposition 2, Q_{m2} is positively correlated with α_2; p_{j2} is positively correlated with β_2; the degree of correlation is determined by p_m, c_{jm}, ω_m^+, ω_m^-, ω_j^+ and ω_j^+.

As can be seen from Lemma 2, when the overseas warehouse has the preference of out-of-stock aversion and the cross-border e-commerce platform has the preference of waste aversion, the optimal order quantity for the overseas warehouse increases while the selling price for the cross-border e-commerce platform increases as the aversion coefficient increases.

(4) The overseas warehouse has the risk preference of waste aversion, while the cross-border e-commerce platform has the risk preference of out-of-stock aversion.

It is assumed that α_3 and β_3 are the risk preference coefficient per unit of product for the overseas warehouse's waste aversion and the risk preference coefficient per unit of product for the cross-border e-commerce platform's out-of-stock aversion respectively.

When α_3 and β_3 are larger, the degree of aversion is higher. Meanwhile, it is assumed that $U_{m3}(\Pi_m(Q))$ and $U_{j3}(\Pi_j(Q))$ are respectively the utility functions for the overseas warehouse with the risk preference of waste aversion and the cross-border e-commerce platform with the risk preference of out-of-stock aversion. Thus, the obtained expected utility functions for the overseas warehouse and the cross-border e-commerce platform can be expressed as follows:

$$\begin{aligned} E\left(U_{m3}\left(\Pi_m\left(Q\right)\right)\right) &= p_m S\left(Q\right) + bL\left(Q\right) - p_j Q \\ &\quad - \omega_m^+ L\left(Q\right) - \omega_m^- \mathrm{W}\left(Q\right) - \alpha_3 \int_0^Q \left(x - Q\right) f\left(x\right) dx \\ &= \left(p_m + \omega_m^+ + \omega_m^- - b\right) S\left(Q\right) \\ &\quad + \left(b - p_j - \omega_m^+\right) Q - \omega_m^- \mu - \alpha_3 \int_0^Q \left(Q - x\right) f\left(x\right) dx \end{aligned} \tag{16}$$

$$\begin{aligned} E\left(U_{j3}\left(\Pi_j\left(Q\right)\right)\right) &= p_j Q + \left(v - b\right) L\left(Q\right) - c_{jm} Q \\ &\quad - \omega_j^+ L\left(Q\right) - \omega_j^- W\left(Q\right) - \beta_3 \int_Q^\infty \left(x - Q\right) f\left(x\right) dx \\ &= \left(p_j^- - c_{jm} - \omega_j^+ + v - b\right) Q \\ &\quad + \left(b - v + \omega_j^+ + \omega_j^-\right) S\left(Q\right) \\ &\quad - \omega_j^- \mu - \beta_3 \int_Q^\infty \left(x - Q\right) f\left(x\right) dx \end{aligned} \tag{17}$$

Proposition 3: According to Leibniz's law, $E(U_{m3}(\Pi_m(Q)))$ is a concave function on Q. To achieve the maximum value of $E(U_{m3}(\Pi_m(Q)))$, it is necessary to make its first-order derivative $dE(U_{m3}(\Pi_m(Q)))/dQ=0$ and its second-order derivative $d^2E(U_{m3}(\Pi_m(Q)))/dQ^2<0$. Thus:

$$Q_{m3} = F^{-1}\left(\frac{p_m + \omega_m^- - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_3 - b}\right) \tag{18}$$

In the same way, the following equation can be obtained:

$$Q_{j3} = F^{-1}\left(\frac{p_j + \omega_j^- + \beta_3 - c_{jm}}{\omega_j^+ + \omega_j^- + \beta_3 + b - v}\right) \tag{19}$$

The necessary condition to achieve supply chain equilibrium is $Q_{j3} = Q^*$. This equation can be used to get:

$$\begin{aligned} p_{j3} &= \frac{\left(p_m + \omega_m^- - c_{jm} + \omega_j^-\right)\left(\omega_j^+ + \omega_j^- + b - v\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\ &\quad - \frac{\left(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v\right)\left(\omega_j^- - c_{jm}\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\ &\quad - \frac{\left(c_{jm} + \omega_m^+ + \omega_j^+ - v\right)\beta_3}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \end{aligned} \tag{20}$$

Lemma 3: In Proposition 3, Q_{m3} is negatively correlated with α_3; p_{j3} is negatively correlated with β_3; the degree of correlation is jointly determined by p_m, c_{jm}, ω_m^+, ω_m^-, ω_j^+ and ω_j^+.

As can be seen from Lemma 3, when the overseas warehouse has the preference of waste aversion and the cross-border e-commerce platform has the preference of out-of-stock aversion, the optimal order quantity for the overseas warehouse keeps decreasing while the selling price for the cross-border e-commerce platform keeps decreasing as the aversion coefficient increases.

(5) The overseas warehouse has the risk preference of waste aversion, and the cross-border e-commerce platform also has the risk preference of waste aversion.

It is assumed that α_4 and β_4 are the risk preference coefficient per unit of product for the overseas warehouse's waste aversion and the risk preference coefficient per unit of product for the cross-border e-commerce platform's waste aversion respectively. When α_4 and β_4 are higher, the degree of aversion is higher. Meanwhile, it is assumed that $U_{m4}(\Pi_m(Q))$ and $U_{j4}(\Pi_j(Q))$ are respectively the utility functions for the overseas warehouse and the cross-border e-commerce platform with the risk preference of waste aversion. Thus, the obtained expected utility functions for the overseas warehouse and the cross-border e-commerce platform can be expressed as:

$$\begin{aligned} E\left(U_{m4}\left(\Pi_m\left(Q\right)\right)\right) &= p_m S\left(Q\right) + bL\left(Q\right) - p_j Q \\ &\quad - \omega_m^+ L\left(Q\right) - \omega_m^- \mathrm{W}\left(Q\right) - \alpha_4 \int_0^Q \left(x - Q\right) f\left(x\right) dx \\ &= \left(p_m + \omega_m^+ + \omega_m^- - b\right) S\left(Q\right) + \left(b - p_j - \omega_m^+\right) Q \\ &\quad - \omega_m^- \mu - \alpha_4 \int_0^Q \left(Q - x\right) f\left(x\right) dx \end{aligned} \tag{21}$$

$$\begin{aligned} E\left(U_{j4}\left(\Pi_j\left(Q\right)\right)\right) &= p_j Q + \left(v - b\right) L\left(Q\right) - c_{jm} Q \\ &\quad - \omega_j^+ L\left(Q\right) - \omega_j^- W\left(Q\right) - \beta_4 \int_Q^\infty \left(x - Q\right) f\left(x\right) dx \\ &= \left(p_j^- - c_{jm} - \omega_j^+ + v - b\right) Q \\ &\quad + \left(b - v + \omega_j^+ + \omega_j^-\right) S\left(Q\right) \end{aligned}$$

$$- \omega_j^- \mu - \beta_4 \int_0^Q (Q-x) f(x)\, dx \tag{22}$$

Proposition 4: According to Leibniz's law, $E(U_{m4}(\Pi_m(Q)))$ is a concave function on Q. To achieve the maximum value of $E(U_{m4}(\Pi_m(Q)))$, it is necessary to make its first-order derivative $dE(U_{m4}(\Pi_m(Q)))/dQ=0$ and its second-order derivative $d^2E(U_{m4}(\Pi_m(Q)))/dQ^2<0$. Thus:

$$Q_{m4} = F^{-1}\left(\frac{p_m + \omega_m^- - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_4 - b}\right) \tag{23}$$

In the same way, the following equation can be obtained:

$$Q_{j4} = F^{-1}\left(\frac{p_j + \omega_j^- - c_{jm}}{b - v + \omega_j^+ + \omega_j^- + \beta_4}\right) \tag{24}$$

The necessary condition to achieve supply chain equilibrium is $Q_{j4} = Q^*$. This equation can be used to get:

$$\begin{aligned} p_{j4} = & \frac{\left(p_m + \omega_m^- - c_{jm} + \omega_j^-\right)\left(\omega_j^+ + \omega_j^- + b - v\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\ & + \frac{\left(c_{jm} - \omega_j^-\right)\left(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v\right)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \\ & + \frac{\beta_4(p_m + \omega_m^- - c_{jm} + \omega_j^-)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} \end{aligned} \tag{25}$$

Lemma 4: In Proposition 4, Q_{m4} is negatively correlated with α_4; p_{j4} is positively correlated with β_4; the degree of correlation is jointly determined by p_m, c_{jm}, ω_m^+, ω_m^-, ω_j^+ and ω_j^+.

As can be seen from Lemma 4, when the overseas warehouse has the preference of waste aversion and the cross-border e-commerce platform has the preference of waste aversion, the optimal order quantity for the overseas warehouse decreases and the selling price for the cross-border e-commerce platform increases as the aversion coefficient increases.

E. SUMMARIZE

The detailed information of the optimal ordering strategy under different risk preference combinations is shown in Table 3.

IV. NUMERICAL ANALYSIS

A. CASE DATA AND COMPARATIVE ANALYSIS

The findings in Section III are analyzed numerically to provide a more intuitive picture of the impact of different risk preference combinations on the performance of the supply chain as well as the changing trends in the ordering strategy for the overseas warehouse and the selling price set by the cross-border e-commerce platform. Amazon, which currently holds the title of the world's largest online retailer, achieved rapid growth between 2019 and 2022. Despite this success, the company has faced criticisms from its suppliers. In fact, between October 18, 2022 and January 1, 2023, around 12,600 comments were posted on Amazon's redesigned seller forum, conveying concerns about shipping stock to the company. To obtain relatively realistic data for the simulation of our model, we investigate the products listed on Amazon. Our focus is put on a specific bath towel product of which the production cost is \$5 and the normal selling price in China is \$10. However, if a large number of such towels are transported to overseas warehouses and sold through cross-border e-commerce, the unit price of this product could be around \$15, higher than the domestic price. This includes an average charge of \$1 for taxes and storage fees. After transactions, the remaining products have a value of \$3 and would be repurchased by the cross-border e-commerce platform at a price of \$8 fee. The corresponding data above is put into the model in this article, so that the initial selling price for the overseas warehouse p_m=15, the ordering price p_j=10, the transaction cost c_{jm} =2, the out-of-stock cost for the overseas warehouse ω_m^-=1, the stock-up cost ω_m^+=1, the out-of-stock cost for the cross-border e-commerce platform ω_j^-=1, the stock-up cost ω_j^+=1, the salvage value v=3, and the repurchase price b=8. In addition, it is assumed that the risk preference coefficients of the two decision makers satisfy $\alpha_i\sim$ [0,20] and $\beta_i\sim$ [0,20], and that the market demand follows the uniform distribution *F(x)*~ *[10], [20]*.

Firstly, the initial data is put into Equation 5, obtaining that the optimal order quantity for the overseas warehouse in the cross-border e-commerce supply chain is about 37.27 when no risk is considered. Secondly, the equilibrium solutions for cross-border e-commerce supply chain decision making under different risk preference combinations are obtained with an interval of 2, as shown in Table 4.

From Table 4, it can be seen that although the order quantity for overseas warehouse is nonlinearly related to the risk aversion preference coefficient in the equation, the results concerning quantity are approximately linearly related after

TABLE 3. Results.

risk preference combinations	p_j	Q_m
Out of stock – out of stock	$p_{j1} = \frac{(p_m + \omega_m^- - c_{jm} + \omega_j^-)(\omega_j^+ + \omega_j^- + b - v)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} - \frac{(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v)(\omega_j^- - c_{jm})}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} - \frac{(c_{jm} + \omega_m^+ + \omega_j^+ - v)\beta_1}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v}$	$F^{-1}\left(\frac{p_m + \omega_m^+ + \alpha_1 - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_1 - b}\right)$
Out of stock - waste	$p_{j2} = \frac{(p_m + \omega_m^- - c_{jm} + \omega_j^-)(\omega_j^+ + \omega_j^- + b - v)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} + \frac{(c_{jm} - \omega_j^-)(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} + \frac{\beta_2(p_m + \omega_m^- - c_{jm} + \omega_j^-)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v}$	$F^{-1}(\frac{p_m + \omega_m^+ + \alpha_2 - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_2 - b})$
Waste - out of stock	$p_{j3} = \frac{(p_m + \omega_m^- - c_{jm} + \omega_j^-)(\omega_j^+ + \omega_j^- + b - v)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} - \frac{(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v)(\omega_j^- - c_{jm})}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} - \frac{(c_{jm} + \omega_m^+ + \omega_j^+ - v)\beta_3}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v}$	$F^{-1}\left(\frac{p_m + \omega_m^- - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_3 - b}\right)$
Waste - waste	$p_{j4} = \frac{(p_m + \omega_m^- - c_{jm} + \omega_j^-)(\omega_j^+ + \omega_j^- + b - v)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} + \frac{(c_{jm} - \omega_j^-)(p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v} + \frac{\beta_4(p_m + \omega_m^- - c_{jm} + \omega_j^-)}{p_m + \omega_m^+ + \omega_m^- + \omega_j^+ + \omega_j^- - v}$	$F^{-1}(\frac{p_m + \omega_m^- - p_j}{p_m + \omega_m^+ + \omega_m^- + \alpha_4 - b})$

TABLE 4. Equilibrium solutions FOR cross-border e-commerce supply chain decision making under different risk preference combinations.

Parameter	Corresponding values										
α_1	0	2	4	6	8	10	12	14	16	18	20
Q_1	16.67	17.27	17.69	18.00	18.24	18.42	18.57	18.70	18.80	18.89	18.97
β_1	0	2	4	6	8	10	12	14	16	18	20
p_1	7.56	7.44	7.31	7.19	7.06	6.94	6.81	6.69	6.56	6.44	6.31
α_2	0	2	4	6	8	10	12	14	16	18	20
Q_2	16.67	17.27	17.69	18.00	18.24	18.42	18.57	18.70	18.80	18.89	18.97
β_2	0	2	4	6	8	10	12	14	16	18	20
p_2	7.56	9.44	11.31	13.19	15.06	16.94	18.81	20.69	22.56	24.44	26.31
α_3	0	2	4	6	8	10	12	14	16	18	20
Q_3	16.67	15.45	14.62	14.00	13.53	13.16	12.86	12.61	12.40	12.22	12.07
β_3	0	2	4	6	8	10	12	14	16	18	20
p_3	7.56	7.44	7.31	7.19	7.06	6.94	6.81	6.69	6.56	6.44	6.31
α_4	0	2	4	6	8	10	12	14	16	18	20
Q_4	16.67	15.45	14.62	14.00	13.53	13.16	12.86	12.61	12.40	12.22	12.07
β_4	0	2	4	6	8	10	12	14	16	18	20
p_4	7.56	9.44	11.31	13.19	15.06	16.94	18.81	20.69	22.56	24.44	26.31

retaining two decimal places due to the small out-of-stock and waste cost for the overseas warehouse and the cross-border e-commerce platform. When decision makers in the cross-border e-commerce supply chain consider internal risks, even when the risk preference coefficient is 0, the optimal order quantity for the overseas warehouse decreases on the whole compared to when no risk is considered. This suggests that the impact of risks on the cross-border e-commerce supply chain results in higher costs [60]. Such costs can drive decision makers to remeasure their behaviors and take the impact of risks as a condition to gain value [13]. According to utility theory, the losses caused by the costs triggered by risk shock force decision makers to adopt a relatively conservative strategy to ensure resilience of the supply chain, avoid disruptions to the supply chain and appropriately reduce order quantity in the supply chain. Furthermore, under situations where risks are present, the price decided by the cross-border e-commerce supply chain is typically lower than the initial wholesale price, but higher than the transaction cost. This indicates that the supply chain automatically adjusts pricing to address any potential issues caused by excessive profits in the market. This approach is consistent with the study by Wang et al. [54]. Moreover, when faced with different risks, the cross-border platform tends to appropriately set a price lower than their initial wholesale price to ensure the smooth operation of the supply chain. This pattern is also aligned with what we observe in real-life scenarios involving the export of general commodities via cross-border e-commerce.

B. TREND ANALYSIS

According to Table 4, the specific changes in cross-border e-commerce supply chain decision making under different risk preference combinations are shown in Figures 1-4.

As shown in Figure 1, when both the overseas warehouse and the cross-border e-commerce platform have a risk preference towards out-of-stock aversion, the optimal order quantity for the overseas warehouse increases as the out-of-stock aversion coefficient rises. Conversely, the optimal price for the cross-border e-commerce platform decreases as the out-of-stock aversion coefficient increases. This finding confirms the validity of Lemma 1. Figure 1 also reveals that the increase of the order quantity for the overseas warehouse gradually slows as the risk coefficient rises. However, the selling price for the cross-border e-commerce platform

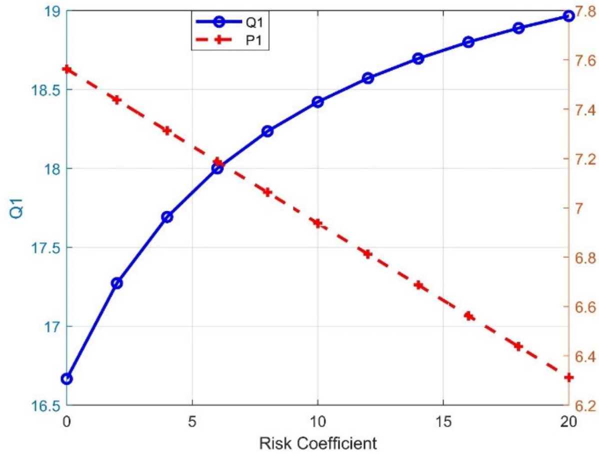

FIGURE 1. Decision maker's ordering strategy under the combination of out-of-stock and out-of-stock aversion.

only fluctuates within a reasonable range and cannot decline continuously, as low prices result in degraded supply chain performance. Therefore, the main focus of Figure 1 should be on the early stage where the risk coefficient is small. As the out-of-stock risk aversion of the overseas warehouse increases, its order quantity will also increase significantly.

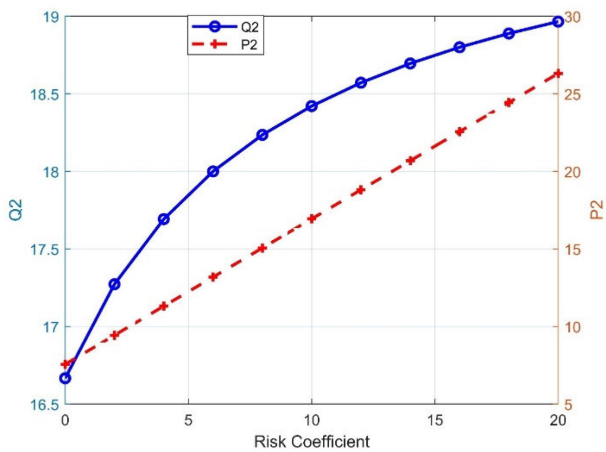

FIGURE 2. Decision maker's ordering strategy under the combination of out-of-stock and waste aversion.

As shown in Figure 2, when the overseas warehouse has a risk preference towards out-of-stock aversion and the cross-border e-commerce platform has a risk preference towards waste aversion, the optimal order quantity for the overseas warehouse increases as the out-of-stock aversion coefficient rises. Similarly, the optimal price for the cross-border e-commerce platform also increases as the waste aversion coefficient rises. This result confirms the validity of Lemma 2. In addition, Figure 2 reveals that the increase of the optimal order quantity for the overseas warehouse gradually slows as the risk coefficient rises. However, the selling price for the cross-border e-commerce platform cannot rise continuously or even exceed the initial market price, as high prices reduce consumer demand. Therefore, the main focus of Figure 2 should be on the early stage where the risk coefficient is small. As the out-of-stock aversion of the overseas warehouse increases, its order quantity also increases significantly.

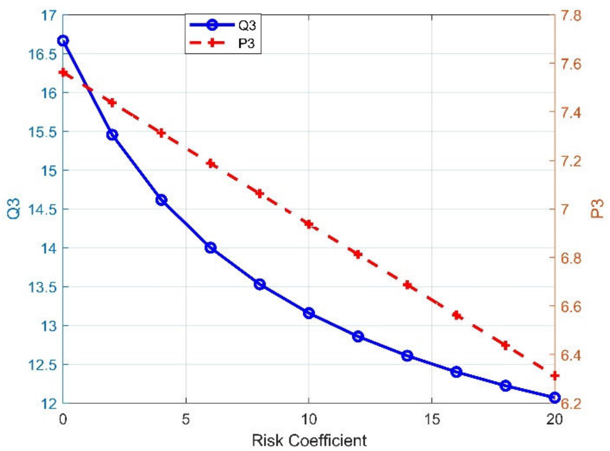

FIGURE 3. Decision maker's ordering strategy under the combination of waste and out-of-stock aversion.

As depicted in Figure 3, when the overseas warehouse has a risk preference towards waste aversion and the cross-border e-commerce platform has a risk preference towards out-of-stock aversion, the optimal order quantity for the overseas warehouse decreases as the aversion coefficient rises. Similarly, the optimal price for the cross-border e-commerce platform also decreases as the aversion coefficient rises. This result confirms the validity of Lemma 3. Moreover, Figure 3 illustrates that the reduction of the optimal order quantity for the overseas warehouse gradually slows as the risk coefficient increases. However, the selling price for the cross-border e-commerce platform can only fluctuate within a reasonable range and cannot decline continuously, as low prices degrade supply chain performance. Therefore, the main focus of Figure 3 should be on the early stage where the risk coefficient is small. As the waste aversion of the overseas warehouse increases, its order quantity decreases significantly.

As shown in Figure 4, when both the overseas warehouse and the cross-border e-commerce platform have a risk preference towards waste aversion, the optimal order quantity for the overseas warehouse decreases as the waste aversion coefficient increases, while the optimal price for the cross-border e-commerce platform increases as the waste aversion coefficient rises. This result confirms the validity of Lemma 4. Furthermore, Figure 4 reveals that the decline of the optimal order quantity for the overseas warehouse gradually slows as the risk coefficient increases. However, the selling price for the cross-border e-commerce platform cannot rise continuously or even exceed the market price, as high prices reduce consumer demand. Therefore, the main focus of

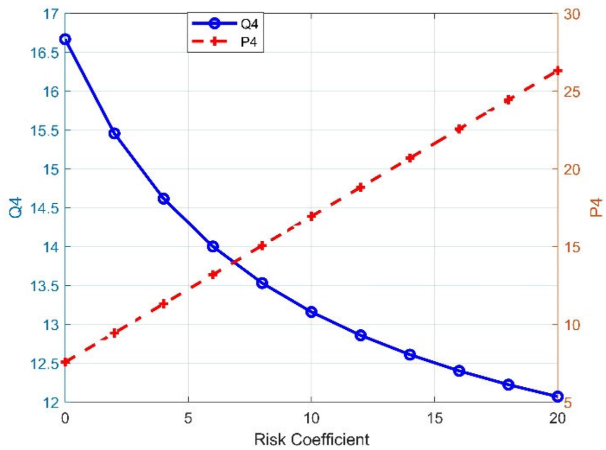

FIGURE 4. Decision maker's ordering strategy under the combination of waste and waste aversion.

Figure 4 should be on the early stage where the risk coefficient is small. As the waste aversion of the overseas warehouse increases, its order quantity decreases significantly.

C. SENSITIVITY ANALYSIS

Under the basic structure of the cross-border e-commerce supply chain, the parameters of risk preference in this article are adjusted based on the optimal decision making by supply chain members. This can be executed by designing a sensitivity analysis which enables decision makers to understand possible variations in the economic benefits of different risk preferences, so that they can make rational decisions, reduce decision costs and ensure efficient operation of the supply chain.

A sensitivity analysis is conducted after adjusting the risk preference coefficient of each decision maker in the cross-border e-commerce supply chain to +20% and +40% (whereby only the corresponding parameters of risk preference are changed and other factors are remained unchanged). The sensitivity analysis of the optimal decision making by decision makers under different risk preference combinations is shown in Table 5 below.

TABLE 5. Sensitivity analysis of the risk preference coefficient under different risk preference combinations.

Item	0	+20%	+40%	+1% on average
Q1	16.67	+1.03	+1.57	0.24%
Q2	16.67	+1.03	+1.57	0.24%
Q3	16.67	-1.21	-3.14	-0.47%
Q4	16.67	-1.21	-3.14	-0.47%
p1	7.56	-0.25	-0.50	-0.20%
p2	7.56	+3.75	+7.50	2.40%
p3	7.56	-0.25	-0.50	-0.20%
P4	7.56	+3.75	+7.50	2.40%

As can be seen from Table 5, when the risk preference coefficient increases by 20%, the ordering strategy for the overseas warehouse under the risk preference of out-of-stock aversion increases by 1.03 or 4.8%, and the ordering strategy for the overseas warehouse under the risk preference of waste aversion decreases by 1.21 or 9.4%; when the risk preference coefficient increases by 20%, the pricing strategy for the cross-border e-commerce platform under the risk preference of out-of-stock aversion decreases by 0.25 or 4%, and the pricing strategy for the cross-border e-commerce platform under the risk preference of waste aversion increases by 3.75 or 48%.

Figure 5 shows that the pricing strategy for the cross-border e-commerce platform is more sensitive to the risk preference of waste aversion, while the ordering strategy for the overseas warehouse is more sensitive to the risk preference of waste aversion. Risk preference has a relatively small overall impact on decision making by supply chain members. This is consistent with the reality that decision making by supply chain members is mainly affected by those factors that are conductive to building competitive advantages such as cost, quality and time [61]. Meanwhile, risk is not a major influencing factor, but has the potential to cause serious losses and bring disruptions to the supply chain [62].

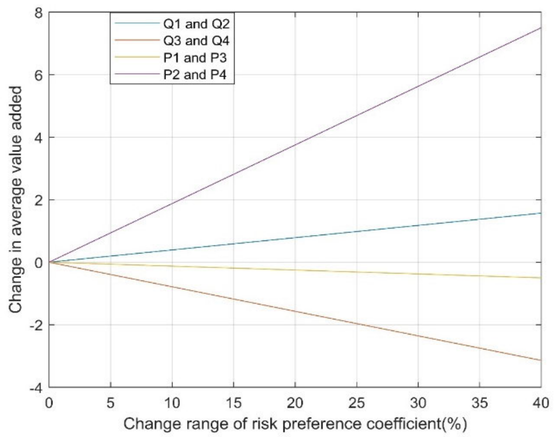

FIGURE 5. Sensitivity analysis of the risk preference coefficient under different risk preference combinations.

V. RESULT AND DISCUSSION

Firstly, the risk preference of the cross-border e-commerce platform in decision making has a more significant impact on the supply chain. As the core enterprise in the cross-border e-commerce supply chain, the platform possesses stronger control over transaction information, occupies a leading position in the supply chain, and is the dominant player in Stackelberg game. As shown in the research results presented in Figures 3 and 4, when the cross-border e-commerce platform holds a dominant position in the supply chain, it can regulate the ordering strategy for the overseas warehouse by adjusting the price, thereby enabling its macro-control over the supply chain and achieving a comprehensive balance between risks and the expected utility. These findings are consistent with some of the conclusions drawn by Yu et al. [63]. When the risk is relatively low, minor changes in the risk preference of the overseas warehouse can result in significant modifications in the ordering strategy, because the overseas warehouse must first consider the maximization of utility for the cross-border e-commerce platform when developing an ordering strategy.

Secondly, if the overseas warehouse prioritizes out-of-stock risk aversion, it would order more products. Conversely, if it prioritizes waste risk aversion, it would order fewer products. These findings align with those obtained by Cao et al. [59] and Zhao and Song [64]. When the overseas warehouse prioritizes out-of-stock aversion and the cross-border e-commerce platform prioritizes waste aversion, the utility loss incurred by the platform to reduce waste risk would result in a higher selling price. Meanwhile, the order quantity for the overseas warehouse would increase as its out-of-stock aversion coefficient rises, leading to the implementation of an aggressive ordering strategy. However, with progression of the supply chain game, the ordering strategy for the overseas warehouse is affected by the price hike made by the cross-border e-commerce platform, eventually leading to a return to rationality and coordination in the supply chain. Similarly, when the overseas warehouse prioritizes waste aversion and the cross-border e-commerce platform prioritizes out-of-stock aversion, the results are similar to those where the roles are reversed. With the progression of the supply chain game, the conservative ordering strategy for the overseas warehouse is affected by the price reduction made by the cross-border e-commerce platform, leading to a reversion to rationality and eventually coordination in the supply chain. These results are more practical and general than those obtained by Cao et al. [59] and Zhao and Song [64]. However, there are two special cases in which the cross-border e-commerce platform shares the same risk attitude with the overseas warehouse. In both cases, the dual homodromous factors affect the ordering strategy for the overseas warehouse, potentially disrupting the supply chain balance. However, the introduction of the repurchase contract allows the overseas warehouse to adjust its ordering strategy and achieve coordination in the supply chain, as concluded by Cao et al. [65]. Therefore, the decision maker with risk preferences can regulate the supply chain by creating repurchase contracts with other decision makers.

Thirdly, both the pricing strategy for the cross-border e-commerce platform and the ordering strategy for the overseas warehouse are highly sensitive to waste aversion risk. When the cross-border e-commerce platform is concerned about waste aversion risk, there are more apparent changes in its pricing, probably due to the presence of repurchase contracts in the supply chain. When there are repurchase contracts in the supply chain, the cross-border e-commerce platform must undertake more complex operations, such as repurchasing and reselling products, compared to those with out-of-stock aversion risk. This makes the cross-border e-commerce platform more averse to waste aversion risk than to out-of-stock aversion risk.

VI. CONCLUSION

This article examines the risk preferences of cross-border e-commerce platforms and overseas warehouses, specifically out-of-stock aversion and waste aversion, and involves the repurchase contract in the analysis of decision making in the cross-border e-commerce supply chain under four risk preference combinations. Additionally, a numerical experiment is conducted to quantify the relationships among the risk preference coefficient, order quantity, and wholesale price, and to gain insights into management practices.

However, there are still some limitations in this article, and in the future, we will conduct further research from the following aspects:

1) Despite the rapid development of overseas warehouses after the outbreak of COVID-19, which once accounted for 60% of the cross-border logistics market, cross-border direct mail still plays an important role. In the future, we can expand our research to cover dual channel supply chains.
2) In this article, we assume that the random variable of consumer demand follows a uniform distribution. This distribution is relatively simple, and in the future, we will incorporate more distribution functions to make the conclusions of the article more rigorous.
3) Relatively accurate and real values collected from research are used in the numerical simulation part of this article. In the assumption part of the model, consumer demand is considered as a random variable with an accurate probability density function and cumulative distribution function, but this is inconsistent with reality. Especially for cross-border e-commerce supply chains, many values are vague and unstable. To address this issue, we will replace random variables with fuzzy variables in the future, thus making the model more scientific.

REFERENCES

[1] Z. Fang and Q. Wang, "Cross-border e-commerce supply chain risk evaluation with FUZZY-ISM model," *Secur. Commun. Netw.*, vol. 2021, pp. 1–14, Sep. 2021.
[2] R. van Hoek and D. Loseby, "Beyond COVID-19 supply chain heroism, no dust settling yet—Lessons learned at Rolls Royce about advancing risk management thinking," *Int. J. Oper. Prod. Manage.*, vol. 41, no. 10, pp. 1579–1592, Oct. 2021.
[3] M. E. Schweitzer and G. P. Cachon, "Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence," *Manage. Sci.*, vol. 46, no. 3, pp. 404–420, Mar. 2000, doi: 10.1287/mnsc.46.3.404.12070.
[4] K. Sombultawee, P. Lenuwat, N. Aleenajitpong, and S. Boon-Itt, "COVID-19 and supply chain management: A review with bibliometric," *Sustainability*, vol. 14, no. 6, p. 3538, Mar. 2022, doi: 10.3390/su14063538.
[5] E. Lee and R. Staelin, "Vertical strategic interaction: Implications for channel pricing strategy," *Marketing Sci.*, vol. 16, no. 3, pp. 185–207, Aug. 1997.
[6] Y. Wang, L. Jiang, and Z.-J. Shen, "Channel performance under consignment contract with revenue sharing," *Manage. Sci.*, vol. 50, no. 1, pp. 34–47, Jan. 2004.
[7] M. Giuffrida, R. Mangiaracina, A. Perego, and A. Tumino, "Cross-border B2C e-commerce to China: An evaluation of different logistics solutions under uncertainty," *Int. J. Phys. Distrib. Logistics Manage.*, vol. 50, no. 3, pp. 355–378, Dec. 2019.
[8] R. Wang, J. Li, H. Xu, and B. Dai, "Optimal sales promotion in a supply chain using consignment contract under stochastic demand," *J. Syst. Sci. Syst. Eng.*, vol. 31, no. 4, pp. 414–436, Aug. 2022.
[9] W. Yan, H. Zhou, and H. Li, "Decision and coordination of cross-border e-commerce supply chain: Based on four modes of cooperation," *Sci. Program.*, vol. 2021, pp. 1–15, May 2021.
[10] X. Lu, Y. Xie, B. Zhang, and K. Li, "Supply–demand docking joint decision of cross-border e-commerce under the influence of internet celebrity," *J. Global Inf. Technol. Manage.*, vol. 25, no. 1, pp. 54–82, Jan. 2022.
[11] E. Sucky, "The bullwhip effect in supply chains—An overestimated problem?" *Int. J. Prod. Econ.*, vol. 118, no. 1, pp. 311–322, Mar. 2009.
[12] J. Heydari, K. Govindan, and Z. Basiri, "Balancing price and green quality in presence of consumer environmental awareness: A green supply chain coordination approach," *Int. J. Prod. Res.*, vol. 59, no. 7, pp. 1957–1975, Apr. 2021.
[13] N. A. Choudhary, S. Singh, T. Schoenherr, and M. Ramkumar, "Risk assessment in supply chains: A state-of-the-art review of methodologies and their applications," *Ann. Oper. Res.*, vol. 322, no. 2, pp. 565–607, Mar. 2023, doi: 10.1007/s10479-022-04700-9.
[14] C. Xie, H. Wang, and J. Jiao, "Cross-border e-commerce logistics collaboration model based on supply chain theory," *Secur. Commun. Netw.*, vol. 2022, Sep. 2022, Art. no. 1498765.
[15] Y. Xu, H. Gui, J. Zhang, and Y. Wei, "Supply chain analysis of cross border importing e-commerce considering with bonded warehouse and direct mailing," *Sustainability*, vol. 11, no. 7, p. 1909, Mar. 2019.
[16] X. Zha, X. Zhang, Y. Liu, and B. Dan, "Bonded-warehouse or direct-mail? Logistics mode choice in a cross-border e-commerce supply chain with platform information sharing," *Electron. Commer. Res. Appl.*, vol. 54, Jul./Aug. 2022, Art. no. 101181.
[17] Y. Sun and Y. Li, "The impact of risk-aware consumer trust on CB e-commerce platforms and purchase intention," *J. Global Inf. Manage.*, vol. 30, no. 3, pp. 1–13, Aug. 2021.
[18] A. Wicaksana, W. Ho, S. Talluri, and A. Dolgui, "A decade of progress in supply chain risk management: Risk typology, emerging topics, and research collaborators," *Int. J. Prod. Res.*, vol. 60, no. 24, pp. 7155–7177, Dec. 2022.
[19] Y. Wang, F. Jia, T. Schoenherr, Y. Gong, and L. Chen, "Cross-border e-commerce firms as supply chain integrators: The management of three flows," *Ind. Marketing Manage.*, vol. 89, pp. 72–88, Aug. 2020.
[20] M. J. Braunscheidel and N. C. Suresh, "The organizational antecedents of a firm's supply chain agility for risk mitigation and response," *J. Oper. Manage.*, vol. 27, no. 2, pp. 119–140, Apr. 2009, doi: 10.1016/j.jom.2008.09.006.
[21] X.-Y. Zhou, N. Lv, F.-M. Yao, and S.-Y. Wang, "A review of the current status and outlook of supply chain network equilibrium optimization research," (in Chinese), *J. Syst. Eng.*, vol. 37, no. 3, pp. 375–396, Mar. 2022.
[22] N. C. Petruzzi and M. Dada, "Pricing and the newsvendor problem: A review with extensions," *Oper. Res.*, vol. 47, no. 2, pp. 183–194, Apr. 1999, doi: 10.1287/opre.47.2.183.
[23] A. Kocabıyıkoğlu and I. Popescu, "An elasticity approach to the newsvendor with price-sensitive demand," *Oper. Res.*, vol. 59, no. 2, pp. 301–312, Apr. 2011, doi: 10.1287/opre.1100.0890.
[24] A. Herbon, "Dynamic pricing vs. acquiring information on consumers' heterogeneous sensitivity to product freshness," *Int. J. Prod. Res.*, vol. 52, no. 3, pp. 918–933, Feb. 2014, doi: 10.1080/00207543.2013.843800.
[25] A. Ozbilge, E. Hassini, and M. Parlar, "A review of bricks-and-clicks dual-channels literature: Trends and opportunities," *Inf. Syst. Oper. Res.*, vol. 60, no. 4, pp. 436–472, Nov. 2022.
[26] K. Govindan, H. Soleimani, and D. Kannan, "Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future," *Eur. J. Oper. Res.*, vol. 240, no. 3, pp. 603–626, Feb. 2015, doi: 10.1016/j.ejor.2014.07.012.
[27] N. M. Ropi, H. Hishamuddin, D. A. Wahab, and N. Saibani, "Optimisation models of remanufacturing uncertainties in closed-loop supply chains—A review," *IEEE Access*, vol. 9, pp. 160533–160551, 2021, doi: 10.1109/ACCESS.2021.3132096.
[28] Z. Li, J. Wang, and J. Liu, "Integrative strategies for omnichannel order fulfillment with risk aversion," *IEEE Trans. Eng. Manag.*, early access, Aug. 16, 2022, doi: 10.1109/TEM.2022.3189690.
[29] A. M. Baydar, H. Süral, and M. Çelik, "Freight villages: A literature review from the sustainability and societal equity perspective," *J. Cleaner Prod.*, vol. 167, pp. 1208–1221, Nov. 2017, doi: 10.1016/j.jclepro.2017.07.224.

[30] H. Huang, J. Zhang, X. Ren, and X. Zhou, "Greenness and pricing decisions of cooperative supply chains considering altruistic preferences," *Int. J. Environ. Res. Public Health*, vol. 16, no. 1, p. 51, Dec. 2018, doi: 10.3390/ijerph16010051.

[31] Y. Wang, Z. Yu, L. Shen, and W. Dong, "E-commerce supply chain models under altruistic preference," *Mathematics*, vol. 9, no. 6, p. 632, Mar. 2021, doi: 10.3390/math9060632.

[32] M. Li and S. Mizuno, "Dynamic pricing and inventory management of a dual-channel supply chain under different power structures," *Eur. J. Oper. Res.*, vol. 303, no. 1, pp. 273–285, Nov. 2022, doi: 10.1016/j.ejor.2022.02.049.

[33] H. Hu, Y. Li, and M. Li, "Decisions and coordination of green supply chain considering big data targeted advertising," *J. Theor. Appl. Electron. Commerce Res.*, vol. 17, no. 3, pp. 1035–1056, Jul. 2022, doi: 10.3390/jtaer17030053.

[34] F. Tao, Y.-Y. Wang, and S.-H. Zhu, "Impact of blockchain technology on the optimal pricing and quality decisions of platform supply chains," *Int. J. Prod. Res.*, pp. 1–15, Mar. 2022, doi: 10.1080/00207543.2022.2050828.

[35] Y. Chen, M. Li, J. Song, X. Ma, Y. Jiang, S. Wu, and G. L. Chen, "A study of cross-border e-commerce research trends: Based on knowledge mapping and literature analysis," *Frontiers Psychol.*, vol. 13, p. 13, Dec. 2022, doi: 10.3389/fpsyg.2022.1009216.

[36] B. B. Hazarika and R. Mousavi, "Review of cross-border e-commerce and directions for future research," *J. Global Inf. Manage.*, vol. 30, no. 2, pp. 1–18, Aug. 2021, doi: 10.4018/JGIM.20220301.oa1.

[37] P. He, T.-Y. Wang, Q. Shang, J. Zhang, and H. Xu, "Knowledge mapping of e-commerce supply chain management: A bibliometric analysis," *Electron. Commerce Res.*, pp. 1–37, Aug. 2022, doi: 10.1007/s10660-022-09609-w.

[38] T. J. Pettit, J. Fiksel, and K. L. Croxton, "Ensuring supply chain resilience: Development of a conceptual framework," *J. Bus. Logistics*, vol. 31, no. 1, pp. 1–21, 2010, doi: 10.1002/j.2158-1592.2010.tb00125.x.

[39] M. Giannakis, R. Dubey, S. Yan, K. Spanaki, and T. Papadopoulos, "Social media and sensemaking patterns in new product development: Demystifying the customer sentiment," *Ann. Oper. Res.*, vol. 308, nos. 1–2, pp. 145–175, Jan. 2022, doi: 10.1007/s10479-020-03775-6.

[40] X. Xu, H. Wang, C. Dang, and P. Ji, "The loss-averse newsvendor model with backordering," *Int. J. Prod. Econ.*, vol. 188, pp. 1–10, Jun. 2017, doi: 10.1016/j.ijpe.2017.03.005.

[41] D. Yang and T. Xiao, "Coordination of a supply chain with loss-averse consumers in service quality," *Int. J. Prod. Res.*, vol. 55, no. 12, pp. 3411–3430, Jun. 2017, doi: 10.1080/00207543.2016.1241444.

[42] L. Yang, G. G. Cai, and J. Chen, "Push, pull, and supply chain risk-averse attitude," *Prod. Oper. Manage.*, vol. 27, no. 8, pp. 1534–1552, Aug. 2018, doi: 10.1111/poms.12881.

[43] Y.-W. Zhou, J. Li, and Y. Zhong, "Cooperative advertising and ordering policies in a two-echelon supply chain with risk-averse agents," *Omega, Int. J. Manage. Sci.*, vol. 75, pp. 97–117, Mar. 2018, doi: 10.1016/j.omega.2017.02.005.

[44] W. Ho, T. Zheng, H. Yildiz, and S. Talluri, "Supply chain risk management: A literature review," *Int. J. Prod. Res.*, vol. 53, no. 16, pp. 5031–5069, Aug. 2015.

[45] M. Jian and Y. L. Wang, "Decision-making strategies in supply chain management with a waste-averse and stockout-averse manufacturer," *Adv. Prod. Eng. Manage.*, vol. 13, no. 3, pp. 345–357, Sep. 2018, doi: 10.14743/apem2018.3.295.

[46] Z. Song, W. Tang, R. Zhao, and G. Zhang, "Inventory strategy of the risk averse supplier and overconfident manufacturer with uncertain demand," *Int. J. Prod. Econ.*, vol. 234, Apr. 2021, Art. no. 108066, doi: 10.1016/j.ijpe.2021.108066.

[47] C. X. Wang and S. Webster, "Channel coordination for a supply chain with a risk-neutral manufacturer and a loss-averse retailer," *Decis. Sci.*, vol. 38, no. 3, pp. 361–389, Aug. 2007, doi: 10.1111/j.1540-5915.2007.00163.x.

[48] Y. Wang, X. Zheng, J. Cai, and Y. Zheng, "Supply chain contract choice with different behavior preferences of retailer," *Discrete Dyn. Nature Soc.*, vol. 2021, pp. 1–9, Oct. 2021, doi: 10.1155/2021/7894885.

[49] K. Chen and T. Xiao, "Reordering policy and coordination of a supply chain with a loss-averse retailer," *J. Ind. Manage. Optim.*, vol. 9, no. 4, pp. 827–853, 2013, doi: 10.3934/jimo.2013.9.827.

[50] T.-M. Choi, C. Ma, B. Shen, and Q. Sun, "Optimal pricing in mass customization supply chains with risk-averse agents and retail competition," *Omega, Int. J. Manage. Sci.*, vol. 88, pp. 150–161, Oct. 2019, doi: 10.1016/j.omega.2018.08.004.

[51] B. Gong, X. Xia, and J. Cheng, "Supply-chain pricing and coordination for new energy vehicles considering heterogeneity in consumers' low carbon preference," *Sustainability*, vol. 12, no. 4, p. 1306, Feb. 2020, doi: 10.3390/su12041306.

[52] S. Song and S. Hu, "Coordination of time-varying price supply chain with inequity-averse retailers," *Math. Problems Eng.*, vol. 2019, pp. 1–8, Jun. 2019, doi: 10.1155/2019/6704131.

[53] W. Yu, G. Hou, and B. Xin, "Decision-making optimization of risk-seeking retailer managed inventory model in a water supply chain," *Discrete Dyn. Nature Soc.*, vol. 2021, pp. 1–18, Apr. 2021.

[54] R. Wang, X. Zhou, and B. Li, "Pricing strategy of dual-channel supply chain with a risk-averse retailer considering consumers' channel preferences," *Ann. Oper. Res.*, vol. 309, no. 1, pp. 305–324, Feb. 2022, doi: 10.1007/s10479-021-04326-3.

[55] Z. Zhao, Z. Liu, Q. Qian, L. Li, Y. Zhao, and Y. Zhu, "Dual-source procurement strategy of cross-border e-commerce supply chain considering Members' risk attitude," *Secur. Commun. Netw.*, vol. 2022, pp. 1–13, Jun. 2022, doi: 10.1155/2022/3592859.

[56] C. Ma, Y. C. E. Lee, C. K. Chan, and Y. Wei, "Auction and contracting mechanisms for channel coordination with consideration of participants' risk attitudes," *J. Ind. Manage. Optim.*, vol. 13, no. 2, pp. 775–801, 2017, doi: 10.3934/jimo.2016046.

[57] C. Fang, X. Liao, and M. Xie, "A hybrid risks-informed approach for the selection of supplier portfolio," *Int. J. Prod. Res.*, vol. 54, no. 7, pp. 2019–2034, Apr. 2016, doi: 10.1080/00207543.2015.1076947.

[58] C. Luo, X. Tian, X. Mao, and Q. Cai, "Coordinating supply chain with buy-back contracts in the presence of risk aversion," *Asia–Pacific J. Oper. Res.*, vol. 35, no. 2, Apr. 2018, Art. no. 1840008, doi: 10.1142/S0217595918400080.

[59] B.-B. Cao, Z.-P. Fan, H. Li, and T.-H. You, "Joint inventory, pricing, and advertising decisions with surplus and stockout loss aversions," *Discrete Dyn. Nature Soc.*, vol. 2016, pp. 1–14, Jun. 2016, doi: 10.1155/2016/1907680.

[60] S. V. Nooraie and M. M. Parast, "Mitigating supply chain disruptions through the assessment of trade-offs among risks, costs and investments in capabilities," *Int. J. Prod. Econ.*, vol. 171, pp. 8–21, Jan. 2016, doi: 10.1016/j.ijpe.2015.10.018.

[61] Q. Zhu, P. Shah, and J. Sarkis, "Addition by subtraction: Integrating product deletion with lean and sustainable supply chain management," *Int. J. Prod. Econ.*, vol. 205, pp. 201–214, Nov. 2018, doi: 10.1016/j.ijpe.2018.08.035.

[62] M. M. Parast and N. Subramanian, "An examination of the effect of supply chain disruption risk drivers on organizational performance: Evidence from Chinese supply chains," *Supply Chain Manag., Int. J.*, vol. 26, no. 4, pp. 548–562, May 2021, doi: 10.1108/SCM-07-2020-0313.

[63] Y. Yu, F. Chu, and H. Chen, "A Stackelberg game and its improvement in a VMI system with a manufacturing vendor," *Eur. J. Oper. Res.*, vol. 192, no. 3, pp. 929–948, Feb. 2009, doi: 10.1016/j.ejor.2007.10.016.

[64] C. Zhao and J. Song, "Coordination of dual-channel supply chain considering differential pricing and loss-aversion based on quality control," *J. Ind. Manage. Optim.*, vol. 19, no. 4, pp. 2507–2527, 2023, doi: 10.3934/jimo.2022053.

[65] Z. Cao, Z. Yang, F. Liu, and Z. Ye, "Buyback and stockout penalty newsvendor model based on reference point prospect theory," *Cluster Comput.*, vol. 22, no. S2, pp. 4989–4999, Mar. 2019, doi: 10.1007/s10586-018-2451-1.

XIN XU received the master's degree in economy from the Dongbei University of Finance and Economics, China.

She is currently an Associate Professor with Dalian Maritime University, China. Her research interests include marine economy, international trade, and supply chain.

SHAOJIE ZHOU received the B.S. degree from the Hebei University of Technology, China. He is currently pursuing the M.S. degree with Dalian Maritime University, China. His research interests include international trade and multilevel supply chains.