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AN INVESTMENT DECISION-MAKING RESEARCH ON CROSS-BORDER E-COMMERCE OVERSEAS WAREHOUSE BASED ON REAL OPTION

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Abstract. *Using a real option model, this paper studies the investment decision-making of cross-border e-commerce overseas warehouse. Through investment cost-revenue analysis, we find that the investment threshold is positively correlated with the volatility of overseas demand. So suppliers can reduce the volatility of overseas demand by allocating different types of overseas warehousing goods, thereby reducing the investment threshold. That can explain why large-scale cross-border e-commerce platforms always take precedence over those smaller ones on overseas warehouse construction.*
Keywords: Cross-border e-commerce, Overseas warehouse, Real option

1. **Introduction.** With the further development of economic globalization, cross-border e-commerce has gradually become an important new international trade way. From January to June in 2016, China's cross-border e-commerce trade volume reached 2.6 trillion, an increase of 30%, accounting for 22.78% of China's total import and export value. The rapid rise of cross-border e-commerce providers has put forward higher requirements to the cross-border logistics. The direct mail way, such as traditional international postal packet, international express or cross-border logistics, can offer cross-border logistics door to door service from sellers to consumers, but many problems greatly reduce the degree of consumer experience. These problems include parcel damaging or missing, barriers to customs clearance, longer delivery time, untracked logistics information in real-time, high transport costs and returns difficulty. Under these circumstances, overseas warehouse becomes one of the developing trends of cross-border e-commerce logistics.

Overseas warehouse is a kind of logistics control and management services, referring that sellers construct or lease warehouse overseas first, then deliver goods to local warehouse in international multimodal transport, and then local warehouse directly delivers after receiving internet customer orders. Lee pointed out that the overseas warehouse of the third party logistics company can help management optimization and service upgrade of cross-border e-commerce [1]. Cao and Xu analyzed the advantages and disadvantages of overseas warehouses [2]. To and Lai believed that overseas warehouse construction is more conducive to Chinese enterprises to participate in international trade activities [3]. Ji and Zhang proposed that overseas warehouses would help to realize the localized operation in cross-border logistics [4]. Wu put forward some suggestions on how to build overseas warehouses [5]. Ge suggested that cross-border logistics enterprises can use economic and trade policies to strengthen the construction and application of large-scale data, and carry out hybrid management to strengthen the third party construction of overseas warehouses [6].

Whether leased or self-built, overseas warehouse operation and maintenance costs are generally high. And it will encounter lots of issues such as inventory turnover, inventory digestion, distribution and after-sales. Therefore, when cross-border e-commerce suppliers make the decision about investing overseas warehouse, they need to forecast future market demand. Because market operating results can be influenced by many factors, the investment decisions of overseas warehouse are of the nature of options: the decision-making process is equivalent to a permanent call option, while the decision result is equivalent to whether the right to exercise. If cross-border e-commerce suppliers expect future potential of overseas market demand is substantial, they should exercise and self-built overseas warehouses; on the contrary, companies can postpone the investment, waiting for better chances to obtain higher returns.

Myers firstly applied option pricing theory to the field of projects investment and put forward real option theory [7]. Trigeorgis and Mason clearly pointed out the effectiveness of appraisal method based on option pricing theory in evaluating the flexibility and strategic role of firms [8]. Dixit and Pindyck applied real option theory to optimal investment decision-making, deciding immediate or delayed investment [9]. Smit and Trigeorgis integrated real options and game theory to extend the application of real options and strategic thinking, and provided powerful decision tools for evaluating whether firm strategy will create value for shareholders or not [10]. Lots of domestic researches focused on the application of real option theory in investment decision-making, and emphasized the uncertainty of economic environment and the irreversibility of investment, such as Gu [11], Li and Chen [12], Zhou et al. [13].

In summary, the existing literatures about overseas warehouse mainly focus on the relationship of overseas warehouse and cross-border logistics, overseas warehouse operation and storage planning. Few literatures researched on the investment of overseas warehouses. On the other hand, lots of literatures focused on the application of real option theory in investment decision-making, but few literatures introduce the real option model into the investment decision-making of overseas warehouses. Therefore, we establish a real option model to study the investment decision-making of overseas warehouses.

This paper is organized as follows: after a real option model is set up in Section 2, Section 3 solves the model. Section 4 analyzes the impact of demand volatility on investment threshold, and deduces one lemma and one corollary. Section 5 offers a conclusion and potential research direction.

2. Model Hypotheses and Establishment.

Considering the overseas warehouse investment, cross-border e-commerce enterprises mainly compare investment costs with investment benefits. The investment benefits are closely related to the demand of cross-border goods, so the value of overseas warehouse construction can be written as a model with two variables, one is investment costs and the other is overseas market demand.

2.1. Basic hypotheses.

Our model makes the assumption that investing costs and market demand will be considered by cross-border e-commerce suppliers when they need to decide whether to invest overseas warehouses or not. Define C as investing costs and Q as market demand of cross-border goods (for facilitating calculation, consider Q as the annual demand), both of which are uncertain and subject to geometric Brownian motion:

$$dC = \mu_C C dt + \sigma_C C dz_C \tag{1}$$

$$dQ = \mu_Q Q dt + \sigma_Q Q dz_Q \tag{2}$$

where μ_C is the expected growth rate of investment costs, σ_C is the volatility of investment costs, and dz_C is the standard Wiener increment, following standard normal distribution: $dz_C = \varepsilon \cdot \sqrt{dt}$, $\varepsilon \sim N(0, 1)$; μ_Q is the expected return of the demand for cross-border goods, σ_Q is the volatility of the demand, and dz_Q is the standard Wiener increment, following standard normal distribution: $dz_Q = \varepsilon \cdot \sqrt{dt}$, $\varepsilon \sim N(0,1)$. And $(dz_Q)^2 = dt$, $(dz_C)^2 = dt$, $E(dz_Q \cdot dz_C) = \rho \cdot dt$, and ρ is the correlation coefficient between dz_Q and dz_C.

The revenue of investing overseas warehouses is mainly affected by the overseas demand Q, so the investment value V can be expressed as a function of Q: $V = V(Q)$. Therefore, investing revenue is $V(Q) - C$; define F as the opportunity value of investing overseas warehouses, which is determined by Q and C, $F = F(Q, C)$. Thus, the foundation of overseas warehouses investment decision-making can be written as follows:

$$Max[V(Q) - C, F(Q, C)] \tag{3}$$

Equation (3) means when cross-border e-commerce suppliers decide whether to invest overseas warehouses immediately or not, they will compare investment revenue with investment opportunity value. If investment revenue is greater than opportunity value, that is $V(Q) - C > F(Q, C)$, they would like to invest immediately; if investment revenue is smaller than opportunity value, that is $V(Q) - C < F(Q, C)$, they would like to delay investment; if investment revenue is equal to opportunity value, that is

$$V(Q) - C = F(Q, C) \tag{4}$$

We can get the optimal investment decisions for suppliers from Equation (4), and its solution Q^* is the investment threshold. Compared with Equation (3), Q^* is more concise and easier to apply, which is the reason that the investment threshold is the main basis for suppliers to make investment decisions. When $Q > Q^*$, suppliers choose to invest immediately; when $Q < Q^*$, suppliers choose to delay investment; and when $Q = Q^*$, spot investment and delayed investment are the same.

2.2. **Model establishment.** Assuming that the life of overseas warehouse is T years. For simplicity, this paper assumes that the average price of goods stored in overseas warehouse is $\overline{P}$, the risk-free interest rate is γ, so the investment value $V(Q)$ is as follows:

$$V(Q) = E\left[\int_0^T \overline{P} Q e^{-\gamma t} dt\right] = \frac{\overline{P} Q \left[1 - e^{-(\gamma - \mu_Q)T}\right]}{\gamma - \mu_Q} \tag{5}$$

Since Q and C obey the geometric Brownian motion, we can see that the investment opportunity value $F = F(Q, C)$ is Ito's process, and

$$dF = \frac{\partial F}{\partial Q} dQ + \frac{\partial F}{\partial C} dC + \frac{1}{2}\frac{\partial^2 F}{\partial Q^2}[dQ]^2 + \frac{1}{2}\frac{\partial^2 F}{\partial C^2}[dC]^2 + \frac{\partial^2 F}{\partial Q \cdot \partial C} dQ dC \tag{6}$$

$$E[dF] = \left[\mu_Q Q F'_Q + \mu_C C F'_C + 0.5\sigma_Q^2 Q^2 F''_{QQ} + 0.5\sigma_C^2 C^2 F''_{CC} + \rho\sigma_Q\sigma_C Q C F''_{QC}\right] dt \tag{7}$$

where $F'_Q = \frac{\partial F}{\partial Q}$, $F'_C = \frac{\partial F}{\partial C}$, $F''_{QQ} = \frac{\partial^2 F}{\partial Q^2}$, $F''_{CC} = \frac{\partial^2 F}{\partial C^2}$, $F''_{QC} = \frac{\partial^2 F}{\partial Q \partial C}$.

In uncertain conditions, the optimization of time dimension can be solved by dynamic programming, according to the Bellman equation:

$$\gamma F(Q, C) dt = E[dF] \tag{8}$$

By solving Equations (7) and (8), we obtain the ordinary differential equation:

$$\mu_Q Q F'_Q + \mu_C C F'_C + 0.5\sigma_Q^2 Q^2 F''_{QQ} + 0.5\sigma_C^2 C^2 F''_{CC} + \rho\sigma_Q\sigma_C Q C F''_{QC} - \gamma F = 0 \tag{9}$$

3. **Model Solving.** As a binary partial differential equation of Q and C, Equation (9) is difficult to solve directly, so it can be transformed into an equation of one variable. There is a positive correlation between overseas demand Q and investment costs C. Assuming that when Q and C increase proportionally, and the investment opportunity value F also increases in proportion, thus F can be expressed as the commodity demand of unit cost:

$$F(Q,C) = CF\left(\frac{Q}{C},1\right) = Cf(h) \tag{10}$$

In Equation (10), $h = \frac{Q}{C}$ is the commodity demand of unit cost (h can also be understood as the goods storage of unit cost, on behalf of the storage capacity of overseas warehouses).

So, $F'_Q = f'(h)$, $F'_C = f(h) - hf'(h)$, $F''_{QQ} = \frac{f''(h)}{C}$, $F''_{CC} = \frac{h^2 f''(h)}{C}$, $F''_{QC} = -\frac{hf''(h)}{C}$; thus, Equation (9) can be simplified as follows:

$$0.5\left(\sigma_Q^2 + \sigma_C^2 - 2\rho\sigma_Q\sigma_C\right)h^2 f''(h) + (\mu_Q - \mu_C)\,hf'(h) - (\gamma - \mu_C)\,f(h) = 0 \tag{11}$$

The solution form of Equation (11) is:

$$f(h) = Ah^\beta \tag{12}$$

So we can get the solution:

$$\beta_1 = \frac{1}{2} - \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{\theta}{\sigma^2}} > 1, \quad \beta_2 = \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{\theta}{\sigma^2}} < 0 \tag{13}$$

where $\sigma^2 = \sigma_Q^2 + \sigma_C^2 - 2\rho\sigma_Q\sigma_C$, $\mu = \mu_Q - \mu_C$, $\theta = \gamma - \mu_C$. Considering actual meaning, the positive solution β_1 is retained and the negative one β_2 is abandoned.

According to Dixit and Pindyck [9], the solution of $f(h)$ satisfies value matching condition and smooth transition condition, which are written as Equations (14) and (15):

$$f(h) = \frac{V(Q)}{C} - 1 = \overline{P}h\frac{1 - e^{-(\gamma-\mu_Q)T}}{\gamma - \mu_Q} - 1 \tag{14}$$

$$f'(h) = \overline{P}\frac{1 - e^{-(\gamma-\mu_Q)T}}{\gamma - \mu_Q} \tag{15}$$

According to Equations (12)-(15), we can get the solution of h:

$$h^* = \frac{1}{\overline{P}} \cdot \frac{\beta_1}{\beta_1 - 1} \cdot \frac{\gamma - \mu_Q}{1 - e^{-(\gamma-\mu_Q)T}} \tag{16}$$

Considering $h = \frac{Q}{C}$, thus the investment threshold Q^* is:

$$Q^* = \frac{C}{\overline{P}} \cdot \frac{\beta_1}{\beta_1 - 1} \cdot \frac{\gamma - \mu_Q}{1 - e^{-(\gamma-\mu_Q)T}} \tag{17}$$

4. **The Impact of Demand Volatility on Investment Threshold.** Substituting Equations (12) and (13) into Equation (11), we can get an equation about σ_Q, which is marked as J:

$$J = \frac{1}{2}\sigma^2\beta_1(\beta_1 - 1) + \mu\beta_1 - \theta = 0 \tag{18}$$

where $\sigma^2 = \sigma_Q^2 + \sigma_C^2 - 2\rho\sigma_Q\sigma_C$, $\mu = \mu_Q - \mu_C$, $\theta = \gamma - \mu_C$.

Equation (18) can be written as follows:

$$\frac{\partial J}{\partial \sigma_Q} = \frac{\partial J}{\partial \sigma}\frac{\partial \sigma}{\partial \sigma_Q} + \frac{\partial J}{\partial \beta_1}\frac{\partial \beta_1}{\partial \sigma_Q} = 0 \tag{19}$$

According to Equations (18) and (19), we can get Equation (20):

$$\frac{\partial \beta_1}{\partial \sigma_Q} = -\left(\frac{\partial J}{\partial \sigma}\frac{\partial \sigma}{\partial \sigma_Q}\Big/\frac{\partial J}{\partial \beta_1}\right) = -\frac{\beta_1(\beta_1 - 1)(\sigma_Q - \rho\sigma_C)}{\mu + (\beta_1 - 0.5)\sigma^2} \tag{20}$$

Under normal circumstances, the construction costs of overseas warehouses will reduce with the progress of technology ($\mu_C < 0$), while with the development international trade, the overseas demand shows an increasing trend ($\mu_Q > 0$), so $\mu = (\mu_Q - \mu_C) > 0$. Comparing with the construction costs of overseas warehouses, the demand is easily affected by lots of factors, such as competition, and consumer revenue. Therefore, the volatility of demand is greater than that of investment costs ($\sigma_Q > \sigma_C$).

The value of non-zero correlation coefficient ρ is between -1 and 1, and $\beta_1 > 1$, so $\sigma_Q - \rho\sigma_C > 0$, $\frac{\partial \beta_1}{\partial \sigma_Q} < 0$.

And

$$\frac{\partial Q^*}{\partial \beta_1} = -\frac{C}{\overline{P}} \frac{\gamma - \mu_Q}{1 - e^{-(\gamma - \mu_Q)T}} \frac{1}{(\beta_1 - 1)^2} < 0 \tag{21}$$

So

$$\frac{\partial Q^*}{\partial \sigma_Q} = \frac{\partial Q^*}{\partial \beta_1} \frac{\partial \beta_1}{\partial \sigma_Q} > 0 \tag{22}$$

Lemma 4.1. *The investment threshold is positively correlated with the volatility of overseas demand, that is, the investment threshold increases with the increase of the demand volatility.*

According to the portfolio theory, investors can reduce the total risk by diversifying investment, without reducing the expected return. The allocation of cross-border e-commerce suppliers on overseas warehousing commodities can also be regarded as the investing process of financial market. By allocating different types of goods in overseas warehouses, suppliers can reduce volatility of overseas demand without reducing the expected earnings. It can be written as follows:

$$\begin{aligned} \operatorname{var}\left(\sum_{i=1}^{n} \kappa_i Q_i\right) &= \kappa_1^2 \operatorname{var}(Q_1) + \kappa_2^2 \operatorname{var}(Q_2) + \cdots + \kappa_n^2 \operatorname{var}(Q_n) + \sum_{j \neq k} \rho_{jk} \kappa_j \kappa_k \sigma_j \sigma_k \\ &\leq \min\left[\operatorname{var}(Q_1), \operatorname{var}(Q_2), \ldots, \operatorname{var}(Q_n)\right] \end{aligned} \tag{23}$$

where $\sum_{i=1}^{n} \kappa_i = 1$, $\kappa_i \geq 0$. ρ_{jk} is the correlation coefficient between the demand for commodity j and commodity k , $-1 \leq \rho_{jk} \leq 1$.

Corollary 4.1. *Suppliers can reduce the volatility of overseas demand by allocating different types of overseas warehousing goods, thereby reducing the investment threshold.*

Example 4.1. *To verify the relationship between the volatility of overseas demand and the investment threshold, we give a group of parameters which are assumed based on reality.*

By substituting these parameters into the investment threshold Q^*, we can get different solutions with different volatility σ_Q. These solutions are shown in Table 2, from which we can see that with the increase of σ_Q, Q^* also increases.

Table 1. Parameters of overseas warehouse investment decision-making model

Parameters	*Variables*	*Value*
Investing costs (million)	C	*8*
Average price (dollar)	$\overline{P}$	*80*
Risk-free interest rate	γ	*5%*
The expected return of overseas demand	μ_Q	*3%*
The expected growth rate of investment costs	μ_C	*−2.5%*
The volatility of investment costs	σ_C	*0.5%*
The correlation coefficient between dz_Q and dz_C	ρ	*0.5*
The life of overseas warehouse (year)	T	*30*

Table 2. The investment threshold of overseas warehouse

The volatility of overseas demand σ_Q	*1%*	*5%*	*10%*	*15%*	*20%*
The investment threshold Q^*	*16634*	*16964*	*18023*	*19735*	*22036*

5. **Conclusions.** According to the above analyses, we find that the greater the volatility of overseas demand is, the greater the value of waiting is, so suppliers are more inclined to delay the overseas warehouse investment. On the contrary, if the overseas demand is stable, suppliers are more willing to invest immediately. Suppliers with the ability to diversify their merchandise can reduce the investment threshold by allocating different types of overseas warehousing goods, making it easier to invest overseas warehouses immediately. However, those who are unable to diversify their merchandise will not invest immediately.

By focusing on the impact of demand volatility in overseas market, this paper studies the investment decision-making of overseas warehouse. To highlight the research priority, the price of goods stored in overseas warehouse is assumed as a constant $\overline{P}$ during the process of model establishment. Thus, it is necessary to relax the assumption of fixed price to study the impact of pricing strategy on the investment decision-making of overseas warehouse, which will be the further research of this study.

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