*Retraction*

# Retracted: Mobile Communication Procurement Platform Optimization Decision Based on Overseas Retailer Investment under Supply and Demand Disruption Risk

## Wireless Communications and Mobile Computing

This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

## References

[1] D. Wang and W. Li, "Mobile Communication Procurement Platform Optimization Decision Based on Overseas Retailer Investment under Supply and Demand Disruption Risk," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 2630814, 12 pages, 2021.

*Research Article*

# Mobile Communication Procurement Platform Optimization Decision Based on Overseas Retailer Investment under Supply and Demand Disruption Risk

**Deli Wang** [iD] **and Wuwei Li** [iD]

*Glorious Sun School of Business and Management, Donghua University, Shanghai 200051, China*

Correspondence should be addressed to Wuwei Li; m030120227@sues.edu.cn

With the rapid development of mobile communication procurement platform, it is faced with many risks, such as national policy differences, regional market differentiation, trade control, and technical barriers. Among them, the risk of supply and demand interruption will lead to the disconnection between upstream and downstream enterprises and consumers in the crossborder supply chain, making it difficult for them to achieve the profit target of the supply chain and meet the market demand. In order to reduce the risk of supply and demand disruption in mobile communication procurement platform and improve the ability to prevent and deal with disruption emergencies, a two-level supply chain composed of crossborder suppliers, overseas suppliers, and overseas retailers is established, and the procurement decision optimization of crossborder supply chain under the condition of single channel procurement and dual channel procurement before and after investment is studied. The research show that when overseas retailers invest in crossborder suppliers and choose a dual-source ordering strategy, it is more conducive to overseas retailers to reduce the risk of crossborder supply chain interruption and obtain higher expected profits.

## 1. Introduction

Under the background of economic globalization, information technology, and international division of labor, the international supply network is more and more closely linked. At the same time, the traditional decentralized procurement mode is gradually replaced by the new platform procurement mode. Through the intensive platform, the smooth and efficient operation of the procurement process can be realized. For mobile communication procurement platforms, scholars have combined with the transformation of procurement organizations to study how to organize the design of platform procurement; improve VCG payment rules and propose a new platform-based logistic procurement two-way bidding transaction model, and build a duopoly competition enterprise and government-led the bilateral Nash bargaining game model between centralized procurement platforms promotes the collaboration between enterprises and centralized procurement platforms [1–3].

However, there is little research on the supply chain disruption problem of the procurement platform. The mobile communication procurement platform will select multiple suppliers from all over the world, when a certain supplier cannot satisfy the retailer due to complex procedures, machine failures, insufficient human resources, etc. Procurement requirements are prone to supply disruption risks, which will result in the stagnation of production and logistic transportation for companies that place orders on the procurement platform for a long period of time, and the liquidity cannot be returned to the circulation. Supply interruption will stimulate market demand, and the demand will increase rapidly but it is difficult to meet, forming a vicious circle, endangering the stability of supply chain system, and bringing disaster damage to upstream and downstream enterprises and the whole supply chain. Based on the above problems, this article reduces the uncertainty risk of the crossborder supply chain, stabilizes the market demand share, and realizes the overall profit increase of the supply chain of the

crossborder communication procurement platform by means of dual-source procurement and retailer's financial support to suppliers.

From the perspective of supply disruption, we can improve the risk response capability of the supply chain by selecting suitable suppliers, determining the number of suppliers, and formulating procurement and inventory strategies [4]. Ivanov et al. tried to integrate digital technology into risk management from the perspective of digitalization and Industry 4.0 and studied the control strategy of supply chain reaction and interruption risk [5]. Li et al. combined with the real option theory, focused on the analysis of two emergency ordering modes of purchasing from backup suppliers in the case of supply interruption [6]. Kong et al. established a multivariable coupling control model and proposed that when supply disruptions occur, deep learning algorithms can effectively improve the resilience of OEM supply chains [7]. From the perspective of demand disruption, different from the more mature supply system of autoparts manufacturing industry, retailers represented by fresh and cold chain are faced with social responsibilities such as emission reduction; so, the market risk is increasing [8, 9]. Zhang et al. introduced the system dynamic model to model and simulate the two-level supply chain composed of raw material suppliers, manufacturers, and product subcontracting emergency suppliers and obtained the optimal emergency strategy of the production inventory system when the demand drops [10]. Based on the background of demand interruption, Shi et al. compare the coordination mechanism under the situation of no demand interruption and no overconfidence and construct the mobilization chain model of government emergency materials by using the quantitative elastic contract [11].

From the perspective of dual-source procurement, it refers to the design of coordination mechanisms that can reduce the risk of supply chain disruptions by selecting multiple backup suppliers or emergency suppliers in the absence of significant differences in raw materials, products, and services. Xin and Goldberg used the TBS strategy to try to solve the inventory optimality problem for purchasing from two suppliers and proved its applicability to be asymptotically optimal [12]. Lucker et al. conducted a joint analysis of inventory risk inventory (RMI), dual-source sourcing, and agility capabilities in pharmaceutical supply chains to introduce metric parameters modeling to quantify supply chain resilience and reduce supply and inventory risk [13]. Hu et al. discussed the impact of disaster event probability, government reserves, and spot market price on the government enterprise dual-source joint emergency material procurement mode based on the scenario of rapid growth of emergency material demand after disaster [14]. Chen constructed a game model between a manufacturer and two suppliers under two scenarios of random supplier output and supply disruption and found that the manufacturer's profit level can be increased by reducing the probability of disruption through dual-source purchasing decisions [15]. Liu et al., based on passengers' personality, route, and waiting time, used the historical data of the bus to simulate and customize the price for passengers [16]. Han et al. studied the dual-source procurement strategy based on the

update of demand forecasts under the background of two-period demand under the double uncertain information. In this case, the retailer made the most profit [17].

Through the literature review of supply disruption, demand disruption, and dual-source procurement, it is found that dual-source procurement, option contract, and other methods can reduce the risk of supply disruption and effectively deal with the uncertainty of market demand, especially in the process of crossborder e-commerce supply chain operation. However, dual-source procurement mostly focuses on the optimal profit of manufacturers or retailers and transfers risk cost to suppliers through zero inventory or buy back strategy, which is not conducive to the coordinated development of the whole supply chain. Therefore, we can choose to invest in suppliers from the perspective of retailer investment, which can not only strengthen supply chain communication and cooperation but also expand capacity advantage, reduce purchase price, and improve order fulfillment rate [18]. Liu et al. compare the different cooperation strategies among supply chain members in the context of carbon tax constraints and select the optimal decision-making method to reduce carbon emissions and ensure the benefits of enterprises [19]. Krause et al. showed that improvements in sourcing product quality, speed of delivery, and flexibility relied more on direct investments in suppliers [20]. Yang et al. discuss the problem of which investment strategy to adopt when the competitive intensity of two retailers increases, obtain a financing evolution model for the equilibrium scenario, and perform a sensitivity analysis of the capital structure and competitive intensity of the retailers [21]. Niu et al. combined product quality with investment output spillover effect and considered that the manufacturer's optimal strategy was to invest in supplier's quality [22]. Liu et al. found that retailers investing in manufacturers can help the supply chain reduce carbon emissions [23]. In view of the actual operation of crossborder procurement platform supply chain and the research basis of previous scholars, it is of theoretical and practical significance to incorporate retailer investment into crossborder supply chain procurement model [24–26]. Therefore, in the case of supply and demand disruption risk, this paper considers the optimal procurement decision under single source procurement, dual-source procurement, and overseas retailer investment; clarifies the relationship between crossborder supply chain disruption probability, overseas retailer procurement volume, and overseas retailer expected profit under different procurement situations; selects the optimal procurement mode; improves overseas retailer expected profit; and ensures supply the stability of the chain.

## 2. Methods

*2.1. Model Assumptions.* This paper takes the crossborder e-commerce supply chain as the research object and constructs a two-level supply chain composed of cross-border suppliers, overseas suppliers, and overseas retailers, as shown in Figure 1. This paper studies the optimal purchasing decisions of the supply chain under four conditions: retailers purchase only from crossborder suppliers, only from overseas
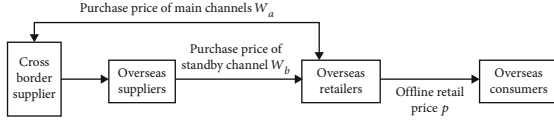
FIGURE 1: Mobile communication procurement platform supply chain procurement flow chart.

suppliers, purchase from both crossborder and overseas suppliers, and purchase from both crossborder and overseas suppliers after retailers invest [27, 28]. This paper mainly solves the following problems:

(1) Establish a supply chain newsboy model under single-source procurement, dual-source procurement, and dual-source procurement after retailer investment and compare the optimal procurement decisions in each situation to select the optimal procurement method and procurement volume

(2) Looking for approach to improve the competitiveness of the crossborder e-commerce supply chain, the lower the probability of supply and demand disruption and the higher the stability of the supply chain, the more able it is to stand out among many crossborder retail platforms and win the trust of consumers

(3) One of the purposes of optimizing the procurement decision of crossborder e-commerce supply chain is to improve the overall profit of the supply chain and to select the most suitable supply chain optimization method by comparing the profit of retailers under different procurement decisions

*2.2. Model Description.* Overseas retailers purchase products from crossborder suppliers or overseas suppliers with the same quality and sell them to overseas consumers to meet market demand [29, 30]. Assuming $D$ is the entire market demand $D = m \cdot \lambda$, $m$ is the deterministic demand (related to product prices, etc.), and $\lambda$ is the uncertain market demand. Suppose $\lambda$ is a random variable defined on $(a, b)$, the probability density function and probability distribution function are $f(\lambda)$ and $F(\lambda)$, respectively, and $F(a) = 0$, $F(b) = 1$. Assume that all participants in the supply chain are completely rational, they all have a risk-neutral attitude. As the main supplier, crossborder suppliers are affected by factors such as distance and policies. They have low stability and high possibility of supply interruption, but they have price advantages, and the purchase price provided by crossborder suppliers is $w_a$. The products of overseas suppliers are provided by crossborder suppliers and then sold to overseas retailers. Therefore, they have high stability and no risk of interruption, but the prices are higher. The purchase price provided by overseas suppliers is $w_b$. The overseas retailer sells the product to the consumer at a price $p$, and $w_a < w_b < p$. Assume that the probability of disruption of the main supplier is $r$, and that the product cannot be supplied after the disruption, the deterministic demand of the consumer increases from $m$ to $m + \Delta m$ after the supply disruption of

the main supplier. If the retailer invests in the main supplier and the amount of investment is $I$, the probability of interruption risk of the main supplier is reduced to $r^* = r - \alpha I$ ($r^* > 0$), and the supply price of the crossborder supplier is reduced to $w_a^* = w_a - \beta I (w_a^* > 0)$, $\alpha$, and $\beta$ and $(\alpha < \beta)$ are the influence coefficients of investment on the risk and supply price, respectively [31–33]. The parameters used in the article are shown in Table 1.

*2.3. Crossborder Suppliers as the Sole Source of Procurement.* When an overseas retailer only purchases from a crossborder supplier, if the crossborder supplier does not experience supply interruption, then the profit function $\pi_{kn}{}^s$ of the overseas retailer can be obtained at this time [34, 35].

$$\pi_{kn}{}^s = p \min \left( Q_k{}^s, D \right) - w_a Q_k{}^s - c[D - Q_k{}^s]^+ + u[Q_k{}^s - D]^+. \tag{1}$$

In which, the expected profit function $E(\pi_{kn}{}^s)$ of overseas retailers can be obtained:

$$E(\pi_{kn}{}^s) = p \left[ \int_A^{Q_k{}^s} Df(D)dD + \int_{Q_k{}^s}^B Q_k{}^s f(D)dD \right] \\ - c \int_{Q_k{}^s}^B (D - Q_k{}^s)Df(D)dD - w_a Q_k{}^s \tag{2} \\ + u \int_A^{Q_k{}^s} (Q_k{}^s - D)f(D)dD.$$

Using the partial integration method to further simplify, we can get

$$E(\pi_{kn}{}^s) = (p + c - w_a)Q_k{}^s - (p + c - u)m \int_A^{\frac{Q_k{}^s}{m}} F(\lambda)d\lambda - cm\mu, \mu \\ = \int_A^B \lambda f(\lambda)d\lambda. \tag{3}$$

According to the derivation of the expected profit function based on the newsboy model, the optimal purchase volume and optimal expected profit of overseas retailers can be obtained under the condition that crossborder suppliers are not interrupted [36, 37]:

$$Q_k{}^s = mF^{-1}\left( \frac{p + c - w_a}{p + c - u} \right), \tag{4}$$

$$E(\pi_{kn}{}^s) = (p + c - w_a)mF^{-1}\left( \frac{p + c - w_a}{p + c - u} \right) \\ - (p + c - u)m \int_A^{F^{-1}\left( \frac{p+c-w_a}{p+c-u} \right)} F(\lambda)d\lambda - cm\mu. \tag{5}$$

When the overseas retailer only purchases from the crossborder supplier, if the crossborder supplier has supply interruption, then the crossborder supplier cannot provide products to the overseas retailer at all, and the purchase

| Parameter | Definition |
| --- | --- |
| $w_a$ | Unit purchase price provided by crossborder suppliers |
| $w_b$ | Unit purchase price provided by overseas suppliers |
| $p$ | Retail price of crossborder e-commerce products |
| $D$ | Random market demand of crossborder e-commerce products |
| $m$ | The deterministic part of stochastic market demand for cross border e-commerce products |
| $\lambda$ | The uncertain part of the random market demand for crossborder e-commerce products, the mean is $\mu$ |
| $\Delta m$ | Increased demand due to supply disruption |
| $r$ | Probability of supply disruption for cross-border suppliers |
| $c$ | Unit shortage cost of overseas retailers |
| $u$ | Residual value of unsold products of overseas retailers |
| $Q_k{}^s$ | The optimal purchase quantity of overseas retailers under the condition that crossborder suppliers are the only source of purchase without interruption |
| $Q_h{}^s$ | The optimal purchasing quantity of overseas retailers with overseas suppliers as the sole purchasing source |
| $Q_k{}^d$ | The purchase quantity of overseas retailers ordering from crossborder suppliers under dual-source procurement |
| $Q_h{}^d$ | The purchase quantity of overseas retailers ordering from overseas suppliers under dual-source procurement |
| $Q_k{}^{d*}$ | After the retailer invests, the purchase quantity of overseas retailers ordering from crossborder suppliers under dual-source purchasing |
| $Q_h{}^{d*}$ | After the retailer invests, the purchase quantity of overseas retailers ordering from overseas suppliers under dual-source procurement |
| $I$ | Investment amount of overseas retailers in crossborder suppliers |
| $r^*$ | Probability of supply disruption for crossborder suppliers after investment |
| $w_a{}^*$ | Supply price of crossborder suppliers after investment |
| $\pi$ | Profits of overseas retailers |

quantity is 0, and then the expected profit function of the overseas retailer is $E(\pi_{ky}{}^s)$ [38–40].

$$E(\pi_{ky}{}^s) = -c(m + \Delta m)\mu, \mu = \int_A^B \lambda f(\lambda) d\lambda. \quad (6)$$

Combining equations (5) and (6), we can obtain that with crossborder suppliers as the sole source of procurement, the expected profit of overseas retailers is

$$\begin{aligned} E(\pi_k{}^s) &= rE(\pi_{ky}{}^s) + (1-r)E(\pi_{kn}{}^s) \\ &= (1-r)\left[ (p+c-w_a)mF^{-1}\left(\frac{p+c-w_a}{p+c-u}\right) \right. \\ &\left. - (p+c-u)m\int_A^{F^{-1}\left(\frac{p+c-w_a}{p+c-u}\right)} F(\lambda)d\lambda \right] - c\mu(m+r\Delta m). \end{aligned} \quad (7)$$

*2.4. Overseas Suppliers as the Sole Source of Procurement.* When overseas retailers only purchase from overseas suppliers, since overseas suppliers do not have the risk of supply interruption, the profit function $\pi_h{}^s$ of overseas retailers at this time can be obtained [41, 42].

$$\pi_h{}^s = p \min (Q_h{}^s, D) - w_b Q_h{}^s - c[D - Q_h{}^s]^+ + u[Q_h{}^s - D]^+. \quad (8)$$

**Lemma 1.** *When overseas suppliers are the sole source of retail purchases, the optimal purchase volume and optimal expected profit of overseas retailers are $Q_h{}^s$ and $E(\pi_h{}^s)$, respectively.*

*Proof.* First of all, the expected profit function of overseas retailers can be obtained by calculation as $E(\pi_h{}^s) = p[\int_A^{Q_h{}^s} D f(D)dD + \int_{Q_h{}^s}^B Q_h{}^s f(D)dD] - c\int_{Q_h{}^s}^B (D - Q_h{}^s)Df(D)dD - w_b Q_h{}^s + u\int_A^{Q_h{}^s}(Q_h{}^s - D)f(D)dD.$. □

Further simplification with the method of integration by parts

$$E(\pi_h{}^s) = (p+c-w_b)Q_h{}^s - (p+c-u)m\int_A^{\frac{Q_h{}^s}{m}} F(\lambda)d\lambda - cm\mu, \mu$$
$$= \int_A^B \lambda f(\lambda) d\lambda. \quad (9)$$

By deriving the expected profit function from the newsboy model, the optimal purchase quantity and the optimal expected profit of the overseas retailer can be obtained under the condition that the supply of the overseas supplier is not interrupted [43, 44].

$$Q_h{}^s = mF^{-1}\left(\frac{p+c-w_b}{p+c-u}\right),$$

$$E(\pi_h{}^s) = (p+c-w_b)mF^{-1}\left(\frac{p+c-w_b}{p+c-u}\right) \tag{10}$$
$$- (p+c-u)m\int_A^{F^{-1}\left(\frac{p+c-w_b}{p+c-u}\right)} F(\lambda)d\lambda - cm\mu.$$

*2.5. Both Crossborder and Overseas Suppliers Are Used as Procurement Sources.* When overseas retailers purchase products from crossborder suppliers and overseas suppliers at the same time, the final purchase volume is the sum of the purchase volume of the two channels, and then the profit function of the overseas retailer at this time is

$$\pi^d = (1-r)\left\{p\min\left(Q_k{}^d + Q_h{}^d, D\right) - w_a Q_k{}^d - w_b Q_h{}^d\right.$$
$$\left. - c\left[D - Q_k{}^d - Q_h{}^d\right]^+ + u\left[Q_k{}^d + Q_h{}^d - D\right]^+\right\}$$
$$+ r\left\{p\min\left(Q_h{}^d, D^*\right) - w_b Q_h{}^d - c\left[D^* - Q_h{}^d\right]^+\right.$$
$$\left. + u\left[Q_h{}^d - D^*\right]^+\right\}, D^* = (m + \Delta m)\lambda. \tag{11}$$

**Lemma 2.** *When the overseas supplier makes dual-source procurement and the probability of supply interruption of the overseas supplier is $r \geq w_b - w_a/p + c - w_a$, the purchase volume of the overseas retailer from the crossborder supplier and the overseas supplier is $Q_k{}^d$ and $Q_h{}^d$, respectively, and $Q_k{}^d + Q_h{}^d = Q_k{}^s$ [45, 46].*

*Proof.* First of all, the expected profit function of overseas retailers can be obtained by calculation

$$E(\pi^d) = (1-r)\left\{p\left[\int_A^{Q_k{}^d + Q_h{}^d} Df(D)dD\right.\right.$$
$$\left. + \int_{Q_k{}^d + Q_h{}^d}^B \left(Q_k{}^d + Q_h{}^d\right)f(D)dD\right] - w_a Q_k{}^d - w_b Q_h{}^d$$
$$- c\int_{Q_k{}^d + Q_h{}^d}^B \left[D - \left(Q_k{}^d + Q_h{}^d\right)\right]Df(D)dD$$
$$\left. + u\int_A^{Q_k{}^d + Q_h{}^d}\left(Q_k{}^d + Q_h{}^d - D\right)f(D)dD\right\}$$
$$+ r\left\{p\left[\int_A^{Q_h{}^d} D^* f(D^*)dD^* + \int_{Q_h{}^d}^B Q_h{}^d f(D^*)dD^*\right]\right.$$
$$- c\int_{Q_h{}^d}^B \left(D^* - Q_h{}^d\right)D^* f(D^*)dD^* - w_b Q_h{}^d$$
$$\left. + u\int_A^{Q_h{}^d}\left(Q_h{}^d - D^*\right)f(D^*)dD^*\right\}. \tag{12}$$

Simplify the above equation using the method of integration by parts

$$E(\pi^d) = (1-r)\left[(p+c-w_a)Q_k{}^d + (p+c-w_b)Q_h{}^d\right.$$
$$- m(p-u+c)\int_A^{\frac{Q_k{}^d + Q_h{}^d}{m}} F(\lambda)d\lambda - cm\mu\right]$$
$$+ r\left[(p+c-w_b)Q_h{}^d - (m+\Delta m)(p-u+c)\int_A^{\frac{Q_h{}^d}{m+\Delta m}} F(\lambda)d\lambda\right.$$
$$\left. - c(m+\Delta m)\mu\right]. \tag{13}$$

Finding the first derivative of $E(\pi^d)$ with respect to $Q_k{}^d$ and $Q_h{}^d$, respectively, we can get

$$\frac{\partial E(\pi^d)}{\partial Q_k{}^d} = (1-r)\left[(p+c-w_a) - (p-u+c)F\left(\frac{Q_k{}^d + Q_h{}^d}{m}\right)\right], \tag{14}$$

$$\frac{\partial E(\pi^d)}{\partial Q_h{}^d} = (1-r)\left[(p+c-w_b) - (p-u+c)F\left(\frac{Q_k{}^d + Q_h{}^d}{m}\right)\right]$$
$$+ r\left[(p+c-w_b) - (p-u+c)F\left(\frac{Q_h{}^d}{m+\Delta m}\right)\right]. \tag{15}$$

Assign the value of 0 to formulae (14) and (15) and solve the system of equations to obtain

$$Q_k{}^d = mF^{-1}\left(\frac{p+c-w_a}{p+c-u}\right) - (m+\Delta m)F^{-1}\left[\frac{(1-r)w_a - w_b + r(p+c)}{r(p+c-u)}\right]. \tag{16}$$

$$Q_h{}^d = (m+\Delta m)F^{-1}\left[\frac{(1-r)w_a - w_b + r(p+c)}{r(p+c-u)}\right]. \tag{17}$$

According to the solution result, it can be found that in $F^{-1}[(1-r)w_a - w_b + r(p+c)/r(p+c-u)]$, only when $(1-r)w_a - w_b + r(p+c) \geq 0$, $Q_h{}^d$ will be greater than 0, overseas retailers will purchase from overseas suppliers, and the phenomenon of dual-source procurement will appear; so, $r \geq w_b - w_a/p + c - w_a$. Then, $Q_k{}^d + Q_h{}^d = mF^{-1}(p+c-w_a/p+c-u) = Q_k{}^s$ is obtained by adding the quantity of crossborder suppliers and overseas suppliers under dual-source procurement, and the proof is complete [47]. □

**Lemma 3.** *Under dual-source procurement, with the increase of the interruption probability of crossborder suppliers, the quantity of products purchased by overseas retailers from crossborder suppliers will decrease, while the quantity of products purchased from overseas suppliers will increase. And when the crossborder supplier interruption probability*

$r > (w_b - w_a)Q_h{}^d / (p + c - w_a)Q_h{}^d - (m + \Delta m)(p - u + c)$ $\int_A^{Q_h{}^d/m+\Delta m} F(\lambda)d\lambda$, the dual-source procurement decision of overseas retailers will be better than the decision of using crossborder suppliers as the sole source of procurement.

*Proof.* $\partial Q_k{}^d / \partial r = -((m + \Delta m)(w_b - w_a)/r^2(p + c - u))f^{-1}[(1 - r)w_a - w_b + r(p + c)/r(p + c - u)] < 0$, and $\partial Q_h{}^d / \partial r = ((m + \Delta m)(w_b - w_a)/r^2(p + c - u))f^{-1}[(1 - r)w_a - w_b + r(p + c)/r(p + c - u)] > 0$, Therefore, the higher the probability of supply interruption of crossborder suppliers, the less the quantity of products purchased from crossborder suppliers, so as to reduce the loss caused by interruption risk to overseas retailers. If the expected profit of the dual-source purchasing decision is better than the expected profit of the crossborder supplier as the only source, overseas retailers will tend to choose dual-source purchasing, and at this point, there is inequality $E(\pi^d) > E(\pi_k{}^s)$. According equation $Q_k{}^d + Q_h{}^d = Q_k{}^s$ derived from Lemma 2, the expected profit of overseas retailers' dual-source procurement is transformed into

$$
\begin{aligned}
E\left(\pi^d\right) = (1 - r)&\left[ (p + c)Q_k{}^s - w_a Q_k{}^d - w_b Q_h{}^d \right. \\
&\left. - m(p - u + c)\int_A^{\frac{Q_k{}^s}{m}} F(\lambda)d\lambda - cm\mu \right] \\
+ r&\left[ (p + c - w_b)Q_h{}^d - (m + \Delta m)(p - u + c)\int_A^{\frac{Q_h{}^d}{m+\Delta m}} F(\lambda)d\lambda \right. \\
&\left. - c(m + \Delta m)\mu \right].
\end{aligned}
\tag{18}
$$

Due to $E(\pi^d) - E(\pi_k{}^s) = (1 - r)(w_a - w_b)Q_h{}^d + r[(p + c - w_b)Q_h{}^d - (m + \Delta m)(p - u + c)\int_A^{Q_h{}^d/m+\Delta m} F(\lambda)d\lambda]$, the solution is available $r > (w_b - w_a)Q_h{}^d / (p + c - w_a)Q_h{}^d - (m + \Delta m)(p - u + c)\int_A^{Q_h{}^d/m+\Delta m} F(\lambda)d\lambda$. □

If an overseas retailer cooperates with a crossborder supplier, and the overseas retailer invests in the crossborder supplier, the amount is $I$, and the crossborder supplier will provide products to the overseas retailer at a lower supply price $w_a{}^*$. After the investment, affected by factors such as the speed of logistics and the quality of transportation equipment, the risk of supply interruption is reduced to $r^*$. At this time, the profit function $\pi_d{}^*$ for overseas retailers' dual-source procurement is

$$
\begin{aligned}
\pi^{d*} = (1 - r^*)&\left\{ p \min\left(Q_k{}^{d*} + Q_h{}^{d*}, D\right) - w_a{}^* Q_k{}^{d*} - w_b Q_h{}^{d*} \right. \\
&\left. - c\left[D - Q_k{}^{d*} - Q_h{}^{d*}\right]^+ + u\left[Q_k{}^{d*} + Q_h{}^{d*} - D\right]^+ \right\} \\
+ r^*&\left\{ p \min\left(Q_h{}^{d*}, D^*\right) - w_b Q_h{}^{d*} - c\left[D^* - Q_h{}^{d*}\right]^+ \right. \\
&\left. + u\left[Q_h{}^{d*} - D^*\right]^+ \right\} - I, D^* = (m + \Delta m)\lambda.
\end{aligned}
\tag{19}
$$

**Lemma 4.** *After the overseas retailers' investment, when the supply interruption risk and investment amount meet the conditions $r \geq \alpha I + (w_b - w_a + \beta I/p + c - w_a + \beta I)$, the purchasing volumes of overseas retailers from crossborder suppliers and overseas suppliers are $Q_k{}^{d*}$ and $Q_h{}^{d*}$, respectively.*

*Proof.* After the investment behavior, the expected profit function of the overseas retailer is $E(\pi^{d*}) = [1 - (r - \alpha I)]\{p [ \int_A^{Q_k{}^{d*}+Q_h{}^{d*}} Df(D)dD + \int_{Q_k{}^{d*}+Q_h{}^{d*}}^B (Q_k{}^{d*} + Q_h{}^{d*})f(D)dD] - (w_a - \beta I)Q_k{}^{d*} - c\int_{Q_k{}^{d*}+Q_h{}^{d*}}^B [D - (Q_k{}^{d*} + Q_h{}^{d*})]Df(D)dD + u \int_A^{Q_k{}^{d*}+Q_h{}^{d*}} (Q_k{}^{d*} + Q_h{}^{d*} - D)f(D)dD - w_b Q_h{}^{d*}\} + (r - \alpha I)\{p [\int_A^{Q_h{}^{d*}} D^* f(D^*)dD^* + \int_{Q_h{}^{d*}}^B Q_h{}^{d*} f(D^*)dD^*] - c\int_{Q_h{}^{d*}}^B (D^* - Q_h{}^{d*})D^* f(D^*)dD^* - w_b Q_h + u\int_A^{Q_h{}^{d*}} (Q_h{}^{d*} - D^*)f(D^*)dD^*\} - I..$ □

Simplify by using the method of integration by parts

$$
\begin{aligned}
E\left(\pi^{d*}\right) = [1 - (r - \alpha I)]&\left[ (p + c - w_a + \beta I)Q_k{}^{d*} + (p + c - w_b)Q_h{}^{d*} \right. \\
&\left. - m(p - u + c)\int_A^{\frac{Q_k{}^{d*}+Q_h{}^{d*}}{m}} F(\lambda)d\lambda - cm\mu \right] + (r - \alpha I) \\
\cdot&\left[ (p + c - w_b)Q_h{}^{d*} - (m + \Delta m)(p - u + c)\int_A^{\frac{Q_h{}^{d*}}{m+\Delta m}} F(\lambda)d\lambda \right. \\
&\left. - c(m + \Delta m)\mu \right] - I.
\end{aligned}
\tag{20}
$$

By finding the derivatives of $E(\pi^{d*})$ with respect to $Q_k{}^{d*}$ and $Q_h{}^{d*}$, we can obtain

$$
\frac{\partial E(\pi^{d*})}{\partial Q_k{}^{d*}} = (1 - r + \alpha I)[(p + c - w_a + \beta I) - (p - u + c)F\left(\frac{Q_k{}^{d*} + Q_h{}^{d*}}{m}\right),
\tag{21}
$$

$$
\begin{aligned}
\frac{\partial E(\pi^{d*})}{\partial Q_h{}^{d*}} = (1 - r + \alpha I)&\left[ (p + c - w_b) - (p - u + c)F\left(\frac{Q_k{}^{d*} + Q_h{}^{d*}}{m}\right) \right] \\
+ (r - \alpha I)&\left[ (p + c - w_b) - (p - u + c)F\left(\frac{Q_h{}^{d*}}{m + \Delta m}\right) \right].
\end{aligned}
\tag{22}
$$

Assigning formulae (21) and (22) to 0, solving the system of equations can be obtained

$$
\begin{aligned}
Q_k{}^{d*} = mF^{-1}&\left(\frac{p + c - w_a + \beta I}{p + c - u}\right) - (m + \Delta m)F^{-1} \\
\cdot&\left[\frac{(1 - r + \alpha I)(w_a - \beta I) - w_b + (r - \alpha I)(p + c)}{(r - \alpha I)(p + c - u)}\right].
\end{aligned}
\tag{23}
$$

$$Q_h^{d*} = (m + \Delta m)F^{-1}\left[\frac{(1 - r + \alpha I)(w_a - \beta I) - w_b + (r - \alpha I)(p + c)}{(r - \alpha I)(p + c - u)}\right].$$

(24)

To make a meaningful solution of equations that must satisfy the condition $(1 - r + \alpha I)(w_a - \beta I) - w_b + (r - \alpha I)(p + c) \geq 0$, in this time, there will exist $Q_h^{d*} > 0$, which is the case of dual-source procurement. So, $r \geq \alpha I + (w_b - w_a + \beta I /p + c - w_a + \beta I)$ and complete the proof of the lemma.

**Lemma 5.** *After overseas retailers have invested, under the dual-source procurement situation, overseas retailers have increased their purchases of products supplied by crossborder suppliers and have reduced their purchases of products supplied by overseas suppliers. The overall purchase volume has increased.*

*Proof.* According to equations (17) and (24), we can get the purchase quantity of overseas retailers from overseas suppliers before and after investment; so,

$$Q_h^d - Q_h^{d*} = (m + \Delta m)\left\{F^{-1}\left[\frac{(1 - r)w_a - w_b + r(p + c)}{r(p + c - u)}\right] - F^{-1}\right.$$
$$\left.\cdot \left[\frac{(1 - r + \alpha I)(w_a - \beta I) - w_b + (r - \alpha I)(p + c)}{(r - \alpha I)(p + c - u)}\right]\right\}.$$

(25)

$F^{-1}(x)$ is the inverse function of $F(x)$, which has the same monotonicity, while as a continuous probability distribution function, function $F(x)$ is monotonous increasing with the increase of $x$, due to

$$\frac{(1 - r)w_a - w_b + r(p + c)}{r(p + c - u)}$$
$$- \frac{(1 - r + \alpha I)(w_a - \beta I) - w_b + (r - \alpha I)(p + c)}{(r - \alpha I)(p + c - u)}$$

$$= \frac{I[\beta r(1 - r) + \alpha(w_b - w_a) + I\alpha\beta r]}{r(r - \alpha I)(p + c - u)}$$
$$> 0 F^{-1}\left[\frac{(1 - r)w_a - w_b + r(p + c)}{r(p + c - u)}\right]$$
$$> F^{-1}\left[\frac{(1 - r + \alpha I)(w_a - \beta I) - w_b + (r - \alpha I)(p + c)}{(r - \alpha I)(p + c - u)}\right].$$

(26)

So, $Q_h^d > Q_h^{d*}$, and the purchase volume of this channel from overseas suppliers has decreased. It is the same because of

$Q_k^d + Q_h^d = mF^{-1}(p + c - w_a/p + c - u), Q_k^{d*} + Q_h^{d*} = mF^{-1}(p + c - w_a + \beta I/p + c - u)$, while $p + c - w_a/p + c - u \leq p + c - w_a + \beta I/p + c - u$; so, we can get, $F^{-1}(p + c - w_a/p + c - u) \leq F^{-1}(p + c - w_a + \beta I/p + c - u)$, $Q_k^d + Q_h^d \leq Q_k^{d*} + Q_h^{d*}$, and the overall purchase volume of retailers has increased. Through the overall procurement volume and the procurement volume from overseas suppliers, it can be found that the volume of products purchased by overseas retailers from crossborder suppliers has increased, and the increase is more than the reduction from overseas suppliers. This is because after the investment, the prices of crossborder suppliers have advantages, the instability is reduced, and overseas retailers can obtain more profits. □

## 3. Results and Discussion

In order to verify the rationality of the model and reveal the changes in the expected profit and purchase volume of overseas retailers under different purchasing methods, this section verifies the conclusions reached above. In the two-tier supply chain composed of crossborder suppliers, overseas suppliers, overseas retailers, and consumers, according to the parameter range set above, select parameter values, random market demand $\lambda \in (100, 200)$ is evenly distributed, crossborder suppliers and overseas suppliers supply prices that are $w_a = 6$ and $w_b = 10$, respectively, overseas retailers sell products at retail prices of $p = 15$, market demand determination part is $m = 18$, if supply interruption, demand increase is $\Delta m = 2$, out-of-stock cost is $c = 4$, the residual value of the product is $u = 1$, and the impact factors of investment on supply disruptions and crossborder supplier supply prices were $\alpha = 0.005$ and $\beta = 0.1$, respectively.

*3.1. The Impact of Supply Disruption Probability on Purchase Volume.* In the case of single source procurement and dual-source procurement, if the disruption probability of crossborder suppliers changes, the purchase volume of overseas retailers in each channel will also change. According to Lemma 4, when $r \geq w_b - w_a/p + c - w_a$, that is $r \geq 0.3077$, there will cause double source procurement. Assuming that $r$ rises from 0.4 to 0.7, we will get the change of procurement quantity in two cases, as shown in Figure 2.

It can be seen from Figure 2 that if the crossborder suppliers do not experience disruption under single-source procurement, then the purchase volume of overseas retailers from crossborder suppliers is equal to the total purchase volume under dual-source procurement. If overseas retailers choose to purchase from single source, the purchase volume of overseas retailers from crossborder suppliers is more than that from overseas suppliers. If overseas retailers choose dual-source procurement, with the increase of supply interruption probability of crossborder suppliers, overseas retailers will reduce the procurement of goods provided by crossborder suppliers and increase the procurement of goods provided by overseas suppliers, so as to avoid risks and reduce losses.

*3.2. The Impact of Supply Disruption Probability on Expected Profit.* In the case of single-source procurement and dual-source procurement, if the disruption probability of crossborder suppliers changes, the expected profits of overseas retailers in various channels will also change. Suppose $r$ goes up from 0.1 to 0.6, the change of expected profit under these two conditions is obtained, as shown in Figure 3.
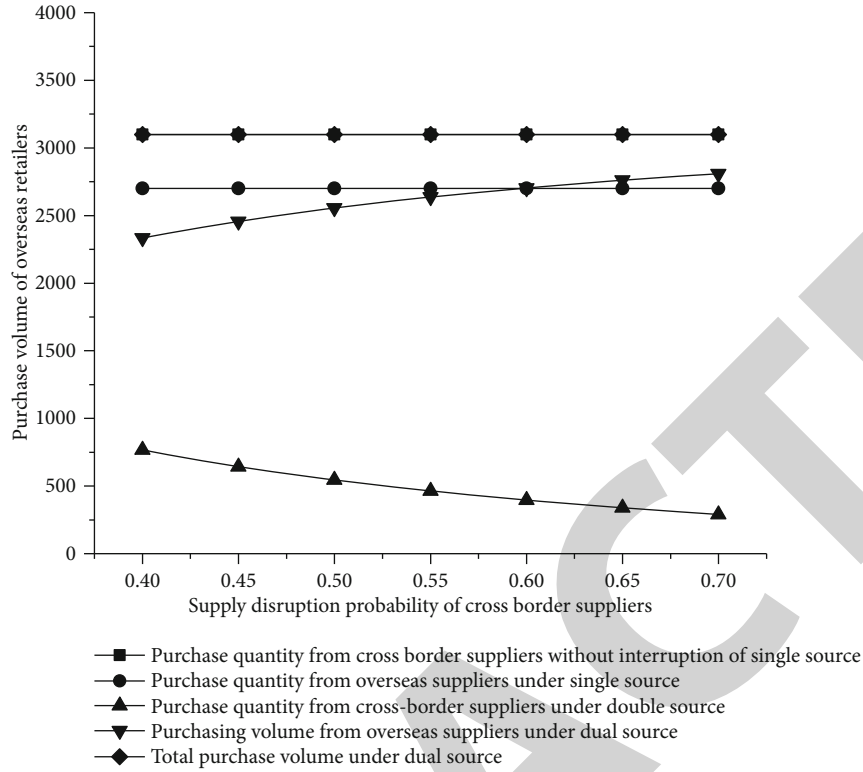
FIGURE 2: The relationship between retailer procurement volume and crossborder supplier supply disruption probability under single-source and dual-source procurement.
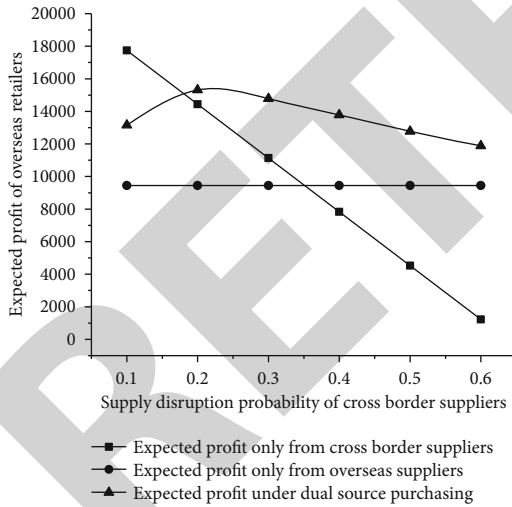


FIGURE 3: The relationship between retailer's expected profit and crossborder supplier supply disruption probability under single-source and dual-source procurement.

It can be seen from Figure 3 that the expected profit of overseas retailers is not affected by the disruption probability when they only purchase from overseas suppliers. With the increase of interruption probability of crossborder suppliers, the expected profit will decrease rapidly and face huge losses if only purchasing from crossborder suppliers. When overseas retailers choose dual-source procurement, it will not only achieve the maximum expected profit within a certain

risk but also effectively curb the decline of expected profit. When the disruption risk is greater than 0.1761, the expected profit from crossborder suppliers is lower than that from dual-source suppliers, and the decision of dual-source suppliers is better than that of single source suppliers.

In combination with Figures 3 and 4, it can be found that under dual-source procurement, overseas retailers will not be too passively affected by the probability of disruption of crossborder supplier supply and will be able to ensure to some extent the expected profits of overseas retailers.

3.3. The Impact of Supply Disruption Probability and Investment Amount on Expected Profit. When the overseas retailer invests in the crossborder supplier, the expected profit of the overseas retailer will be affected by both the supply interruption probability of the crossborder supplier and the investment amount of the overseas retailer. According to Lemma 4, when the supply interruption probability of the crossborder supplier $r$ and the investment amount of the overseas retailer $I$ meet $r \geq \alpha I + (w_b - w_a + \beta I/p + c - w_a + \beta I)$, the situation of dual-source procurement will appear. Thus, suppose $r$ rises from 0.4 to 0.7 and corresponding $I$ rises from 40 to 70. The change of purchasing volume and expected profit after investment of overseas retailers under dual-source procurement is shown in Figure 4.

It can be seen from Figure 4 that after overseas retailers invest, if the probability of crossborder supplier interruption is low, and at the same time they have made large
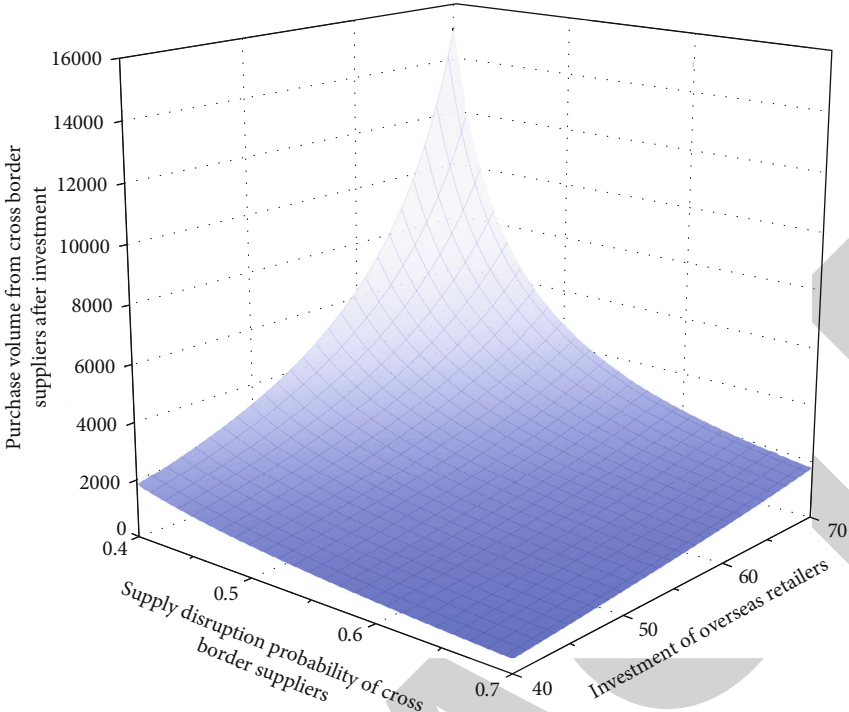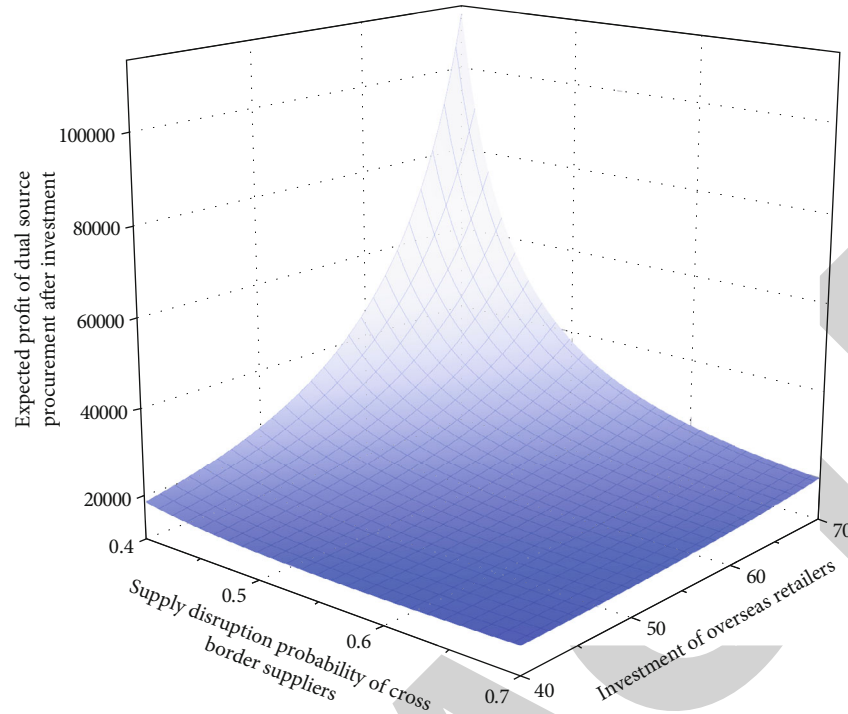
(a) Purchase volume from crossborder suppliers after investment
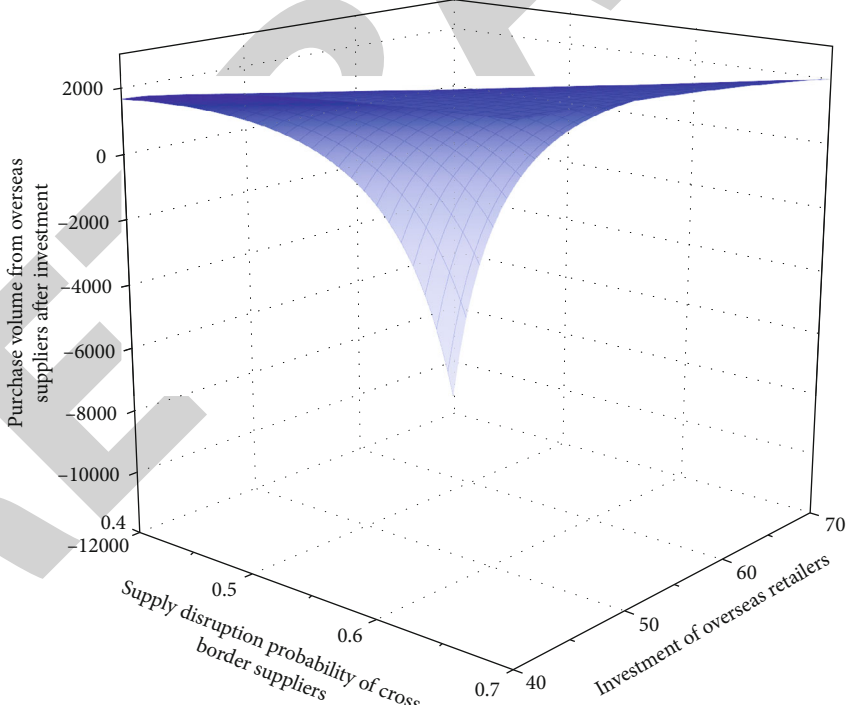


(b) Purchase volume from overseas suppliers after Investment

Figure 4: Continued.

(c) Expected profit of dual-source procurement after investment

FIGURE 4: Changes of various parameters under the dual influence of supply disruption probability and investment amount.

investments in crossborder suppliers, then overseas retailers will purchase a large number of crossborder suppliers' products and greatly reduce the products of overseas suppliers, and the expected profits of overseas retailers will also be very high. In addition, when the risk of supply interruption of crossborder suppliers is large, the higher investment number of overseas retailers, the higher expected profit of dual-source procurement will be received, and the investment behavior of overseas retailers can effectively restrain the risk of crossborder supplier disruption. Therefore, the risk stability of dual-source procurement can be further strengthened through investment by overseas retailers, and the expected profits of retailers can be improved.

## 4. Conclusion

This paper takes the mobile communication procurement platform supply chain as the research object and constructs a two-level supply chain composed of crossborder suppliers, overseas suppliers, and overseas retailers. Study the optimal purchasing decision problem of the supply chain in four situations: only purchasing from crossborder suppliers, purchasing only from overseas suppliers, purchasing from crossborder and overseas suppliers at the same time, and purchasing from crossborder and overseas suppliers at the same time after retailer investment. The analysis found that compared with single-source procurement, dual-source procurement can make overseas retailers not passively affected by the probability of supply disruption by crossborder suppliers and can also ensure the expected profits of overseas

retailers to a certain extent. At the same time, the investment behavior of overseas retailers in crossborder suppliers can effectively curb the possible negative impact of crossborder supplier disruption risk under dual-source procurement. As a result, overseas retailers may consider investing in crossborder suppliers and opting for a two-channel approach to procurement to achieve higher expected profits with stable risk. Of course, the above model has certain limitations. For example, it only considers the risk neutral conditions of each enterprise and does not consider issues such as the risk preference of decision makers and retailer price decisions. In the future, research on supply chain coordination can be carried out from the perspective of supplier risk preference.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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