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Port Competition Study: Cooperative Game Model

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Abstract: Due to the expansion of container port facilities and many market suppliers, competition among container terminals (CTs) is at the level of threatening the management income and expenditure of port management companies. This paper develops a non-cooperative game model and a cooperative game model which involve four CTs located in North Port and two terminals in New port of Busan, Republic of Korea. We apply a game theory for strategic decision making at CTs. A non-cooperative game and a cooperative game are played when managers make decisions together and try to overcome the competition and neglect the mutual profit. Therefore, the purpose of this paper is to find equilibrium price and profit between CTs that are in competitive relation. In order to satisfy the proposed goals, it is required to find what service factors are most important to the shipping companies when they select ports. The solving model of this problem assumes the cooperation of individual terminals as if several TOCs will be a united company in terms of decision making. The Bertrand Nash game model is used to solve this problem. A comparison between current and equilibrium price and profit represents the main goal of applying the game theory.

Keywords: Container terminal (CT); CTs competition; Utility function of CTs; Cooperative game; Bertrand game

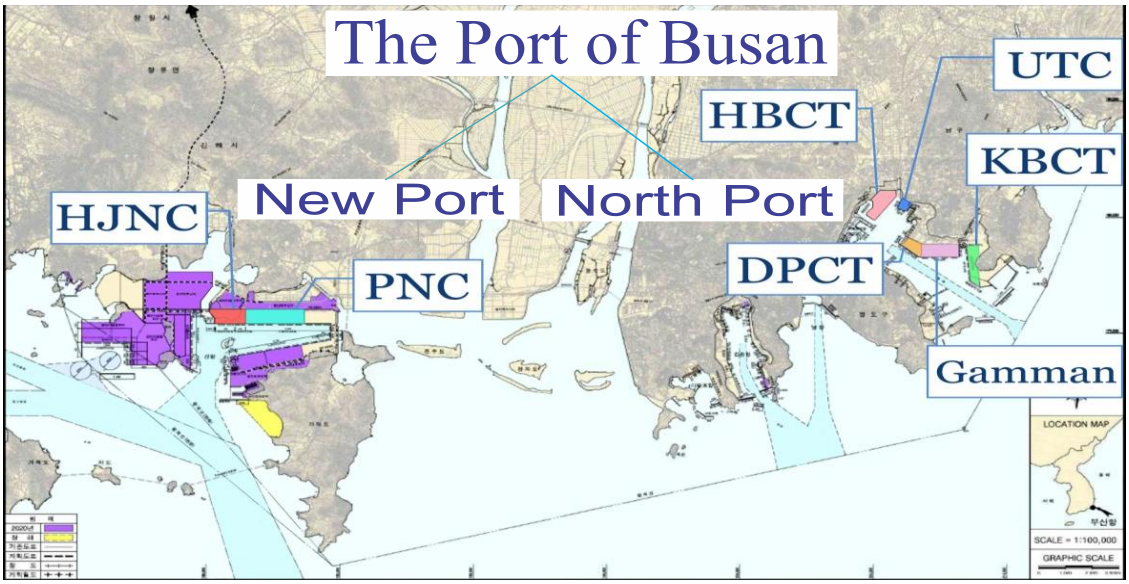
JEL Classifications: M16, M21,M31

1. Introduction

This paper focuses on revealing the equilibrium price and profit without changing total container throughput of CTs. This methodology is founded on distinctive literature review. We derive the utility function on which basis is developed the equilibrium price and profit instead of using assumed value. Using dependent and independent values for six years data (from 2006 to 2011), some values and equilibrium formula regarding price and profit are drawn. After that, we made a comparison and sensitivity analysis is performed.

This study also provides a great contribution of estimating the different cost at CTs and demand in the context of competition and level of optimum handling charge which should be kept for CTs in a competitive situation to a make maximum profit. Competitiveness of CTs has been described and measured in different ways which include four CTs from North Busan Port and two CTs from New Busan Port.

Busan port is divided into North Port and New Port (see Figure 1). We will cover 6 CTs in North Port like KBCT, HBCT, DPCT (Shin-Gamman), Gamman and New Port like PNC and HJNC.



Note: HJNC – Hanjin New CT; PNC – Pusan New Port Company; DPCT – Dongby Pusan Container terminal; HBCT - Hutchison Busan Container Terminal; UTC - U-am CT; KBCT - Korea Express Busan CT; Gamman – Gamman CT

Figure 1. The Location of CTs in Busan port (Source: BPA, 2014)

2. Literature Review

There have been a lot of papers such as (Zan, 1999) to (Kaselimi, et al. 2011) applying and describing the game theory to investigate the behavior of port users. In (Zan, 1999) was proposed a model to simulate the flow of foreign trade container cargo using game theory, and provides a dynamic method for the analysis of the container cargo transportation market. Cooperative game theory to analyze co-operation among members of liner shipping strategic alliances has been applied in (Song, et al. 2002). In (Anderson, 2008) was developed a game-theoretic framework for understanding how competitor ports will respond to development at a focus port, and whether the port will be able to capture or defend market share by building additional capacity. This model is applied to investment and competition currently occurring between the ports of Busan and Shanghai. The interaction between the pricing behavior of competing ports and the optimal investment policies in the ports and hinterland capacity has been analyzed with a two-stage game(VAN, et al. 2008)..

It is introduced a horizontal product differentiation model to analyze competition between container terminals using a game theoretic approach(Kaselimi, et al., 2011). A non-cooperative, two stage game theoretic model with two players (port 1 and port 2) is considered. The competition between the terminals of the ports is taking place following a Bertrand model (Kaselimi, E.N., Notteboom, T., and Saeed, N., 2011).

Following the above mentioned studies (Zan, 1999) to (VAN, et al. 2008), game theory is applied to analyze the competition between container terminals at Karachi port in (Saeed, 2009) where main results are based on (Saeed, 2009) to (Larsen, et al. 2010) A non-cooperative two-stage game to a vertical-structure seaport market with ports as upstream players and shipping lines as downstream players is applied in (Veldman, 2003).

2.1 Basic Concepts of Logit Model and Non-cooperative Game Theory

In this Section, first we describe the demand for CT services and empirical analysis for port selection using a logit model which is used to estimate probability choosing alternative CTs by shipping companies.(Malchow, et al. 2004). Profit for CTs' operators and port authorities are explained, also. Presented formulae of all CTs for total demand, total throughput and individual demand for each terminal are involved in Bertrand Nash equilibrium to obtain the expression for the price responses of all CTs.

2.2 The Demand for CT Services

To precisely define the demand function, we describe and use the structure of Bertrand game for each of obtained terminals (KBCT, HBCT, DPCT, Gamman (Gam), HJNC and PNC) which offer similar services to containers but their charges are not exactly the same. Different shipping companies and consignors (users) are to decide which CT is appropriate for satisfying their needs. Considering CTs' charges for handling and storing containers, it is usually for users to have some additional costs which are defined as other user costs (*OUC*).

Here in our logit model we consider both the cargo (container) handling charge and other user costs. The components of other user costs are: the waiting cost of a vessel which occurs when their number increases, inland transportation cost (i.e., cost of rail and trucking) which depends on the location of terminal, and the cost related to transport time including the cost of container leasing or rental services. Among these costs, the costs related to port selection contain the transportation cost of transferred containers between CTs of North Port and New Port and transportation cost to the other wharf in the same area. The waiting cost of vessel occurs when the number of containers entering a terminal exceeds the capacity of its CT. It is stipulated to be operation cost of vessel dependent of waiting rate. To describe it analytically, we begin with the following general expression for other costs (Kaselimi, et al. 2011) the so-called the other user cost function for terminal *'i'*:

$$OUC_i = CO_i + f\left(\frac{X_i}{CAP_i}\right) \qquad (1)$$

where CO_i is inland transportation cost (a fixed component), X_i is the volume handled by terminal 'i', CAP_i is handling capacity of terminal 'i', and $f(X_i / CAP_i)$ is a function of vessel waiting cost, which is in general an increasing function.

Next is to propose a port selection model. According to Park's study(Park, Nam Kyu., 2009) it consists of two independent variables, i.e. cost and local cargo of port. It should be noticed that the local cargo quantity (container throughput) is related to the economic level of the country. Therefore, we select the cost variable as the model factor. For convenience, we assume the following order of CTs in the port of Busan: KBCT, HBCT, DPCT, Gam, HJNC and PNC, respectively (i.e., KBCT = 1 ,…, PNC = 6). The use of a logit model supposes that utility function must be assigned to each CT. The utility function of CT 'i' $(i = 1,2,3,4,5,6)$ is expressed in the form of a measure of the attractiveness of a terminal and can be expressed as (Saeed, et al. 2010).

$$U_i = a_i + b(p_i + OUC_i) \qquad (2)$$

where U_i is the utility of terminal 'i', p_i is the handling charge per TEU of terminal 'i' including the fee for Busan Port Authority (BPA), b is price coefficient which links the handling price and port cost like ITT(Inter terminal transport) cost etc. to the utility of terminal 'i' and a_i a is the derived constant from regression analysis to estimate the fittest model.

The market share, Q_i, of terminal *'i'* is given by the following the so-called logit expression (Malchow, et al. 2004) and (Train, 2003):

$$Q_i = \frac{e^{U_i}}{\sum_{i=1}^{6} e^{U_i}} \qquad (3)$$

Notice that the market share is determined as the ratio of specific terminal's utility to total utility of CTs belonging to specific considered port. After that, we take the "log" of total utility function, denoted as *LS*, i.e. the *log sum* is

$$LS = \ln\left(\sum_{i=1}^{6} e^{U_i}\right) \qquad (4)$$

Next, a total demand of CTs in Busan Port is denoted as *X* (Saeed, et al. 2010) which was 13.1 million TEU in 2011. Namely,

$$X = Ae^{\theta LS} \qquad (5)$$

where *A* and θ are constants with $0 < \theta < 1$.

The individual demand for terminal 'i' is given as (Saeed, et al. 2010).

$$X_i = XQ_i. \qquad (6)$$

2.3 Profit for CT Operators

From Eq. (6) we see that the container demand of each CT depends on its cost. On the other hand, the profit estimating methods for CTs in Busan Port are classified into two types. One is when facility lease charge is paid to BPA and the other is when facility lease charge is not paid because the terminal was built by private investment. In the case of the first one, the profit estimation (operating surplus) of terminal *'i',* is defined as

$$\Pi_i = (p_i - c_i) \cdot X_i - f_i \qquad (7)$$

where f_i is the fixed cost, i.e. the lease of container terminal, p_i is the handling charge per TEU of terminal 'i' paid by the users, and c_i is the marginal cost per TEU (such as energy and electricity cost, outsourcing cost for recruiting personnel and equipment). In the case of PNC, since it does not pay facility lease charge to BPA, the profit (operating surplus) of CT *'i',* is defined as

$$\Pi_i = (p_i - c_i) \cdot X_i \qquad (8)$$

2.3.1 Non-cooperative game

It is assumed that CTs compete with each other to secure maximum demand and each of them provides different services. Using Bertrand equation, it is possible to make a model which maximizes the total profit of terminals. In other words, each terminal will seek a way to secure maximum profit no matter on what level handling charge would be set up. CTs are maximizing their profit (7) differentiating with respect to port price (i.e., the price level of each terminal is sought by differentiating the profit equation (7) by price and equating this with zero). Namely, Bertrand Nash equilibrium is characterized by the following first order conditions:

$$\frac{\partial \prod_i}{\partial p_i} = 0 \quad i = 1,2,3,4,5,6. \tag{9}$$

Notice that by (5) and (6) we have

$$X_i = XQ_i = Ae^{\theta LS} Q_i. \tag{10}$$

Then substituting (10) into (7), we find that

$$\prod_i = (p_i - c_i) \;\; Ae^{\theta LS} Q_i \tag{11}$$

After differentiation of the right hand size of Equation (11) by p_i and using the condition (9), we get

$$\frac{\partial \Pi_i}{\partial p_i} = Ae^{\theta LS} Q_i + (p_i - c_i) \frac{\partial (Ae^{\theta LS} Q_i)}{\partial p_i} = 0. \tag{12}$$

Further, we can handle the left part of equation (12) with logarithm like;

$$\ln(Ae^{\theta LS} Q_i) = \ln A + \theta LS + \ln Q_i \tag{13}$$

Taking the derivative of equation (13) with respect to p_i, we find that

$$\frac{\partial}{\partial \mathrm{p}_1} \ln\left(Ae^{\theta LS} Q_1 \right) = \partial(\ln(A)) + \partial(\theta LS) + \partial(U_1) - \partial(LS) \tag{14}$$

The right part of equation (14) is changed into equation (15) due to the result of derivative. As $\partial(\ln(A))$ is constant, we omitted it.

$$\partial(\theta LS) + \partial(U_1) - \partial(LS) = \frac{\partial LS}{\partial p} \times \theta + b - \frac{\partial LS}{\partial p} \tag{15}$$

$$\frac{\partial LS}{\partial p} = \partial(\ln \sum e^u) = \frac{\partial e^u}{\sum e^u} = \frac{e^u \times b}{\sum e^u} = Qb \tag{16}$$

When (Equation 16) is substituted to (Equation 15),

$$\frac{\partial (Ae^{\theta LS} Q_1)}{\partial \mathrm{p}_1} = \; Ae^{\theta LS} Q_1 [b(\theta Q_1 + 1 - Q_1] \tag{17}$$

When (Equation 17) is substituted to (Equation 12),

$$1 + \; [b(\theta Q_1 + 1 - Q_1] \cdot \; (p_1 - c_1) = 0 \tag{18}$$

This equation becomes the price response equation of terminal of KBCT.

Finally, taking (18) into (12) we obtain

$$1+(p_i-c_i)b(\theta Q_i+1-Q_i)=0. \quad (19)$$

The equation (19) yields the following expression for the price response (price response equation) of CT$_{i}$:

$$p_i=-\frac{1}{b(\theta Q_i+1-Q_i)}+c_i \quad (20)$$

2.3.2 Cooperative game

In the north part of Busan port, there is a trend of establishing a unit organization to properly react against new port for preventing cargo demand reduction and responding to financial loss. This section assumes four terminals are united to an imaginary firm by themselves without any pressure of the authority. Before realizing a unit company, it is required that the equilibrium price and profit is estimated using cooperative game theory which is a developed theory of non- cooperative game model.

In the case, the profit of four terminals is expressed by equation (21).

$$\Pi_i=(p_i-c_i)\cdot X_i-f_i \quad i=1,2,3,4 \quad (21)$$

This formula can be expended to equation (22) which includes four terminals in north part of Busan port.

$$\Pi_i=X_1(p_1-c_1)-f_1+X_2(p_2-\mathbf{c_2})-f_2+X_3(p_3-c_3)-f_3+X_4(p_4-c_4)-f_4) \quad (22)$$

Here, the equilibrium price level is sought by differentiating the profit equation by price for zero.

$$\Pi_i=(p_i-c_i)\cdot X_i-f_i \text{ and } \frac{\partial\Pi_i}{\partial \mathrm{p}_i}=0, \quad i=1,2,3,4$$

Since , $X_1=Ae^{\theta LS}Q_1$ when it is substituted to Equation (22), it is expressed as in Equation (23).

$$\frac{\partial\Pi_1}{\partial \mathrm{p}_1}=\frac{\partial\left(Ae^{\theta LS}Q_1\right)}{\partial \mathrm{p}_1}(p_1-c_1)+\frac{\partial\left(Ae^{\theta LS}Q_2\right)}{\partial \mathrm{p}_1}(p_2-c_2)$$
$$+\frac{\partial\left(Ae^{\theta LS}Q_3\right)}{\partial \mathrm{p}_1}(p_3-c_3)+\frac{\partial\left(Ae^{\theta LS}Q_4\right)}{\partial \mathrm{p}_1}(p_4-c_4) \quad (23)$$

Since the first term being already solved in equation (18), the following equation is inserted into equation (23), $1+[b(\theta Q_1+1-Q_1]\cdot(p_1-c_1)=0.$ The second term is sought to use cross derivate, i.e. attach logarithm to $Ae^{\theta LS}Q_2$, then it is expressed like

$$\ln\left(Ae^{\theta LS}Q_2\right)=\ln(A)+\theta LS+U_2-LS \quad (24)$$

Equation (24) being differentiated by p_1, first term and third term results into zero and finally we get equation (25) on the next page.

$$\frac{\frac{\partial\left(Ae^{\theta LS}Q_2\right)}{\partial \mathrm{p}_1}}{Ae^{\theta LS}Q_2} = \frac{\partial}{\partial \mathrm{p}_1} + (\theta LS) + (LS) \quad (25)$$

Here, LS (log sum) is expressed in equation (4). $LS = \ln(\sum_J e^{U_i})$

If LS in Equation (25) is differentiated by p_1, then

$$\frac{\partial LS}{\partial \mathrm{p}} = \partial\left(\ln\sum e^U\right) = \frac{\partial e^U}{\sum e^U} = \frac{e^U \mathrm{x}\, b}{\sum e^U} = Qb \quad (26)$$

If equation (26) is substituted into equation (25), then equation (23) is expressed as equation (26). Following this rule, cross derivatives by P_HBCT, P_DPCT, P_GAMMAN is sought to equations (27), (28), (29) and (30):

$$P_{KBCT}: [b(\theta Q_1+\mathrm{I}-Q_1)]\bullet(P_1-C_1)+1+Q_2[b(\theta-1)](P_2-C_2)+Q_3[b(\theta-1)](P_3-C_3)+Q_4[b(\theta-1)](P_4-C_4)=0 \quad (27)$$

$$P_{HBCT}: [b(\theta Q_2+\mathrm{I}-Q_2)]\bullet(P_2-C_2)+1+Q_1[b(\theta-1)](P_1-C_1)+Q_3[b(\theta-1)](P_3-C_3)+Q_4[b(\theta-1)](P_4-C_4)=0 \quad (28)$$

$$P_{DPCT}: [b(\theta Q_3+\mathrm{I}-Q_3)]\bullet(P_3-C_3)+1+Q1[b(\theta-1)](P_1-C_1)+Q_2[b(\theta-1)](P_2-C_2)+Q_4[b(\theta-1)](P_4-C_4)=0 \quad (29)$$

$$P_{GAMMAN}: [b(\theta Q_4+\mathrm{I}-Q_4)]\bullet(P_4-C_4)+1+Q_1[b(\theta-1)](P_1-C_1)+Q_2[b(\theta-1)](P_2-C_2)+Q_3[b(\theta-1)](P_3-C_3)=0 \quad (30)$$

$$P_{KBCT} = \frac{-1-Q_2[b(\theta-1)](P_2-C_2)-Q_3[b(\theta-1)](P_3-C_3)-Q_4[b(\theta-1)](P_4-C_4)}{[\mathrm{b}(\theta Q_1+1-Q_1)]} + C_1 \quad (31)$$

$$P_{HBCT} = \frac{-1-Q_1[b(\theta-1)](P_1-C_1)-Q_3[b(\theta-1)](P_3-C_3)-Q_4[b(\theta-1)](P_4-C_4)}{[\mathrm{b}(\theta Q_2+1-Q_2)]} + C_2 \quad (32)$$

$$P_{DPCT} = \frac{-1-Q_1[b(\theta-1)](P_1-C_1)-Q_2[b(\theta-1)](P_2-C_2)-Q_4[b(\theta-1)](P_4-C_4)}{[\mathrm{b}(\theta Q_3+1-Q_3)]} + C_3 \quad (33)$$

$$P_{GAMMAN} = \frac{-1-Q_1[b(\theta-1)](P_1-C_1)-Q_2[b(\theta-1)](P_2-C_2)-Q_3[b(\theta-1)](P_3-C_3)}{[\mathrm{b}(\theta Q_4+1-Q_4)]} + C_4 \quad (34)$$

3. Input Data for Game Model

In order to set the pricing rule by the users, we will implement the Nash equilibrium for the Bertrand game. Before that, we give the assumptions of some parameters.

3.1 Assumptions about the Parameters of the Model

In this Subsection, we describe in detail the parameters that are necessary for port demand model. It provides similar services at CTs. The following premises were set up for demand modeling: As mentioned before, we have taken into our analysis six CTs with relatively high market share; four North Port and two CTs in New Port.

- The obtained CTs are provided with similar on-dock service; however, they are not exact substitutes to each other.

- The model assumes the cost which occurs in the same amount like inland transportation, berthing charge, port charge, wharfage etc. Regardless of the location of CTs is not considered in model, because the utility model deals with customer behavior is depending on the difference of cost or service
- In the case when a specific CT lowers handling charge or other charge for the consignor, containers move to that CT.
- User at CT pays basic terminal charge (onboard handling charge, marshaling charge, transfer loading charge) and additional charges (inland transportation charge, additional service charge) in the accordance of CT selection.
- Therefore, even if it would be assumed that basic charges are the same, the selection of CT becomes different when there is additional transportation cost caused by traffic congestion and transfer loading.

3.1.1 Estimates values of a_i and b

As explained in Eq. (2), specific constant a_i and price parameter b are based on the utility function. For determining the value a_i we can assume that $a_1 = a_2 = \cdots = a_6 = a$. In literature (Ohasi, et al. 2005) and (Radmilovic, et al. 2005) the b value is estimated in different ways. In our case, we must introduce the input data regarding average utility, handling charge and other user cost for considered CTs and did a linear regression analysis to estimate the related values.

From Table 1, we can see that the utilities of all CTs have similar values. This allows us that, using data in Table 1 for handling charge and other user costs, we compute the values of a_i and b applying linear regression method shown in Table 2. According to the results presented in Table 2, the value of the coefficient determination R^2 is 0.346, F is 14.321, Significance is 0.001. Finally, the obtained values of related constants are $a = 30.111$, $b = -0.046$ with significant level 7% and t-value (see Table 2). For comparison, the elastics value of Greek port was estimated to be -0.056 (Polydoropoulou, A., and Litinas, N., 2007)

Table 1. Input Data regarding Average Utility, Handling Charge and OUC for CTs (2006 to 2011)

Terminal	Utility of terminal i (U_i)*	Handling charge (USD) (p_i)*	Shuttle cost (USD)*	Waiting cost (USD)**	Total Cost (USD) ($p_i + OUC_i$)
KBCT	27.29	41.7	19	3.6	64.3
HBCT	27.03	48.7	16	2.7	67.4
DPCT	26.84	37.8	14	6.4	58.2
Gam	28.2	35.7	16	6.0	57.7
HJNC	26.95	39.5	17	4.0	60.5
PNC	26.79	40.1	17	3.1	60.2

Source: Authors' estimates (2014)

To quantify the utility of each terminal, we solved the expression (3) with logarithm as follows on the next page,

$$Q_i = \frac{e^{U_i}}{\sum_{i=1}^{6} e^{U_i}} \text{ , and } \ln Q_i = \ln\left(\frac{e^{U_i}}{\sum_{i=1} e^{U_i}}\right),$$

$$U_i = \ln Q_i + \text{Total U values}$$

As we do not express total utility in cardinality, we try to use total throughput of CTs in Busan as a proxy variable of total utility.

As a result, we can draw the utility to be between 26.79~28.20 in the port of Busan.

Table 2. Linear Regression Analysis Results related to Estimation of a_i and b Values

Model	non-standardized coefficient (β)	Standard error	Standardized coefficient (β)	t-value	Significant probability
Constant	30.111	1.514	-	19.883	0.000
Cost	-0.046	0.025	-0.346	-1.878	0.072
R^2=0.346, F=14.321, Sig= 0.001					

3.1.2 Assumed values for marginal cost and average cost of CT

To determine the handling charge, it is necessary to use marginal costs. This provides the charge at the point where marginal cost and marginal revenue match with each other. It is the most advantageous method in the adjustment of service supply when a public entity is the sole service supplier. However, public entity setting this marginal cost upper limit, they set average cost as atual price under the level of marginal cost. In Table 3, the average values of different costs, charges and capacity from 2006 to 2011 in the case of six CTs are presented. There are exceptions for HJNC and PNC terminals, for which only 2011 data are reflected because their normal capacities began to occur from 2011

Table 3. Different Types of Average Costs, Charges and Capacity for CTs (2006 to 2011)

Category	KBCT	HBCT	DPCT	Gam	HJNC	PNC
Cost per TEU (US $)	29.03	46.93	21.99	30.65	33.39	29.71
Marginal cost per TEU (US $),	16.51	33.56	8.23	20.57	22.12	29.71
Rental cost per TEU (US $)	12.52	13.37	13.76	10.08	11.27	0
Handling charge per TEU (US $)	41.7	48.7	37.8	35.7	39.5	40.1
Annual average handling capacity in million TEU	2,4	1,9	1,2	2,3	2,0	3,2
Handling capacity per berth in TEU	488,433	384,974	402,237	580,607	504,571*	536,462*

Remark: * As HJNC and PNC have been in operation since 2011, we use one year data for the capacity categories.

Source: Korea Financial Supervisory Service , BPA and Author's estimation (2014)

3.1.3 Assumed value for Θ

Theta value (θ- value) can be drawn in accordance with the principle that the total demand of a port is caused by the total utility of the port. However this paper assumes the total demand for a period does not change because total volume of a port is dependent on exogenous

factors like economy development, calling strategy of liner. Therefore, the theta value in this study will be assumed to be a small value, namely 0.01.

Table 4. Input Average Data for CTs from 2006 to 2011

Category	KBCT	HBCT	DPCT	Gam	HJNC	PNC	Sum
Individual demand for terminal *'i'* (X_i) (in million TEU)	2.4	1.9	1.2	2.3	2.0	3.2	13.0
Rental cost (in million US $) (f_i)	30.6	25.7	16.6	23.4	22.8	0	119.1
Handling charge per TEU (US $) (p_i)	41.7	48.7	37.8	35.7	39.5	40.1	n.a
Market share of terminal *'i'* (Q_i)	0.19	0.15	0.09	0.18	0.15	0.25	1
Lease charge of terminal *'i'* /TEU (US $) (l_i)	12.52	13.37	13.76	10.08	11.27	0	n.a
Shuttle fee/TEU (US $) CO_i	19	16	14	16	17	16	n.a
Marginal cost (c_i)	16.51	33.55	8.23	20.57	22.12	29.71	n.a
Handling capacity of terminal *'i'* (in million US $) (CAP_i)	2	1,7	0.8	1,6	1,6	2,8	10,5
The ratio X_i / CAP_i for terminal *'i'*	1.22	1.13	1.55	1.49	1.26	1.17	n.a
Vessel/cargo delay cost (US $)	3.63	2.70	6.38	5.93	4.02	3.06	n.a
Current profit of terminal *'i'* (in million US $), $\prod_i = (p_i - c_i) \cdot X_i - f_i$	30.9	3.4	19.0	11.7	12.3	33.3	110.6

Source: Korea Financial Supervisory Service and Author's estimation(2014)

3.2 Input Parameters of CTs

The current operating status of CTs that includes demand, rental cost, handling charge, market share, marginal cost, vessel/cargo delay costs and profit are presented in Table 4. In our numerical analysis, the element that has an impact on quantity transfer is the additional inland transportation cost for the cargo that is unloaded at the North Port but has to be moved to the New Port because the vessel calls at the New Port. Likewise, there is also additional cost for the containers that are unloaded at New Port but should be handled at North Port. In that circumstance, the inland transportation cost, i.e. shuttle fee/TEU (CO_i) paid by shipping companies is estimated by Eq. (35). These relations can be expressed by the following equation:

$$CO_i = TSR_i \cdot OBR_i \cdot TR_i + TSR_i \cdot (1 - OBR_i) \cdot TR_2 \qquad (35)$$

where TSR_i is a ratio of transfer to other area of terminal 'i'; OBR_i - ratio of transfer loading to other area of terminal 'i'; TR_1 - transfer loading transportation cost to other area of terminal 'i'; (1 - OBR_i) - ratio of transfer loading in the same area of terminal 'i' and TR_2 is transfer loading transportation cost in the ***same area of terminal 'i'.***

Calculation of Waiting Cost Exceeding Handling Capacity

Simulation model was adopted to calculate the waiting cost caused by the increase in terminal capacity. This model was designed by ARENA 13.9 in respect to KBCT. We considered five berths of KBCT. In accordance to positive relation between ship waiting ratio and throughput per berth, we can estimate the relationship between simulated throughput per

berth for coincidence with waiting ratio and waiting cost. The relationship provides *OUC* per each container terminal; see more in Table 5 (Park, et al. 2012).

Table 5. Handling Capacity and Waiting Cost by Vessel Waiting Rate

Waiting ratio*	Number of handled containers*	The ratio X_i / CAP_i	Waiting cost (US $)	Waiting cost/TEU (US $)
0.017	296923	0.74	1393096	4.692
0.019	344934	0.86	1556990	4.514
0.028	418796	1.05	2294512	5.479
0.031	485361	1.21	2540352	5.234
0.053	565753	1.41	4343183	7.677
0.071	591715	1.48	5818226	9.833
0.113	595013	1.49	9259994	15.563
0.130	602862	1.51	10653090	17.671
0.594	639321	1.60	48676427	76.138

Notes: * Waiting ration and number of handled containers is drawn from simulation
*The Capacity is cited from KBCT terminal in Busan Port * Handling capacity in TEU is estimated 400,000.
Data Source: Author's estimation (2014)

The results of estimating waiting ratio and cost per TEU are shown in Table 5 while Figure 2 on the next page presents relationship between waiting ratio and waiting cost per TEU. Finally, other costs for terminal *'i'* are expressed using trend formula as follows

$$OUC_i = CO_i + 0.6192(\frac{X_i}{CAP_i})^3 - 7.2968(\frac{X_i}{CAP_i})^2 + \ +25.051(\frac{X_i}{CAP_i})^1 - 17.209 \qquad (36)$$

In this expression it is possible to see that, when number of handled containers exceeds handling capacity by 50% or more, the waiting cost rapidly increases.

4. Non Cooperative Equilibrium Price and Profit Estimation

Table 6 shows the results of Bertrand Nash equilibrium which is characterized by the first-order condition given by Eq. (7). It is solved using an equation modeling

Table 6. Equilibrium Price and Profit Estimation for CTs(Non cooperative)

Category	KBCT	HBCT	DPCT	Gam	HJNC	PNC	Total sum
Equilibrium price per TEU ($/TEU), p_i	43.2	57.9	38.5	45.6	48.0	54.5	n.a
User cost $/TEU ($p_i + OUC_i$)	22.6	18.7	20.4	21.9	21.0	20.1	n.a
Equilibrium Market Share, Q_i	0.19	0.11	0.29	0.13	0.163	0.12	1
Individual demand, X_i=XQ_i = 13.1Q_i (in million)	2.47	1.40	3.75	1.75	2.14	1.62	13.1
Marginal cost per TEU (c_i)	16.51	33.55	8.23	20.57	22.12	29.71	n.a
Lease charge of terminal *'i'* (US $) (l_i)	12.52	13.37	13.76	20.57	11.27	0	61
Demand in million TEU (X_i)	2.4	1.4	3.7	1.8	2.1	1.6	13.1
Profit (in million $)	35.0	15.4	62.1	26.2	31.3	40.2	210.2

Source: Korea Financial Supervisory Service and Author's estimation (2014)

4.1 Comparison of Prices

The equilibrium handling price of CTs is estimated almost 18% higher than current one according to non-cooperative game formula.

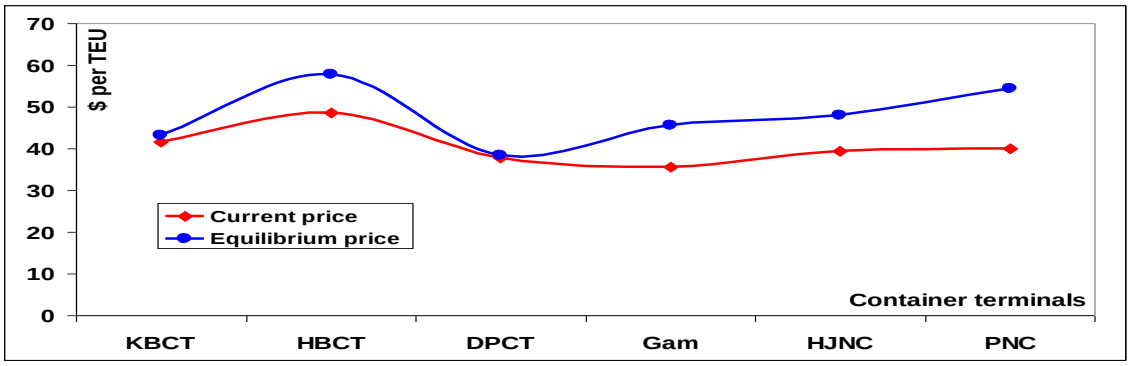


Figure 2. Current Competing Prices and Equilibrium Prices for CTs (Author's Estimation)

4.2 Comparison of Market Share

Figure 3 presents the market shares for current competition and equilibrium market shares of considered CTs. The equilibrium market share of DPCT of 29% is much higher than the current one of 9%.

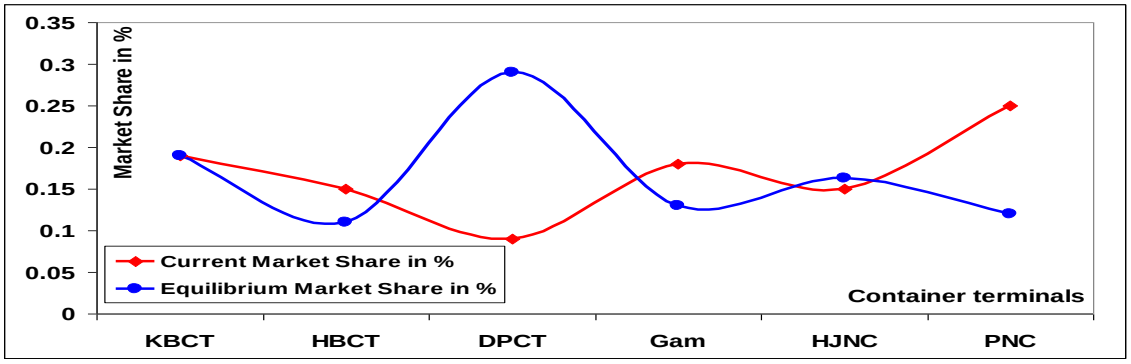


Figure 3. The Current and Equilibrium Market Shares for CTs (Source: Author's Estimation)

4.3 Comparison of Profits

Figure 4 presents the competition of current and equilibrium profits of considered CTs. The equilibrium profit of CTs is estimated almost twice higher than the current one.

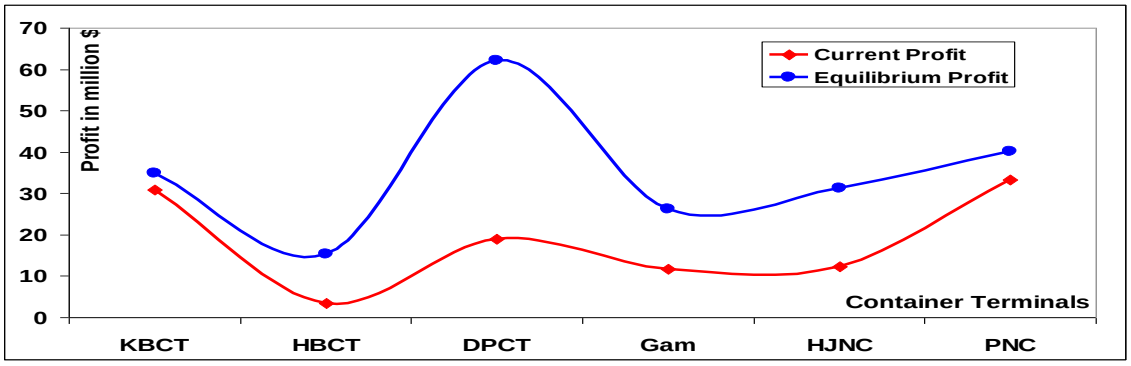


Figure 4. The Current and Equilibrium Profits (Source: Author's Estimation, 2014)

5. Cooperative Equilibrium Price and Profit Estimation

Table 7 shows the results of Bertrand Nash equilibrium which is characterized by the first-order condition given by Eq. (7). It is solved using an equation modeling. If the equilibrium prices would be kept, we can see that DPCT terminal will have the biggest market share and HBCT will have the smallest market share. In this case, the annual total profit of CTs in Busan Port will be US $ 288.4 million, which will be about twice more than the current profit (see Table 7).

Table 7. Equilibrium Price and Profit Estimation for CTs (Cooperative Game)

Category	KBCT	HBCT	HJNC	PNC	DPCT	Gamman	Total sum
quilibrium price per TEU ($/TEU), p_i	*52.4*	*70.6*	*48.0*	*54.5*	*42.6*	*58.5*	*n.a*
User cost $/TEU ($p_i$ + OUC_i)	*22.6*	*18.7*	*21.0*	*20.1*	*20.4*	*22*	*n.a*
Equilibrium Market Share, Q_i	*0.19*	*0.11*	*0.16*	*0.12*	*0.29*	*0.13*	*1*
Individual demand, X_i=XQ_i = 13.1Q_i (in million)	*2.47*	*1,40*	*2.14*	*1.62*	*3.75*	*1.75*	*13.1*
Marginal cost per TEU (c_i)	*16.51*	*33.55*	*22.12*	*29.71*	*8.23*	*20.57*	*n.a*
Lease charge of terminal 'i' (US $) (l_i)	*12.52*	*13.37*	*11.27*	*0*	*13.76*	*10.08*	*61*
Profit (in million $), Eqs. (7) and (8)	57.6	33.3	31.3	40.3	77.2	48.7	288.4

Source: Korea Financial Supervisory Service and Author's estimation (2014)

As a result of cooperative game model, equilibrium price of KBCT is estimated US $52.4, HBCT is 70.6, DPCT is US 42.6 and Gamman is US $58.5. In comparison with non-cooperative game, the price level of cooperative game model shows 15% higher. According to price level change, the profit of cooperative game model shows 37% higher than that of non-cooperative game model.

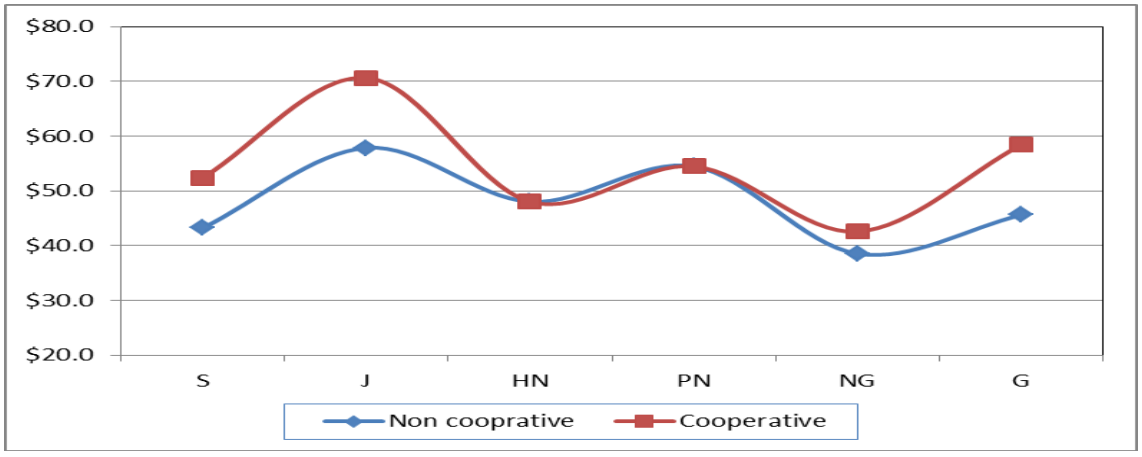


Figure 5. The Non-cooperative and Cooperative Price (Source: Author's estimation, 2014)

As a result of cooperative game model, equilibrium profit of KBCT is estimated US $57.6 million. According to price level change, the profit of cooperative game model shows 37% higher than that of non-cooperative game model.

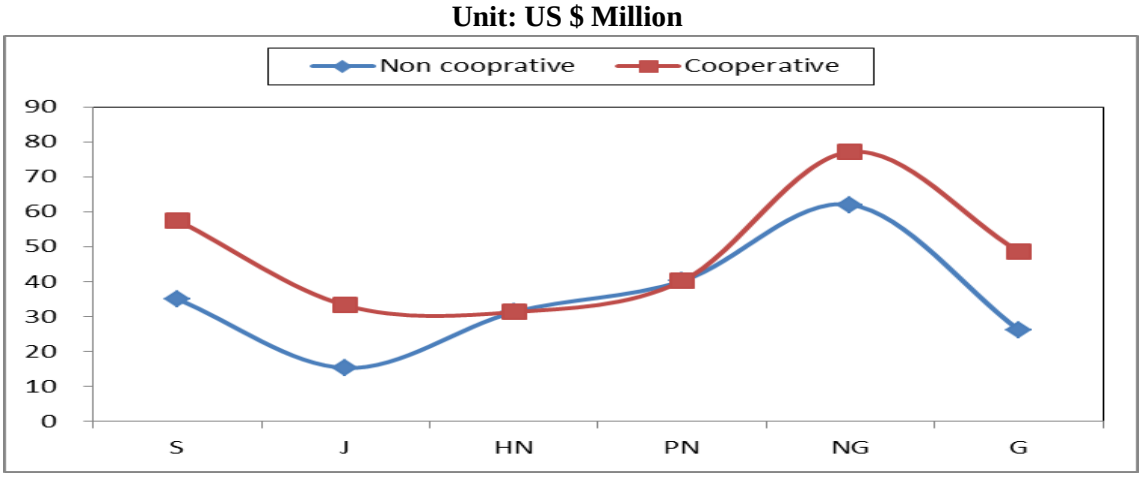


Figure 6. The non-cooperative and cooperative profit (Source: Author's estimation, 2014)

6. Conclusion

The purpose of this study is finding equilibrium price and profit between CTs that are in competitive relation. First, it is required to find what service factors and demand model are important to the shipping companies when they select ports. The obtained results further indicate that the demand model consists of functional equation, in which the port demand changes by -0.046 when the port cost changes. On this basis, it is possible to find the behavior principle of port operating companies in competitive situation by applying Bertrand's game model equation. For example, if one CT would raise their handling charge to maximize a profit, the competing CT will keep current price level and in that case the first one will lose its demand. On the contrary, if a strategy of lower price would be adopted, the competing company will also adopt the strategy to lower price to attract the users; therefore, both companies will end up suffering loss. Refer to handling charge in the case of non-cooperative, the price level is 18% higher than current value in resulting to achieve maximum annual total profit of US$ 210.2 million i.e. the profit is 90.0% higher than current profit.

Considering CTs' behavior under severe competition, four terminals in north part of Busan port are trying to be a unit organization consisting of KBCT, HBCT, DPCT and Gamman terminal to overcome a difficult situation. The result of cooperation of four terminals shows 13% higher price and 37% more profit than that of non- cooperative strategy.

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References

[1] Anderson, C. M., Park, Y. A., Chang, Y.T., Yang, C.H., Lee, T.W., and Luo, M. (2008). "A game theoretic analysis of competition among container port hubs: The case of Busan and Shanghai", *Maritime Policy & Management*, 35 (1): 5-26

[2] Kaselmi, E.N., Notteboom, T., and De, Borger, B. (2011). "A game theoretical approach to competition between multi-user terminals: the impact of dedicated terminals", *Maritime*

Policy & Management, 38 (4): 395-414.

[3] Kaselimi, E.N., Notteboom, T., and Saeed, N. (2011). "*A game theoretical approach to the inter-relation between terminal scale and port competition*", Proceedings of International Association of Maritime Economists (IAME) Conference, Santiago de Chile, 25–28, October 2011, pp.1-26.

[4] Larsen, O. I., and Saeed, N. (2010). "Container terminal concessions: A game theory application to the case of the ports of Pakistan", *Maritime Economics & Logistics*, 12 (3): 37-262.

[5] Malchow, B.M., and Kanafani, A. (2004). "A disaggregate analysis of port selection", *Transportation Research*, 40 (7): 317-337.

[6] Ohasi, H., Kim, T.S., and Oum,.H., and Yu, C. (2005). "Choice of air cargo transshipment airport: An application to air cargo traffic to/from Northeast Asia", *Journal of Air Transport Management*, 11(3): 149-159.

[7] Park, Nam, Kyu., and LIM, CHAE, KWAN. S. (2012). "*Port Logistics System Using Simulation System*" (Revision Supplement edition), Seoul in Korea: Beom Han Publisher, 181-182.

[8] Park, Nam Kyu. (2009). "Choice factors of trans-shipment port in Northeast Asia", *Korean Journal of Navigation and Port Research*, 33 (7): 491-500.

[9] Polydoropoulou, A., and Litinas, N. (2007). "Demand Models for Greek Passenger Shipping", *Maritime Transport: The Greek Paradigm*, 21(Chapter 9): 297-322.

[10] Radmilovic, Z., Dragovic, B., and Mestrovic, R. (2005). "Optimal Number and Capacity of Servers in $M^{X=\bar{a}}/M/c(\infty)$ Queuing Systems", *International Journal of Information and Management Sciences*, 16 (3): 1-16.

[11] Saeed, N. (2009). "An analysis of carriers' selection criteria when choosing container terminals in Pakistan", *Maritime Economics & Logistics*, 11 (3): 270-288.

[12] Saeed, N., and Larsen, O. I. (2010). "An application of cooperative game among container terminals of one port", *European Journal of Operational Research*, 203 (2): 393-403.

[13] Song, D.W., and Panayides, P. M. (2002). "A conceptual application of cooperative game theory to liner s hipping strategic alliances", *Maritime Policy & Management*, 29(3): 285-301.

[14]Train, K.E. (2003). *Discrete Choice Methods with Simulation*, Cambridge: Cambridge University Press.

[15] Van, Dender, K.,and De , Borger, B. Proos, T, S. (2008). "Private port pricing and public investment in port and hinterland capacity", *Journal of Transport Economics and Policy*, 42(3): 527-561.

[16] Zan, Y. (1999). "Analysis of container port policy by the reaction of an equilibrium shipping market", *Maritime Policy & Management*, 26 (4): 369-381.