International Journal of Innovative Computing, Information and Control
Volume **15**, Number **2**, April **2019**
ICIC International ©2019 ISSN 1349-4198
pp. 803–810

RESEARCH ON THE TRANSFORMATION STRATEGY OF INTERNATIONAL PORT LOGISTICS SERVICE UNDER THE CROSS-BORDER E-COMMERCE ENVIRONMENT

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Received June 2018; revised October 2018

Abstract. *The transformation of international port logistics services for cross-border e-commerce, not only can promote the development of cross-border e-commerce, but also the inherent requirements of the international port development. However, the transformation of the international port is bound to face a large number of investment, uncertainty and risk. Therefore, this paper based on the principle of risk neutral, uses real option theory to establish a decision model of the transformation of the international port logistics services for cross-border e-commerce, analyzes the factors affecting international port service transformation and how to choose transformation time. Research results show that the volatility of cross-border e-commerce logistics demand is positively related to the critical service transition logistics demand; therefore, it should reduce the volatility of cross-border e-commerce logistics demand. Finally, this paper puts forward that the international port can reduce the volatility of cross-border e-commerce logistics demand by constructing cross-border e-commerce logistics service category, and then promote the early realization of the services transformation.*

Keywords: Cross-border e-commerce, Port logistics, Real options, Transformation of international port

1. **Introduction.** At present, the international development of the port is divided into four generations in chronological order (UNCTAD, 1992; UNCTAD, 1999) [1,2]. From 2000 to now, with the development of science and technology, economy and society, a discussion on the fifth generation port began to appear, and these discussions are based on the major technical, economic and social changes, such as the low-carbon ports based on environmental requirements, and information technology based intelligent port. And there is no denying that the revolution of e-commerce is the most profound business revolution that our society faces, and cross-border e-commerce is a revolution to the electronic commerce in recent years. It is expected to be a new paradigm of international trade and will replace the traditional international trade. Many researchers have pointed out that cross-border e-commerce and international port have the relationship of coordinated development. Zhang and Ma think cross-border logistics is the most important obstacle of cross-border e-commerce [3]. Zhang et al. also point out that in the area of cross-border e-commerce logistics demand and logistics supply do not match [4]. Zhang argues that Tianjin Port should innovate its business model based on the cross-border e-commerce [5]. Hu and Zhao have studied the coordinated development of port logistics industrial cluster and cross-border e-commerce [6]. Zheng et al. use complex network to identify

DOI: 10.24507/ijicic.15.02.803

the key ports of B2C export cross-border e-commerce [7]. He believes that under the background of the rapid development of cross-border e-commerce mode, the current port services have lagged behind and must be changed [8]. Wu believes that the development of cross-border e-commerce directly promoted the development of port transportation [9]. Lu analyzes the advantages and disadvantages of Tianjin Port in developing cross-border e-commerce through SWOT technology, and points out that facing the competition of Dalian, Qingdao and other ports, Tianjin Port must seize the opportunity to provide services for the development of cross-border e-commerce [10]. Although these scholars believe that ports should transform their services for cross-border e-commerce, they fail to put forward specific strategies for port transformation. Those studies have recognized the importance of cross-border e-commerce to international port; they did not point out the interactive mechanism of international port and cross-border e-commerce. Therefore, it is of great value to discuss the transformation of international port logistics service under the cross-border e-commerce environment. It is mainly reflected in the following three aspects. Firstly, providing logistics service for cross-border e-commerce is the need of international port logistics development. Secondly, the development of cross-border e-commerce provides a new possibility for the transformation of international port logistics service. Finally, providing logistics services for cross-border e-commerce can avoid the homogenous competition of international ports and promote the orderly development of international ports.

In short, with the development of cross-border e-commerce, service transformation for cross-border e-commerce has certain significance for international ports. However, the transformation of international ports inevitably faces uncertainties and risks. On the one hand, cross-border e-commerce is still in the process of rapid development, and therefore, the growth and volatility of cross-border e-commerce logistics service demand has a direct impact on the benefits of international port service transformation; on the other hand, after service transformation, the international port is bound to lose part of the traditional transport business, in addition, business transformation inevitably brings new investment costs, and these are the opportunity cost of logistics service transformation. Therefore, international ports face a dilemma. If not transformation it may lose the chance of developing cross-border e-commerce logistics, later transition may lag behind other ports, and eventually may be in a disadvantage competition position in the future, if transformation the transition may be failure due to uncertainty. Real option theory is especially suitable for investment decisions under uncertain conditions [11,12]. The transformation of international ports for cross-border e-commerce logistics service is also an investment decision. Therefore, this paper uses real option theory to build a decision-making model of international port's service transformation for cross-border e-commerce based on the risk neutral principle, and analyzes the factors influencing international port's service transformation and the transformation time.

This paper is arranged as the following: the first part is the introduction; the second part is the transformation strategy model of international port logistics service for cross-border e-commerce; the third part shows results analysis and suggestions; the fourth part is case study; the fifth part is conclusion.

2. **The Transformation Strategy Model of International Port Logistics Service for Cross-Border E-Commerce.** The transformation of international ports for cross-border e-commerce will inevitably require a lot of investment, as well as the contraction of traditional businesses. Therefore, it is necessary to choose the right time.

2.1. **The real option principle of decision making of international port's logistics service transformation for cross-border e-commerce.** Traditional investment decision methods (such as NPV, and ROI) have two major drawbacks: first, the cost of investment and the future revenue is constant; second, it ignores investors' choice of investment opportunity, and the flexibility of investment. Myers first considered investment opportunities as "growth options", and pioneered the investment decision making using real option theory [13]. Dixit and Pindyck systematically described the methods and models of investment decision making under uncertain conditions, "If an investment has the following three characteristics, the real option method can be used to make investment decisions: (1) the investment part or all is not reversible; (2) the future return on investment or investment costs, or both are uncertain; (3) investors can choose the investment opportunity" [14]. The international port logistics service transformation decision has the above three characteristics. First of all, investment is not reversible, and a large amount of capital is required to be invested in the whole transformation process. If the transformation fails, a large part of these funds are not recoverable. Secondly, the future logistics service income and logistics service quantity are closely related. However, the logistics service volume is highly correlated with the development speed of cross-border e-commerce, which is very uncertain. In addition, the investment in service transformation of international ports is also uncertain. Finally, the ports have great flexibility and autonomy in the transformation of logistics services. So, this paper will analyze the decision of international ports to transform the logistics service for cross-border e-commerce based on real option theory.

The value V of international port's transformation of logistics service for cross-border e-commerce depends mainly on the future cross-border e-commerce logistics service quantity Q, $V = V(Q)$, the value of service transformation is bigger when the logistics service is larger, whereas the value is smaller. The value F of logistics service transformation opportunity depends on Q and the opportunity cost C of logistics service transformation, $F = F(Q, C)$. Q and C are uncertain. The income of logistics service transformation is $V(Q) - C$. According to the principle of exercising the option, the decision-making process can be expressed as follows:

$$\max[V(Q) - C, F(Q, C)] \tag{1}$$

Formula (1) means whether the international ports undertake the transformation of logistics service for cross-border e-commerce depends on the relationship between the income of logistics service transformation and the value of logistics service transformation opportunity. If the income of logistics service transformation is greater than the opportunity value of logistics service transformation, $V(Q) - C > F(Q, C)$, international ports choose to transform immediately; if the income of logistics service transformation is less than the opportunity value of logistics service transformation, that is $V(Q) - C < F(Q, C)$, international ports choose to retain the transition opportunity and delay the transformation. When the income of logistics service transformation is equal to the opportunity value of logistics service transformation, that is $V(Q) - C = F(Q, C)$, according to this formula, we can solve the optimal logistic service demand Q^*. This quantity is the port logistics service transition critical demand. At the same time, according to Q^*, the option value $F(Q^*, C^*)$ of the transformation opportunity of logistics service is calculated. The optimal logistics service demand Q^* is the critical value for international ports to carry out the transformation of logistics service for cross-border e-commerce. When cross-border e-commerce logistics demand $Q > Q^*$, international ports should choose the transformation of logistics service immediately; when $Q < Q^*$, international ports should choose to wait until cross-border e-commerce logistics demand is greater than Q^*. When $Q = Q^*$, whether the international ports undertake the transformation or not is no different. The model of this article is based on the above principles.

2.2. **The basic assumptions of the model.** Assume that Q and C will be considered when international ports are transforming their services for cross-border e-commerce. And they are both uncertain and subject to the geometric Brownian motion.

First of all, let us assume that the demand for cross-border e-commerce logistics is subject to geometric Brownian motion: $dQ = \mu_Q Q dt + \sigma_Q Q dz_Q$. μ_Q is the future expectation demand growth rate of cross-border e-commerce logistics service. σ_Q is the future demand volatility of cross-border e-commerce logistics service, dz_Q is a standard wiener process increment, obeying the standard normal distribution $dz_Q = \varepsilon\sqrt{dt}$, $\varepsilon \sim N(0,1)$.

Secondly, it is assumed that the opportunity cost of international port to transform logistics service for cross-border e-commerce is subject to geometric Brownian motion: $dC = \mu_C C dt + \sigma_C C dz_C$. Among them, μ_C is the expected growth rate of the opportunity cost of logistics service transformation for cross-border e-commerce of international ports, and σ_C is the volatility of service transformation opportunity cost. dz_C is the increment of standard wiener process, obeying standard normal distribution $dz_C = \varepsilon\sqrt{dt}$, $\varepsilon \sim N(0,1)$.

And $(dz_Q)^2 = dt$, $(dz_C)^2 = dt$, $E[dz_Q dz_C] = \rho dt$, ρ is the correlation coefficient between dz_Q and dz_C.

Assume that cross-border e-commerce logistics service can operate T years before replaced, unit price is P, and the price P is constant during the operating period. If the risk-free rate is r, the value of international port's logistics service upgrading for cross-border e-commerce is as follows:

$$V(Q) = E\left[\int_0^T PQe^{-rt}dt\right] = \frac{PQ\left[1 - e^{-(r-\mu_Q)T}\right]}{r - \mu_Q} \tag{2}$$

The value of the logistic service transformation opportunity is $F = F(Q, C)$, because Q and C are random processes and subject to geometric Brownian motion. The equation of motion is

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

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

Among them: $F'_C = \frac{\partial F}{\partial C}$; $F'_Q = \frac{\partial F}{\partial Q}$; $F''_{QQ} = \frac{\partial^2 F}{\partial Q^2}$; $F''_{CC} = \frac{\partial^2 F}{\partial C^2}$; $F''_{CQ} = \frac{\partial^2 F}{\partial C \partial Q}$.

2.3. **Model construction and solution.** According to the dynamic optimization principle, the optimal solution of dynamic optimization can guarantee that the sub dynamic optimization from any time is optimal. So,

$$rF(Q, C)dt = E[dF]$$

$$\mu_C C F'_C + \mu_Q Q F'_Q + 0.5\sigma_Q^2 Q^2 F''_{QQ} + \rho\sigma_C\sigma_Q CQ F''_{CQ} + 0.5\sigma_C^2 C^2 F''_{CC} - rF = 0 \tag{3}$$

$F(Q, C)$ is a bivariate partial differential equation of Q and C. Because Equation (3) is a bivariate partial differential equation, it is difficult to solve directly. Li and Chen used variable substitution to solve it [15]. Because F represents the option value of the transformation of international port logistics service, and C represents the opportunity cost of service transformation, the effect of increased cost on option value is often first order, namely how much the cost increases, and how much the option value is reduced. So $F(Q, C)$ is the first order homogeneous equation of cost C. As a result, $F(Q, C) = CF\left(\frac{Q}{C}, 1\right)$. Let $h = \frac{Q}{C}$, then $F(Q, C) = CF(h, 1) = Cf(h)$. So: $F'_Q = f'(h)$, $F'_C = f(h) -$

$hf'(h)$, $F''_{QQ} = \frac{f''(h)}{C}$, $F''_{CC} = \frac{h^2 f''(h)}{C}$, $F''_{QC} = -\frac{hf''(h)}{C}$. Substituting them in (3), the first order ordinary differential equation of h can be obtained.

$$\frac{1}{2}\left(\sigma_Q^2 + \sigma_C^2 - 2\rho\sigma_Q\sigma_C\right) h^2 f''(h) + (\mu_Q - \mu_C)hf'(h) - (r - \mu_C)f(h) = 0$$

Let $\sigma^2 = \sigma_Q^2 + \sigma_C^2 - 2\rho\sigma_Q\sigma_C$, the above equation can be simplified as

$$\frac{1}{2}\sigma^2 h^2 f''(h) + (\mu_Q - \mu_C)hf'(h) - (r - \mu_C)f(h) = 0$$

According to the solution principle of ordinary differential equation, the solution of this differential equation is as follows:

$$f(h) = A_1 h^{\beta_1} + A_2 h^{\beta_2}$$

where β_1 and β_2 are two roots of equation: $\frac{1}{2}\sigma^2\beta(\beta-1) + (\mu_Q - \mu_C)\beta - (r - \mu_C) = 0$. So,

$$\beta_1 = \frac{1}{2} - \frac{\mu_Q - \mu_C}{\sigma^2} + \sqrt{\left[\frac{\mu_Q - \mu_C}{\sigma^2} - \frac{1}{2}\right] + 2\frac{r - \mu_C}{\sigma^2}}$$

$$\beta_2 = \frac{1}{2} - \frac{\mu_Q - \mu_C}{\sigma^2} - \sqrt{\left[\frac{\mu_Q - \mu_C}{\sigma^2} - \frac{1}{2}\right] + 2\frac{r - \mu_C}{\sigma^2}}$$

Let $Q = \frac{1}{2}\sigma^2\beta(\beta-1) + (\mu_Q - \mu_C)\beta - (r - \mu_C)$, then Q is a parabola that opens upwards. $Q(0) = -(r - \mu_C) < 0$. In general, we assume that the growth rate of opportunity costs is less than the risk-free rate. $Q(1) = \mu_Q - r < 0$, because if $\mu_Q - r > 0$ the option will never be executed. When $\beta \to \pm\infty$, $Q \to +\infty$. So $\beta_1 > 1$, $\beta_2 < 0$. See Figure 1.

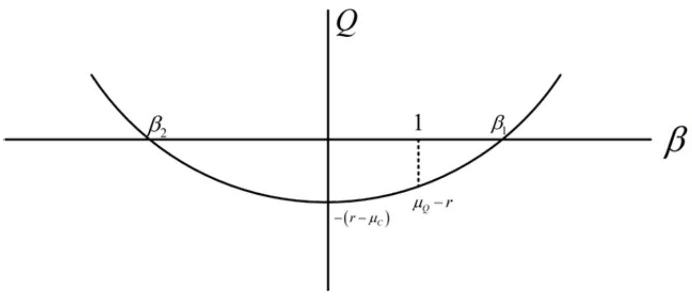

FIGURE 1. Q-β diagram

In order to satisfy the boundary condition $f(0) = 0$, let $A_2 = 0$. So, $f(h) = A_1 h^{\beta}$. Dixit and Pindyck pointed out that the solution of this equation must satisfy two conditions, value matching condition and smooth transfer condition [14]. The value matching condition refers to the transition critical of logistics service should make the option value equal to the transformation income, namely

$$F(Q,C) = V(Q) - C$$

$$F(Q,C) = \frac{PQ\left[1 - e^{-(r-\mu_Q)T}\right]}{r - \mu_Q} - C$$

Because this paper assumes that the price of logistics service is stable during the whole port logistics service transformation period, without affecting the analysis, let $P = 1$. At the same time, because $Cf(h) = F(Q,C)$,

$$Cf(h,1) = \frac{Q\left[1 - e^{-(r-\mu_Q)T}\right]}{r - \mu_Q} - C$$

After tidying up, $f(h,1)=\frac{Q\left[1-e^{-(r-\mu_Q)T}\right]}{C(r-\mu_Q)}-1=h\frac{1-e^{-(r-\mu_Q)T}}{r-\mu_Q}-1$.

The smoothness condition refers to the change rate of option value equal to the change rate of service transition income:

$$f'(h)=\frac{1-e^{-(r-\mu_Q)T}}{r-\mu_Q}$$

According to these two conditions, we can solve the ratio between the critical logistics demand and opportunity cost of logistics service transformation in international ports: $h^*=\frac{\beta_1}{\beta_1-1}\frac{(r-\mu_Q)}{1-e^{-(r-\mu_Q)T}}$. Because $h=\frac{Q}{C}$,

$$Q^*=\left(\frac{\beta_1}{\beta_1-1}\frac{(r-\mu_Q)}{1-e^{-(r-\mu_Q)T}}\right)C$$

3. Results Analysis and Suggestions.

3.1. Results analysis. If the fluctuation rate of initial logistics service demand is very high, the transformation risk of international ports will increase, and the demand for initial logistics service will be increased. So we have Lemma 3.1.

Lemma 3.1. *The critical logistics demand of logistics service transformation is proportional to its fluctuation rate.*

Proof: Because $Q=\frac{1}{2}\sigma^2\beta(\beta-1)+(\mu_Q-\mu_C)\beta-(r-\mu_C)$, it is a parabola that opens up. See Figure 1. Write the full differential of Q with respect to σ:

$$\frac{\partial Q}{\partial\beta}\frac{\partial\beta}{\partial\sigma}+\frac{\partial Q}{\partial\sigma}=0$$

At $\beta_1>1$, $\frac{\partial Q}{\partial\beta}>0$, and $\frac{\partial Q}{\partial\sigma}=\sigma\beta(\beta-1)>0$, so $\frac{\partial\beta}{\partial\sigma}<0$. If σ increases, β_1 decreases, $\frac{\beta_1}{\beta_1-1}$ increases, Q^* increases. □

3.2. International port logistics transformation strategy based on commodity portfolio. According to Lemma 3.1, we know that by reducing the fluctuation rate of e-commerce logistics demand in the future, it can reduce the critical logistics demand. Therefore, this paper proposes a strategy to reduce the critical logistics demand of service transformation by constructing an appropriate portfolio of commodities. So we get Corollary 3.1.

Corollary 3.1. *By providing cross-border e-commerce logistics services to a portfolio of goods, it can effectively reduce the critical logistics demand of international port's logistic service transformation for cross-border e-commerce.*

Proof: Suppose we construct a portfolio of goods for, containing n products, and the growth rate of the logistics demand for each commodity is μ_i, $i=1,2,\dots,n$. σ_{ij} is the covariance of the demand for the logistics of product i and j. Under the premise that the demand growth rate of portfolio logistics is μ_Q, the minimum combination variance can be obtained by the following mathematical programming:

$$\min\ \sigma_P^2=\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_i\omega_j\sigma_{ij}$$

$$\text{s.t. } \mu_Q=\sum_{i=1}^{n}\omega_i\mu_i$$

$$\sum_{i=1}^{n} \omega_i = 1$$

where ω_i is the proportion of the i^{th} commodity logistics volume to the total logistics volume. Let $\mu_k = \mu_Q$, then $\omega_k = 1$, $\omega_i = 0$ $(i \neq k)$ is a feasible solution, $\sigma_P^2 \leq \sigma_k^2$, $(k = 1, 2, \ldots, n)$.

Therefore, it can effectively reduce the critical logistics demand of cross-border e-commerce transformation by constructing commodity portfolio. □

4. **Case Study.** Suppose an international port faces 4 contexts, and the parameters are shown in Table 1.

Table 1. The parameters an international port faces

Parameter	Case1	Case2	Case3	Case4
C	500.00	500.00	1000.00	1000.00
r	0.15	0.15	0.15	0.15
μ_Q	0.10	0.10	0.10	0.10
σ_Q^2	0.02	0.03	0.02	0.03
μ_C	0.05	0.05	0.05	0.05
σ_C^2	0.10	0.10	0.10	0.10
ρ	0.00	0.00	0.00	0.00
T	20.00	20.00	20.00	20.00
Q	155.31	167.83	310.63	335.65

Firstly, we compare Case1 and Case2. The cost C in these two cases is 500, but σ_Q^2 in Case1 is 0.02 and in Case2 is 0.03. In Case1, the logistics volume Q required for port transformation is 155.31, while in Case2, the logistics volume Q required for port transformation is 167.83. Analysis of Case3 and Case4 has similar conclusions.

Secondly, we compare Case1 and Case3, both σ_Q^2 of which are 0.02, but the cost C of Case1 is 500 and that of Case3 is 1000. In Case1, the logistics volume Q required for port transformation is 155.31, while in Case3, the logistics volume Q required for port transformation is 310.63. Analysis of Case2 and Case4 has similar conclusions.

So, we can draw the conclusion that when σ_Q^2 becomes larger, the critical service transition logistics demand becomes larger. This proves our analysis.

5. **Conclusion.** In order to adapt to the rapid development of cross-border e-commerce, this paper first proposed that international ports should transform the logistics service for cross-border e-commerce. On the one hand, cross-border e-commerce development requires international ports to provide logistics service support; on the other hand, with the development of cross-border e-commerce, international ports also face the difficulty of the sluggish growth of traditional logistics services, while providing logistics services for cross-border e-commerce is a new opportunity for port development.

However, the transformation of logistics service for cross-border e-commerce requires a lot of investment, as well as the loss of some traditional logistics services. This paper uses real option theory to build a decision-making model of international port's service transformation for cross-border e-commerce based on the risk neutral principle. Through the analysis of the model, two important conclusions are drawn.

1) The critical logistics demand of logistics service transformation is positively related to its fluctuation rate.

2) By providing cross-border e-commerce logistics services to a portfolio of goods, it can effectively reduce the critical logistics demand. Therefore, it may not be out of reach for international ports to carry out logistics transformation for cross-border e-commerce.

These conclusions provide theoretical guidance for international ports to transform the logistics service for cross-border e-commerce.

The research of this paper has the following limitations: first of all, the model does not consider the fluctuation of logistics service price; secondly, this model is a theoretical model there is no empirical study for lack of corresponding data. The authors will further study these two aspects in the future.

Acknowledgment. This work is partially supported by Social Science Foundation of Liaoning Province (No. L16CGL001) and Natural Science Foundation of Liaoning Province (No. 201601310). The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

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