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Analyzing the Dynamic Evolution of Co-Opetition Mechanism among Shipping Service Resources

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Abstract

Considering the major shipper choice factors of potential demand, charge sensitivity and service cost coefficient, the paper analyzes the dynamic evolution of co-opetition mechanism among shipping service resources. A number of interesting results are obtained: when the strategy profile moves from perfectly competition to perfectly co-operation, the optimal charge will increase while the improvement of shipping service is uncertain; because long-term equilibrium state is perfectly competition strategy profile, there is a need for appropriate institutional arrangement to reduce the saddle-point position in order to achieve maximize profit for the overall shipping service resources.

1. Introduction

In recent years, with the rapidly growing intercontinental container shipping services, China's container through put has been maintaining the first of the world for eleven consecutive years more, which increased up 6.1% to 200.93 million TEUs in 2014, forming five regionalization, scale-up and modernization port clusters involving Southwest Coast, Pearl River Delta, Southeast Coast, Yangtze River Delta and Bohai Sea. Among the world's 10 largest container port throughput rankings, China's container ports including Hong Kong take seven seats on the list of 2014. To capture a larger share of global shipping, many coastal ports of China are investing heavily in container terminals to expand the capacity to serve as a hub port, and usually the joint ventures terminals are established to obtain a large capital investment required. Therefore, more and more capacity and region imbalances are emerging, such as excess capacity, underutilized berth, rising costs and many other issues, resulting in fierce price competition among shipping service resources.

2. Related Literature

Researches related to competition and cooperation between ports mainly include: the possible competition and

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co-operation of the adjacent container ports in Hong Kong and South China was examined from a strategic perspective, suggesting that ports have to concentrate on new ways for co-operation in an effort to establish a countervailing power as in [1]. The multiple port cooperation would lead to increases of all ports' total profits, decreases of the service time and the service price, the higher the level of cooperation between regional multiple ports is, the higher the all ports' total profits would be, the port cooperation can be achieved by designing effective profit allocation mechanismas in [2]. The competition and cooperation between neighboring ports, several models were developed in the research to analyze the relationship between Shanghai port and Ningbo-Zhoushan portas in [3]. A two-stage game that involves three container terminals located in Karachi Port in Pakistan, the concepts of ''characteristic function'' and ''core'' were used to analyze the stability of these coalitions and this revealed that one combination did not satisfy the superadditivity property of the characteristic function and can therefore be ruled outas in [4]. Causal relationships between influence factors, types of port cooperation (i.e. complementary cooperation and co-opetition), and port competitiveness, besides, potentially important items for port cooperation were also identifiedas in [5]. Some of the key ways in which seaports had been developed from a position of direct competition to increasing collaboration in order to remain competitive in a fast-changing world., strategic port cooperation was considered through a new conceptual cooperation/competition matrix, which can be used to evaluate the response strategies of ports to inter-port rivalry and changing maritime competitive dynamicsas in [6]. Alternative duopoly games, namely a Stackelberg game and a simultaneous game, were used to model port competition, where ports provided differentiated services in the sectors of containerized cargo and dry-bulk cargoas in [7].

3. Co-Opetition among Shipping Service Resources

We consider the shipping service resources include "prompt response", "24 h a day, seven days a week service" and "zero waiting time service"; hinterland condition includes "professionals and skilled labor in terminal operations", "size and activity of free trade zone or special zone in the hinterland" and "volume of total container cargos"; availability includes "availability of a vessel berth on arrival" and "terminal congestion"; convenience includes "water depth in approach channels and at berth", "sophistication of terminal information and its application" and "the stability of terminal labor"; logistics costs include "inland transportation cost", "costs related to vessels and cargoes entering terminal" and "free dwell time on the terminal", so the demand function may be expressed:

$$q_i = a_i - p_i + bp_{-i} + s_i - vs_{-i} \tag{1}$$

where a_i representspotential demand of the shipping service resource i, reflecting the attraction to its customers, with a_i is positive and the sum of $a_1, a_2,…,a_n$ is a constant; s_i and s_{-i} are services of the shipping service resource i and others respectively; v is the sensitivity of the shipping service resource i demand to others' service quality, in general the impact of service quality of the shipping service resource i on its demand is higher than others', that is $1 > v > 0$; p_i and p_{-i} represent full charges of the shipping service resourcei and $-i$ respectively; b is the sensitivity of the shipping service resource i demand to others' charge, in general the impact of the charge of the shipping service resource i on its demand is higher than others', satisfying $1 > b > 0$.

Therefore the profit function of the shipping service resource is given:

$$R_i^j = (p_i - m_i)q_i - \lambda_i s_i^2 / 2 \tag{2}$$

where R_i^j is the profit function of the shipping service resource i under the circumstance j = 1, 2, 3, 4, meaning the competition strategy profile, cooperation strategy profile and mixed strategy profile, such as when the shipping service resource i selects competitive strategy to realize its profit-maximizing, the other adopts cooperative strategy to realize overall profit-maximizing. m_i is the variable unit cost of the shipping service resource i; λ_i is the service cost coefficient of the shipping service resource i, with $\lambda_i > 0$, assume that the service cost is monotonically increasing convex function of service quality; $\lambda_i s_i^2/2$ represents the service cost.

If the probability of the shipping service resource choosing cooperation strategy is denoted by x, then the competition strategy's probability is $1–x$; similarly, the probability of the shipping service resource $–i$ choosing cooperation strategy is denoted by y, then the competition strategy's probability is $1–y$.

So the fitness of the shipping service resource selecting co-opetition strategies may be expressed:

$$U_i = yR_i^2 + (1-y)R_i^4, U_i' = yR_i^3 + (1-y)R_i^1 \tag{3}$$

Yield average fitness of the shipping service resource:

$$U_i^- = xU_i + (1-x)U_i^{'} \tag{4}$$

The replicator dynamics of the shipping service resource selecting cooperation strategy is:

$$\frac{dx}{dt} = x(U_i - U_i^-) \tag{5}$$

4. Analyzing the Dynamic Evolution of Co-Opetition Mechanism

Firstly, how will the potential demand affect system evolution? The range of value for a_{-i} is assumed to be [60, 100], step is assumed to be 2.5, and dynamic evolution of the system through Analytic Technologies Net-Draw is shown in **Figure 1**.

Accompanying potential demand of the shipping service resource $-i$ gradually increasing, the strategy profile of complete competition evolves into complete cooperation from the point 1 (a_{-i}= 60) to the point 27 (a_{-i}= 100). In the process of evolution, service utility and charge of the shipping service resource i have been reducing, while the shipping service resource $-i$ is just the opposite. Moreover, the profits of the shipping service resource and the overall are declining.

Secondly, how will the charge sensitivity affect system evolution? The range of value for b is assumed to be [0.0685, 0.26], step is assumed to be 0.005, and dynamic evolution of the system is seen as **Figure 2**.

Going along with charge sensitivity of the shipping service resource gradually heightening, the strategy profile is evolved from the point 1 ($b = 0.0685$) of complete cooperation to the point 20 ($b = 0.1635$) of complete competition, in the process of evolution, and service utility of the shipping service resource i has been descending, while the charge of the shipping service resource $-i$ has been raising; the charges of the shipping service resource, the profits of the shipping service resource and the overall are enhancing; then evolving into the complete cooperation strategy profile of the point 40 ($b = 0.26$), service utility of the shipping service resource i has been cutting down, while the charge of the shipping service resource $-i$ has been enhancing, and the charges of the shipping service resource, the profits of shipping service resource and the overall experience the process of down then up.

Finally, how will the service cost coefficient affect system evolution? The range of value for λ_{-i} is assumed to be [0.9275, 1.9125], step is assumed to be 0.05, and dynamic evolution of the system is given by **Figure 3**.

Coupling with the service cost coefficient of the shipping service resource $-i$ gradually increasing, the strategy profile is evolved from the point 1 (λ_{-i} = 0.9275) of complete competition to the point 10 (λ_{-i} = 1.3775) of
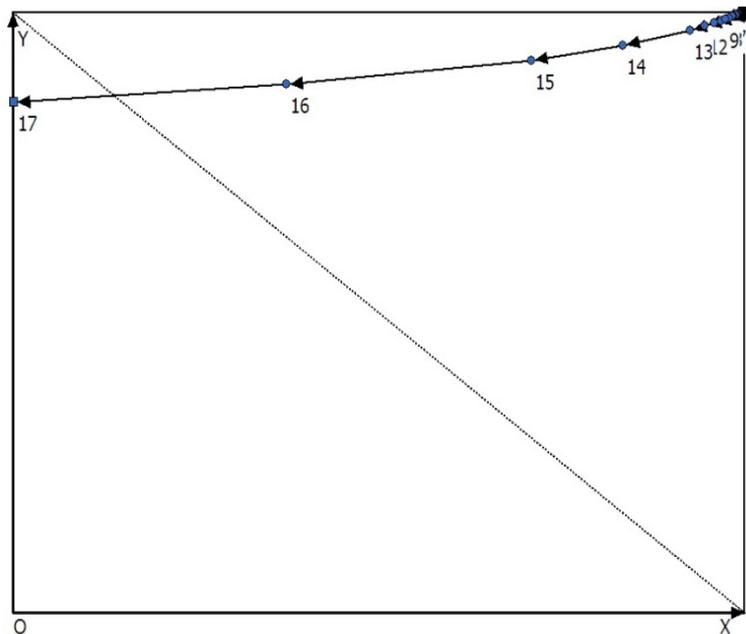

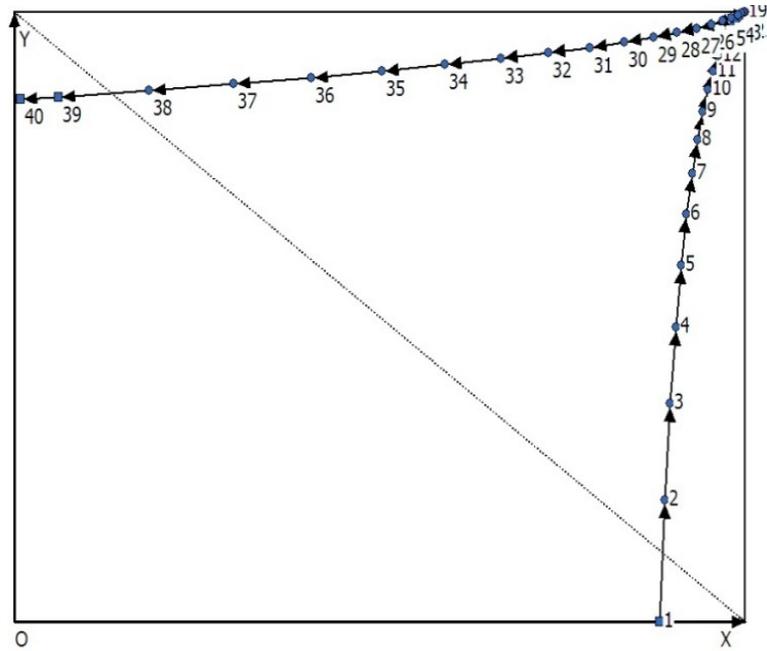**Figure 1.** Dynamic evolution with scope of potential demand.

Figure 2. Dynamic evolution with scope of charge sensitivity.
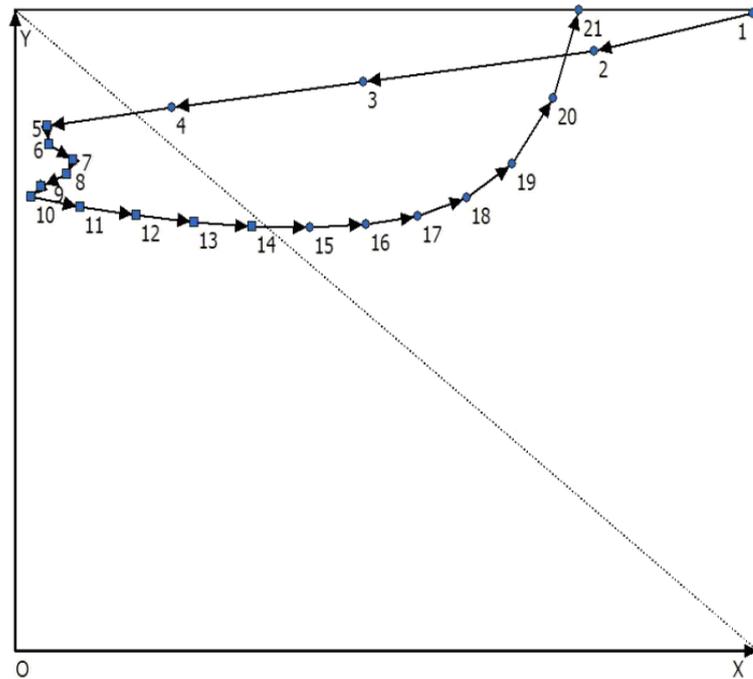

Figure 3. Dynamic evolution with scope of service cost coefficient.

mixed strategy profile, in the process of evolution, and service utility and charge of the shipping service resource i frequently fluctuate, undergoing an experience of the process of down then up, while the shipping service resource $-i$ is on the contrary. Moreover, the profits of the shipping service resource and the overall experience the process of down then up and then down. Then evolving into the complete competition strategy profile of the point 1 (λ_{-i} = 1.9125), service utility and charge of the shipping service resource i have been decreasing, while the shipping service resource $-i$ is just the opposite; the profits of the shipping service resource and the overall are descending.

Acknowledgements

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