“SHOULD WE CONCESSION ONE LARGE CONTAINER TERMINAL OR TWO SMALLER ONES?”: A GAME THEORETICAL APPROACH WITH APPLICATION TO VALPARAISO PORT

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Abstract

During the pre-bidding phase of a terminal awarding procedure, landlord port authorities are sometimes confronted with the strategic decision whether to split an available port site into two or more sections to be concessioned separately to different terminal operators. A recent case includes the port of Brisbane in Australia. The port authority of Valparaiso in Chile is now facing a similar challenge. The port authority of Valparaiso concessioned terminal 1 to a private operator and is considering whether it should concession the second site to the same terminal operator or, alternatively, opt for a competitive bidding procedure to attract another terminal operator, thereby initiating intra-port competition. The port is already facing inter-port competition from neighbouring port San Antonio which handles about the same container volume as port of Valparaiso.

In this paper, a game theoretical model is developed in order to shed light on the best option for the port authority of Valparaiso. For this purpose, a non-cooperative two-stage game is developed that models intra-port in and inter-port competition between the port of Valparaiso and San Antonio. In the first stage, the port authority of Valparaiso decides on the way it is going to subdivide its respective port infrastructure. In the second stage, competition between the terminals of the two ports is modelled as a Bertrand game. The game is solved backwards. This paper builds further on earlier work of the authors with respect to the application of game theory to inter-port and intra-port competition by providing a real-life application to Chilean ports.

Keywords

container terminals, competition, concessions, game theory, Chile
1. Introduction

The topography plays an important role in the Chilean transport system. The narrow and elongated landmass of Chile bordered by the Andes Mountain range in the East and the Pacific Ocean in the West directs Chilean foreign trade through Chilean seaports. The ports of Valparaiso and San Antonio are both located in the V región of Chile with a road of 88.21 km separating them. The annual throughput of containerized and break bulk cargos of both ports amounts to some 20 million tons. Each port is managed by a public port authority. Each port has two container terminals and operates under the landlord port management system.

*Figure 1. Location of Valparaiso and San Antonio vis-à-vis main hinterland region Santiago*

The port authority of Valparaiso in Chile is now confronted with the strategic decision whether to split an available port site into two or more sections to be concessioned separately to different terminal operators. To be more specific, the port authority of Valparaiso concessioned terminal 1 to a private operator and is considering whether it should concession the second site to the same terminal operator or, alternatively, opt for a competitive bidding procedure to attract another terminal operator, thereby initiating intra-port competition. The port is already facing inter-port competition from neighbouring port San Antonio which handles about the same container volume as port of Valparaiso.

*Source: Puerto Valparaiso*
In this paper, a game theoretical model is developed in order to shed light on the best option for the port authority of Valparaiso. For this purpose, a non-cooperative two-stage game is developed that models intra-port in and inter-port competition between the port of Valparaiso and San Antonio. In the first stage, the port authority of Valparaiso decides on the way it is going to subdivide its respective port infrastructure. In the second stage, competition between the terminals of the two ports is modelled as a Bertrand game. The game is solved backwards.

2. Background Information About The Case Study

2.1 Port of Valparaiso

The Valparaíso port is located 110 km north-east of the capital city of Santiago. It has a total national market share of 28% on a tonnage basis and a 50% regional market share. During 2011, the port of Valparaiso transferred a total of 10.5 million tons (88.3% was container cargo and 11.7% break bulk cargo such as cars, fruit, etc.), mainly for distribution to the heavily populated Metropolitan Region. It has no facilities for solid and liquid bulk. The Port of Valparaiso covers a total area of 132,3 hectares. The maritime area covers approximately 66 hectares of sheltered waters. It has approximately 1,590m of berths, comprising in total ten berths. However, only berth no. 1 to no. 8 are fully operational. The total length includes 985m of quay concessioned to TPSV and 605m operated by Valparaiso’s Port Authority.

The port serves the Central Zone which covers the V, IV, VI, VII and Metropolitana regions. The port hinterland reaches up to Argentina’s region of Cuyo which consists of Mendoza, San Juan, San Luis and La Rioja provinces.

Valparaíso port is managed by Empresa Portuaria Valparaiso (EPV), a state owned autonomous company that was created in 1997 to manage, operate, develop and preserve the port of Valparaiso and its properties. Valparaiso port has two container terminals, terminal 1 and terminal 2. Terminal 1 is concessioned to Terminal Pacífico Sur Valparaíso S.A. (TPSV), controlled by Ultramar, a local shipping and port operating conglomerate. The second terminal of the port, Terminal 2 (T2) or “Espigón”, is a conventional terminal currently operated by EPV.

During the last 11 years, the demand of port Valparaíso has experienced an important and sustained growth with a compound annual growth rate of 12.7% for containers and 9.4% for general cargo (figure 2).

Figure 2: General Cargo Growth in Valparaiso
In order to satisfy the expected future demand, port Valparaíso has decided to carry out an international bidding process to award a long term concession to an investor to develop, build and operate a new general cargo terminal specialized in containers that will replace and enhance the existing conventional T2 (figure 3).

Figure 3: Configuration of Port of Valparaíso

In 2000, EPV awarded the first long-term concession in the port of Valparaíso. EPV awarded a concession for the development, maintenance and running of Valparaíso port’s Terminal 1 (berths 1 to 5 and supporting areas as shown in figure 4). The initial concession was for 20 years period but can be extended 10 years more up to 30 years.
Figure 4: Configuration of Terminal 1

Source: Puerto Valparaiso

TPSV has a quay length of 985 meter with a maximum depth of 13.2 meters. This enables it to simultaneously serve up to 3 vessels that today sail on the west coast of S. America.

Terminal 2 is administered directly by EPV through a multi-operators system.

2.1.2 Terminal 2 – T2

EPV has authorized ASSET Chile Investment Bank to act as its financial advisor to lead an international bidding process. The concession is expected to be for a 30-year period, with the flexibility to present configurations developed by interested operators.

The new concessionaire will receive T2 in operation. Currently Espigón1 consists in 2 operating sites and transfers approximately 1.0 million tons per year.

2.2 Port of San Antonio

The port of San Antonio is located in the city and province of San Antonio, in the V Region of Chile. Port San Antonio’s area of interest is composed of central Chile and the province of Mendoza, Argentina. In 2011, San Antonio transferred 12.1 million tons of which 58% relates to containers, 25% solid bulk, 9% liquid bulk and 8% other cargo.
The port of San Antonio has two terminals: San Antonio Terminal International (STI) and Puerto Central (PC). Empresa Portuaria San Antonio (EPSA), a State-owned entity is in charge of managing the San Antonio port. In 1999, EPSA, in cooperation with the Chilean State, awarded two long term concessions. They awarded STI (a consortium of private investors) with a twenty year port concession to operate the Molo Sur, to transfer containerized cargo and general cargo, and Puerto Panul (a consortium of local investors) with a thirty year concession to transfer dry bulk cargo. Two other terminals currently operate in San Antonio, transferring dry and liquid bulk cargo and containerized cargo. In 2011, EPSA awarded a concession to a new investor (Puerto Central), to build and operate a new container terminal, replacing the existing Espigon (Terminal Costanera). This terminal is Puerto Central (PC) with a depth of ten meters and is currently in use.

2.2.1 San Antonio Terminal International (STI)

Terminal STI is operated and managed by the South terminal Molo specializing in shipping containers. The terminal has 769 meters of berth with a maximum depth of 15 meters alongside which allows simultaneous operation of up to 3 vessels. The berth expansion project will increase vessel handling capabilities to 4 vessels operating simultaneously however, this project is not on construction yet.

Figure 5: Configuration of STI

Source: Puerto Valparaiso

3. Literature Review

3.1 Terminal Operator Competition

The interest in the level and conditions of intra-port competition is an issue that has been approached by a lot of port economists from a theoretical point of view. Langen and Pallis (2007) argue that intra-port competition is widely regarded as beneficial for the competitiveness
of ports, for local and national economies and for consumers and exporting industries. According to Langen and Pallis (2006), intra-port competition is associated with two types of benefits, the substance of which leads to thoughts that this might be the answer in conditions of limited inter-port competition (Flor and Defilippi, 2003). First, it affects the distribution of economic rent in seaports as it prevents (monopolistic) rent seeking by port service providers (Goss, 1999). Second, it acts as an engine of flexibility innovation and specialization, within contemporary production and distribution processes. Defillipi (2004) focuses on the benefits of turning mono-operator concession schemes to multi-operator schemes via subsidies, with the ultimate target of lowering prices paid by users, whereas Flor and Defillipi (2003) focus on the role of the regulator to enact an access mandate appropriate for reversing monopolistic situations (i.e. by creating incentives to reach a Nash Equilibrium) and the relevant basic principles to arrive at the optimal charge. Notteboom (2002) indicates that an outcome of the consolidation process in the terminal business is that a large number of European ports have a few big terminal operators within the port area and/or are confronted with an intra-port monopoly situation in container handling. A much quoted market-related drawback of having just one player or one very dominant terminal operator in an individual port relates to the limitation of the freedom of choice for the customer at least within the port area. However, a market configuration of one or two operators within a specific port area is said to provide a better answer to carrier power and to carriers’ demand for dedicated terminals and generally offers a larger financial base for investments in expensive terminal infrastructure. In addition, the character of local monopolies in the terminal operating market sometimes leads to abuse of market dominance whereby the economic rent is not passed on to the consumers. These issues constitute the core of many legal disputes handled by competition authorities around the world and fuels the debate on the cost/benefit balance linked to allowing new entrants vis-à-vis allowing incumbents to grow.

3.2 Game Theory

In recent years, a growing number of port economists have introduced quantitative models for the analysis of intra-port competition especially using game theory. The oligopoly structure of the container terminal market with its geographically segmented markets, each populated by a number of terminals, makes game theory an appropriate modelling technique for studying intra-port competition.

Lam and Yap (2006) use a static Cournot game to model the competition between container terminal operators with application to Southeast Asia by considering the ports of Singapore, Port Klang and Tanjung Pelepas. Yip et al. (2010) propose a non-cooperative Cournot game theory model in order to examine the effects of inter- and intra-competition on terminal concession awarding in Chinese and Malaysian ports. Kaselimi and van Reeven (2008) use a
symmetric horizontal product differentiation model to explore the preferable entry strategy of Global Terminal Operators into the container terminal handling business. Also, Kaselimi et al. (2011a) address again the issue of intra-port competition focusing on the examination of implications of the introduction of fully dedicated terminal facilities on the existing multi-user terminal operators. The paper demonstrates how the shift towards a dedicated terminal impacts on intra-port and inter-port competition between the remaining multi-user terminals.

Reynaerts (2010) uses a combination of the Antitrust Logit Model (ALM) with Bertrand competition (modelling container handling competition in ports) to empirically examine the effect of the 2001 merger between two terminal operators in the port of Antwerp (i.e. Hessenatie and Noordnatie) on consumer prices and welfare. The work of Defilippi (2004) forms the exception to the game theory approach and uses Monte Carlo simulation and real option theory to examine whether a mono- or multi-operator concession alternative is more beneficial for Callao port in Peru.

All the above models are mainly examining inter- and intra-port competition without taking into account terminal scale. For the purposes of this study, a model is needed that examines terminal competition in relation with terminal scale. Saeed and Larsen (2010a) succeed in that by examining intra- and inter-port competition between two ports in Pakistan. The focus of the discussion is the decision whether the three terminals in Karachi port should act as a singleton or, alternatively, should enter into a coalition with one or both of the other terminals (taking into account the terminal in the competing port of Muhammad Bin Qasim). Finally, Kaselimi et al. (2011b) introduce a game theory model to analyse the interrelation between economies of scale and intra-port competition and its effect on port authorities concessioning decisions. The model is illustrated by referring to a number of hypothetical cases of terminal competition in the realistic setting of two ports of Pakistan.

4. The Model

4.1 Basic Modeling Considerations

The present paper applies the model developed by the authors in previous work (Saeed and Larsen, 2010 a & b) to the ports of Valparaiso and San Antonio in the region V of Chile. It examines the effects that a decision of the Valparaiso port authority (regarding the question whether to go for two independent terminals) will have on intra-port competition in the port of Valparaiso and inter-port competition between Valparaiso and San Antonio. This is achieved by looking at different scenarios where two or more terminals operating inside the Valparaiso port unify under one management.
We develop a non-cooperative, two stage game theoretic model. The authors support the idea that in the pre-bidding phase, the competition between terminal operators is a game on quantities (capacities) and therefore Cournot is the relevant tool to model terminal competition. When the terminals have started to operate, the competition that takes place is on prices and in that case Bertrand becomes the most appropriate approach (Kaselimi et al., 2010). In addition, in a competitive situation with few players and a heterogeneous product, the outcome in terms of market shares and prices can often be treated as the result of a game where each player maximizes profit, but with due consideration of the expected reaction of its competitors. When the competitor’s actions are confined to setting the prices of their own product (service), the outcome can be modelled as Bertrand equilibrium (Pindyck and Rubinfeld, 2001). In this context, we concentrate on the second part where the terminals have started to operate and thus competition between terminals is treated as Bertrand.

The two main players are Valparaiso port and San Antonio port. In the first stage, EPV decides on the way it is going to subdivide the port’s infrastructure: award T2 to TPSV or initiate a new concession. The dilemma of EPV is illustrated in the model as the choice between one big terminal or the splitting of the available land into two sections. The "big" terminal is illustrated as the sum of two small terminals so that the division of the port in one or two sections is given by adding up two of the separate terminals together (TPSV2 = TPSV + T2). EPV concessions the terminals with a “fixed” fee per TEU handled. In the second stage, the competition between the terminals of the two ports is taking place following Bertrand competition. The outcomes of the Bertrand game are used to investigate the payoff for different terminal operating management schemes.

The model is solved backwards, by examining first the results of the second stage and accordingly decisions are made in the first stage.

4.2 General Specification

4.2.1 The Demand for container terminal services

In order to detail the structure of the Bertrand game, the demand function faced by each port must be made explicit. From the perspective of individual customers competitors are supposed to offer similar but not quite homogeneous services. Different ports and terminals can rarely be considered as perfect substitutes from a user perspective (see Notteboom (2009) for a detailed analysis on the complementarity and substitutability among adjacent seaport terminals).

The term ‘terminal users’ is used for the agents who pay the cost of container freight and handling and make the choice of which terminal to use. In addition to the terminals charges for handling and storing containers, the user will have additional costs which we may call other user
costs (OUC). As OUC are considered among others the inland transport (i.e. rail and trucks) cost for containers to and from terminals within the port area, freight rates charged by container lines\(^1\), cost related to transport time\(^2\) and container lease cost\(^3\).

Even if terminal charges are equal, differences in OUC may thus lead to different market shares for competing terminals. Differences in OUC may lead to persistent differences in terminal charges and market shares even in a competitive setting. In our model, we assume that OUC is composed of two components. The first component is independent of the volume of containers handled by each terminal. The second one is a variable component which follows an increasing function of the volume handled (and decreasing in rated capacity).

The rationale for a variable component of OUC is two-fold. First, marginal customers will, on average, have longer transport distances and a higher transport cost to the terminal than the average customer. Second, when the volume of containers approaches or exceeds the rated terminal capacity different types of delays are expected to increase. Structural delays due to a chronic undercapacity situation affect ship turnaround time and might subsequently give incentive to shipping lines to impose congestion surcharges, while other types of delays may affect the dwell time of containers in port.

A counteracting force may be that the level of service in terms of vessel calls will improve with the volume of containers handled. Within surface and air transport, this aspect is generally referred to as the Mohring effect (UNITE, 2003). Veldman and Rachman (2008) use the throughput share of the port to capture the Mohring effect. However, in this case with constant capacity we must expect that the two reasons for introducing a variable component of OUC have a stronger negative impact on OUC than the positive ‘Mohring effect’.

The market share of each terminal is determined by an aggregate multinomial logit model\(^4\) and the demand (in TEUs) for all terminals combined is a function of the logsum from the logit model. We further assume a U-shaped cost curve since the capacity of each terminal is fixed. The capacity expansion will involve major investments and take a long time for implementation (if it is physically possible to expand at all). The use of a logit model presupposes that a ‘utility function’ can be assigned to each terminal. The utility functions in an aggregate logit model can be interpreted as a measure of the attractiveness of a terminal as perceived by the ‘average’ user.

Total aggregate demand (in TEUs) for all the terminals is given by: 

$$X = Ae^{\theta S}$$  \hspace{1cm} (1)

where \(A\) and \(\theta\) are constants and \(0 < \theta < 1\),

Individual demand for terminal “i” is given by the equation: 

$$X_i = X_i Q_i$$  \hspace{1cm} (2)

\(^1\) In particular any surcharges related to port and terminal efficiency  
\(^2\) Including the cost of container lease or rental  
\(^3\) With the increase in transport time, the lease period will also increase which will result in increased costs  
\(^4\) For details about the logit model see Ben-Akiva and Lerman (1985) and Train (2003).
where i refers to a specific terminal.

The demand faced by a terminal will thus depend on handling charges (including unit fee) and OUC for all terminals. We assume that the private terminals will keep the handling charge, but the revenue from the fees is transferred to the Port Authority. Individual demand is elastic because a change in price and other attributes of one terminal will shift the traffic between that terminal and other terminals. There will also be a slight effect on the total demand via the logsum.

### 4.2.2 Revenue/profit for terminal operators and port authorities

The operating surplus of the private terminal ‘i’ is given by:

\[
\Pi_i = (p_i - w_i - c_i) \cdot X_i \quad (3)
\]

where \( p_i \) is the handling charge per TEU paid by the users, \( w_i \) is the fee paid by private terminals per TEU handled and \( c_i \) is the marginal cost per TEU. If the contract implies that the unit fee is a percentage of the handling charge, the surplus is alternatively given by:

\[
\Pi_i = (p_i (1 - \delta_i) - c_i) \cdot X_i \quad (4)
\]

where \( \delta_i \) is the fee and \( p_i (1 - \delta_i) \) is the share of the handling charges retained by the terminal.

For any contract between the Port Authority and private terminal operator which will be viable in the long run we must have:

\[
\Pi_i = (p_i - w_i - c_i) \cdot X_i \geq annual\ rent(i) \quad (5)
\]

That is, the operating surplus must be greater than the annual rent paid to the port authority. This constraint is set in general terms; however it is not incorporated in the numerical solutions of the model because the constraint never becomes binding in our model\(^5\).

Insofar as \( w_i \) (or \( \delta_i \)) will influence the outcome of a game between competing terminals, i.e. the total revenue \( (p_i \cdot X_i) \), a contract that specifies the magnitudes of \( \delta_i \) and annual rent constitutes an important strategic decision for a port authority that attempts to maximize total revenue.

Whatever price other terminals are charging, terminal i’s profit is maximized when the incremental profit from a very small increase in its own price is just zero. Thus, in order to find the best reply for player i, we differentiate his profit function with respect to \( p_i \) and set the

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\(^5\) Annual rent is a fixed cost so whether is included in the model or not, it will not affect the solutions which are obtained.
derivative equal to zero. The Bertrand Nash equilibrium is characterized by the first-order conditions:

\[ \frac{\partial \Pi_i}{\partial p_i} = 0, \]

where, \( i \) refers to a specific terminal.

The profit function, say for TPSV is given by:

\[ \Pi_{TPSV} = (p_{TPSV} - w_{TPSV} - c_{TPSV}) X_{TPSV} \]  \hspace{1cm} (7)

Since \( X_{TPSV} = Ae^{\theta LS} Q_{TPSV} \) (11) can also be written as:

\[ \Pi_{TPSV} = (p_{TPSV} - w_{TPSV} - c_{TPSV}) \left( Ae^{\theta LS} Q_{TPSV} \right) \]  \hspace{1cm} (12)

By taking the derivative of equation (12) and setting it equal to zero we get the condition:

\[ \frac{\partial \Pi_{TPSV}}{\partial p_{TPSV}} = Ae^{\theta LS} Q_{TPSV} + (p_{TPSV} - w_{TPSV} - c_{TPSV}) \frac{\partial \left( Ae^{\theta LS} Q_{TPSV} \right)}{\partial p_{TPSV}} = 0 \]  \hspace{1cm} (8)

By taking the log of last term of equation (7) we get:

\[ \ln(Ae^{\theta LS} Q_{TPSV}) = \ln(A) + \theta LS + U_{TPSV} - LS \]

By taking the derivative of above equation with respect to \( P1 \) we get:

\[ \ln(Ae^{\theta LS} Q_{TPSV}) = \ln(A) + \theta LS + U_{TPSV} - LS \]  \hspace{1cm} (7a)

By substituting equation (7a) in equation (8) we get

\[ 1 + \left[ b \left( \theta Q_{TPSV} + 1 - Q_{TPSV} \right) \right] \left( p_{TPSV} - w_{TPSV} - c_{TPSV} \right) = 0 \]  \hspace{1cm} (9)

This is the implicit reaction curve (pricing rule) for terminal 1. The reaction curve for the second terminal is the same since both have signed the fixed fee concession contract. Thus reaction curve for T2 is as follows:

\[ 1 + \left[ b \left( \theta Q_{T2} + 1 - Q_{T2} \right) \right] \left( p_{T2} - w_{T2} - c_{T2} \right) = 0 \]  \hspace{1cm} (10)

After solving the first-order conditions, we get the results of Bertrand Nash equilibrium.

4.2.3 User’s surplus

For the estimation of the users’ benefits, “the rule of the half” is applied. Thus, a change in users’ surplus is estimated as changes in the generalised costs multiplied by the average demand before and after merging of terminals:

\[ \Delta US = \frac{1}{2} (GC_i - GC_0).(X_i + X_0) \]  \hspace{1cm} (11)

where \( US \) = users’ surplus; \( GC0 \) = generalized costs in the present case, \( GCi \) = generalised costs in a hypothetical merging \( i \) (i= the hypothetical cases examined), \( X0 \) = demand in the present case, \( Xi \) = demand in a hypothetical merging \( i \) (i= the hypothetical cases examined).
In our analyses, however, there are changes in the generalised costs both for public and private terminal users. Thus, we have applied an alternative method for estimating the user’s surplus, based on the well known property of the logit model. Changes in the logsum of the logit model are, as de la Barra (1989) amongst others points out, conceptually equivalent to the traditional user’s surplus indicator shown in (11). Thus, (11) can be written as:

\[
\Delta US = \frac{1}{2} (X_i + X_0) \cdot \frac{1}{b} (LS_i - LS_0)
\]

(12),

where LS_0 = logsum of the logit model in the present case, LS_i = logsum in a hypothetical merging i (i= the hypothetical cases examined), b= the co-efficient of price at terminals.

### 4.3 Application of the Model

**Analysis of Numerical Examples**

We solve the reaction functions and the equilibrium of the Bertrand game in order to get the pricing rule set by the players that will yield the Nash equilibrium. Regarding data collection, Valparaiso port authority provided us with the data needed for both ports of Valparaiso and San Antonio.

#### 4.3.1 Base Case - Two independent terminals in Valparaiso port

The current situation in Valparaiso port consists the base case of the model. EPV decides to split the available infrastructure of 12.12 million tones into two uneven pieces. The terminal with capacity of 10.1 million tones is given to a private terminal operator TPSV and the second one, T2 of 2.02 million tones, is operated by EPV.

As mentioned above, the data are obtained from the Valparaiso port authority and the official websites of the terminals. We examine data regarding the number of ships and the number of TEU handled that call at the four terminals of Valparaiso and San Antonio ports for the years 2000-2011 in order to get estimations of the demand and market shares of the terminals (see tables 1 and 2).

<table>
<thead>
<tr>
<th></th>
<th>Valparaiso Port (PV)</th>
<th>San Antonio Port (SAI)</th>
</tr>
</thead>
</table>

Table 1: Market share & handling charges
Table 2: General parameters of demand

<table>
<thead>
<tr>
<th>Level of Demand (A) (in tones)</th>
<th>Logsum parameter (θ)</th>
<th>Price parameter (λ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,193,000</td>
<td>0.010</td>
<td>-0.050</td>
</tr>
</tbody>
</table>

Source: own compilation

The $a_i$, the alternative specific constant for terminal ‘i’ in the utility functions (Appendix A.2) takes the following forms: $T_2 = T_{PC} = 0$, while $a_{TPSV}$ and $a_{STI} > 0$. Alternative specific constants are included in the utility functions for TPSV and STI, to capture the attributes due to which these terminals capture a high market share compared to their competitors. User costs constant, for terminals T2 and PC are assumed to be high due to low capacities and non-availability of modern equipments at these terminals.

The user cost function is $OUC(i) = C0_i + 0.5(\frac{X_i}{CAP_i} * 0.65)^3$. The parameter of 0.65 implies that the user cost starts to rise sharply when throughput exceeds 65% of rated terminal capacity. High levels of terminal capacity utilisation imply longer ship turnaround times due to lower berth availability and or a longer time at berth (e.g. due to a low crane density). In this paper we use the intrinsic capacity of a terminal (also known as the maximum attainable throughput or MAT) as a reference point not the practical capacity or highest efficient attainable throughput (HEAT). The intrinsic capacity is the level of throughput that can be attained under ideal conditions of berth utilisation and taking into account planned factors such as preventive maintenance, training and setup times. The practical capacity is an actual attainable throughput taking into account realistic operating conditions at the seaport and unplanned activities such as unexpected machine breakdowns, worker absenteeism and weather conditions (NCHRP, 1998).
Table 3: Terminal specific parameters

<table>
<thead>
<tr>
<th></th>
<th>PV</th>
<th>SAI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TPSV</td>
<td>T2</td>
</tr>
<tr>
<td>Alt.spec. constant ( (\alpha_i) )</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>User cost constants in $ ( (C_0_i) )</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td>Marginal cost in $ ( (c_i) )</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Capacity (1000s tones) ( (CAP_i) )</td>
<td>10100</td>
<td>2020</td>
</tr>
<tr>
<td>Terminal fee in $ per TEU ( (w_i, \delta_i) )</td>
<td>0.38</td>
<td>0.34</td>
</tr>
</tbody>
</table>

*Source: own compilation*

Terminal fees are calculated based on the following equation: \( 7209000 + (A.T.-5452000)*0.95 \), where A.T. is the Annual Transfer of tones of previous year, (0.95) is the variable fee based on the last year transfer, in USD, \((7,209,000)\) and \((5452000)\) are constant and they are adjusted annually by PPI (USA Product Price Index). This equation allows EPV to make estimated\(^7\) calculations on the payment of TPSV and T2. A model consisting of equations (A.1), (A.3), (A.4), (5), (7), (8), (9), (14), (15) and (18) is solved using an equation solver. Table 4 shows the results of the Bertrand Nash equilibrium.

Table 4 – Bertrand equilibrium with 4 terminals (present situation)

<table>
<thead>
<tr>
<th></th>
<th>TPSV</th>
<th>T2</th>
<th>STI</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilibrium Price (US$/TEU)</td>
<td>108.90</td>
<td>92.00</td>
<td>107.90</td>
<td>93.40</td>
</tr>
<tr>
<td>User Cost (US$/TEU)</td>
<td>8.30</td>
<td>47.10</td>
<td>6.10</td>
<td>41.90</td>
</tr>
<tr>
<td>Market share</td>
<td>41%</td>
<td>9%</td>
<td>39%</td>
<td>11%</td>
</tr>
<tr>
<td>Profit (in Mill US$)</td>
<td>281.3</td>
<td>44.6</td>
<td>262.4</td>
<td>51.2</td>
</tr>
<tr>
<td>Total Demand (in 1000s tones)</td>
<td></td>
<td>20607</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined profit (Ter. 1-2) Valparaiso Port (in mil US$)</td>
<td></td>
<td></td>
<td>326</td>
<td></td>
</tr>
<tr>
<td>Combined profit (Ter. 3-4) S. Antonio Port (in mil)</td>
<td></td>
<td></td>
<td>313</td>
<td></td>
</tr>
</tbody>
</table>

\(^7\) This is an assumption because we don't have the exact constant of STI equation
Market shares for the four terminals are obtained by solving the Bertrand model (see table 4). The results are quite close to the actual market shares (see Table 1) which confirms the validity of this model.

EPV’s profits are stemming from the operation of T2 and equal 43.2 mil. US$. In addition to this, EPV receives the terminal fee from TPSV which equals 0.38 US$ per TEU.

4.3.2 Case 1: New concession contract resulting in 1 terminal in port of Valparaiso

4.3.2.1 TPSV & Terminal 2 under one private management

We assume that the port authority decides to give T2 to the same terminal operator as TPSV, or the terminal TPSV2. TPSV2 with a capacity of 1,200,000 TEU is under the same management and operated as one terminal. The chosen form of the user cost function now becomes $OUC(i) = C_0 + 0.5(X_i / CAP * 0.75)\theta$ to reflect that a rise in user cost takes place when throughput exceeds 75% of rated capacity.

We assume that the combination of the two terminals under one management leads to economies of scale and a better utilization of the bigger capacity. The logic behind this is that when two smaller terminals serve as a single unit, combined capacity is more as compared to the capacities of individual terminals. This increased capacity implies less average waiting time for ships if all other operational factors are unchanged. Thus, due to economies of scale, marginal cost of the new terminal TPSV2 is expected to decrease from 70$. Since we do not know how much the decrease of marginal cost (MC) will be, we solve the model for three different values, MC=70, MC=60 and MC=50. The lower the marginal cost the better for TPSV2 thus we run the model for a marginal cost of MC=50. The results for the other two scenarios are shown in the appendix (tables A1 and A2).

In addition, the T2 is assumed to be handed over to TPSV in its present situation as a conventional terminal without modern equipment which is expected to lead to an increase of the user cost of the new terminal. Here it is assumed to be 26$.

Source: own compilation

<table>
<thead>
<tr>
<th>Logsum</th>
<th>4.51</th>
</tr>
</thead>
<tbody>
<tr>
<td>US$)</td>
<td></td>
</tr>
</tbody>
</table>
EPV signs a concession contract with TPSV2 in which TPSV2 pays a ‘fixed fee’ per TEU handled to EPV. It is assumed that EPV chooses one of the two following options for the private terminal operator: (a) It keeps the present fee and (b) It increases the fee.

### 4.3.2.2 EPV keeps the present fee for the private terminal operator

EPV keeps the present fee for the private terminal operator at the same level as in base case, unit fee of 0.38 US$ per TEU. The marginal cost is 50. The results are shown in table 5.

<table>
<thead>
<tr>
<th></th>
<th>P.V.</th>
<th>SAI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TPSV2</td>
<td>STI</td>
</tr>
<tr>
<td>Equilibrium Price (US$/TEU)</td>
<td>88.60</td>
<td>108.60</td>
</tr>
<tr>
<td>User Cost (US$/TEU)</td>
<td>26.70</td>
<td>6.30</td>
</tr>
<tr>
<td>Users’ Surplus</td>
<td>-28,840</td>
<td>48%</td>
</tr>
<tr>
<td>Market share</td>
<td>48%</td>
<td>40%</td>
</tr>
<tr>
<td>Profit (in Mill US$)</td>
<td>378.9</td>
<td>275.8</td>
</tr>
<tr>
<td>Total Demand (in 1000s tones)</td>
<td>20593.2</td>
<td></td>
</tr>
<tr>
<td>EPV’s profit</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>Combined profit of Valparaiso Port (in mil US$)</td>
<td>382.6</td>
<td></td>
</tr>
<tr>
<td>Combined profit S. Antonio Port (in mil US$)</td>
<td>329.7</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** own compilation

### 4.3.2.3 Discussion

Users of Valparaiso port terminals are better off if served by TPSV2 since they will now pay a lower price. The new terminal TPSV2 can take advantage of economies of scale and charges a lower price. Indeed TPSV2 is able to charge a lower price of 88.60 US$/TEU compared to the previous price, 108.90 US$/TEU, charged by TPSV. However, for the users of T2 which is now part of the new terminal, the trend is different. Price for T2 also decreases when integrated to the new terminal TPSV2 from 88.6 US$ per TEU to 89.00 US$ per TEU.

Regarding user costs, in the previous case users of TPSV faced lower user cost of 8.30$. Now after merging with T2, users of TPSV2 will face increased by 221.7% cost. The users of TPSV now have to wait to be served along with the users of the previous T2 terminal and there is also the chance that they are served by conventional T2. On the other hand, users of T2 will face
lower user cost of 26.7$ instead of 47.10$, a decrease of 43.3%. This can be explained by the fact that users of conventional T2 now have the chance to be served by a modern fully equipped terminal, TPSV.

The market share of each of the terminals, TPSV and T2, increases from 41% and 9% to 48% for TPSV2, an increase not so strong to outreach the total market share of the two separate terminals. This shows that the higher user cost of the new terminal, TPSV2, has affected a large segment of the users who despite lower price at TPSV2 will switch to the competing terminals. As a consequence, the market share of STI and PC will increase from 39% and 11% to 40% and 12% respectively.

Moreover, EPV’s profits now are stemming only from one source of revenue which is the terminal fee. The fees from the terminal TPSV2 equals 3.8 mill US$ which is lower than EPV’s profits before of 44.6 mill US$. However, EPV is not supposed to be a profit maximizing entity and the overall situation seems to be beneficial for Valparaiso port. TPSV’s profit has increased from 281.3 mill US$ to 378.9 mill US$. Similarly, the combined profit of the two terminals, TPSV and T2, in previous case, was 326 mill US$ while now combined profit of new terminal TPSV2 is 382.6 mill US$. The profits of Valparaiso port has increased from 326 mill US$ to 386.4 mill US$ (=378.9+3.8).

Moreover, it is observed that prices and profits of competing terminals of port of San Antonio have also increased indicating a better economic position for the San Antonio port. In addition, the market shares of those terminals have also increased 39% and 11% to 40% and 12% respectively signifying a better competitive position for both ports of the V region.

4.3.2.4 Valparaiso port authority increases the fee for the private terminal operator

In this case, we assume that EPV can negotiate new concession fees when it will concession the T2 to TPSV. Valparaiso port authority increases the fee for the private terminal operator above the level of the base case and charges for example the same fee as the new terminal PC is paying at competing port San Antonio. Unit fee is set at 0.97 US$ per TEU. The results of this sub-case are shown in table 6.

<table>
<thead>
<tr>
<th>Table 6 – Bertrand equilibrium when TPSV &amp; T2 under one management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Equilibrium Price (US$/TEU)</td>
</tr>
<tr>
<td>User Cost (US$/TEU)</td>
</tr>
</tbody>
</table>
### Users’ Surplus

<table>
<thead>
<tr>
<th>Users’ Surplus</th>
<th>-16,479</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market share</td>
<td>48%</td>
</tr>
<tr>
<td>Profit (in Mill US$)</td>
<td>374.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Demand (in 1000s tones)</th>
<th>20590.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPV’s profit</td>
<td>9.5</td>
</tr>
<tr>
<td>Combined profit of Valparaiso Port (in mil US$)</td>
<td>384</td>
</tr>
<tr>
<td>Combined profit (Ter. 3-4) S. Antonio Port (in mil US$)</td>
<td>332.5</td>
</tr>
<tr>
<td>Logsum</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Source: own compilation

### 4.3.2.5 Discussion

The results are very similar to the previous case where EPV charges a lower terminal fee. As it is expected, the higher terminal fee lead to higher results and profits for EPV as it can increase its profit, by charging high terminal fee, without affecting its market share. The higher terminal fee that the new terminal, TPSV2, has to pay to EPV results in a slight increase in the price charged by TPSV2 to its users from 92.60 mil US$ to 93 mil US$ that brings a slight decrease in the market share and the profits of the terminal.

The overall situation seems to be even more beneficial for Valparaiso port as its profits undergo a quite big increase. Profits for EPV rise to 9.5 mill US$ from 3.8 mill US$ in the above sub-case. Combined profit of Valparaiso has increased from 382.6 mill US$ to 384 mill US$.

Also in this sub-case, prices and profits of competing terminals of port of San Antonio increase leading to a more competitive position for both ports of the V region than before.

### 4.3.3 Case 2: New concession contract resulting in 2 independent terminals in port of Valparaiso

#### 4.3.3.1 TPSV & T2 as independent terminals

In this case, EPV decides to concession T2 to a new terminal operator, different from TPSV. EPV signs a concession contract with T2 in which T2 pays a ‘fixed fee’ per TEU handled.
to EPV. It is assumed that EPV chooses one of the two following options for the private terminal operator: (a) It keeps the same terminal fee as TPSV is paying and (b) It increases the fee.

### 4.3.3.2 EPV keeps the present fee for the two private terminal operators

For this sub-case, the new operator of T2 is requested to pay 0.38 US $ per TEU.

<table>
<thead>
<tr>
<th>Table 7 – Bertrand equilibrium with 4 independent private terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV</strong></td>
</tr>
<tr>
<td><strong>TPSV</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Equilibrium Price (US$/TEU)</td>
</tr>
<tr>
<td>User Cost (US$/TEU)</td>
</tr>
<tr>
<td>Users’ Surplus</td>
</tr>
<tr>
<td>Market share</td>
</tr>
<tr>
<td>Profit (in Mill US$)</td>
</tr>
<tr>
<td>Total Demand (in 1000s tones)</td>
</tr>
<tr>
<td>EPV’s profit</td>
</tr>
<tr>
<td>Combined profit of Valparaíso Port (in mil US$)</td>
</tr>
<tr>
<td>Combined profit (Ter. 3-4) S. Antonio Port (in mil US$)</td>
</tr>
<tr>
<td>Logsum</td>
</tr>
</tbody>
</table>

*Source: own compilation*

### 4.3.3.3 Discussion

For TPSV, results are similar to the base case (present situation). For T2 the situation is differentiating. The terminal operator of T2 has to pay a terminal fee equal to the one TPSV
pays. This puts pressure to the new operator to increase the user price a bit higher than the one that EPV is charging at the present situation. The consequent increase in the user cost provokes a small reduction to T2’s profits from 44.6 mill US$ to 40.9 mill US$. In addition, EPV’s profits now are constrained to 3.9 mill US$ which is lower than the 44.6 mill US$ from the operation of T2.

However, the combined profits for port of Valparaiso are increased from 326 mill US$ to 326.6 mill US$. The combined profits for port of S. Antonio are increased (slightly) as well from 313 mill US$ to 314.2 mill US$. Also the total demand of both ports increases.

4.3.3.4 EPV increases the fee for the two private terminal operators

In this situation we assume that Valparaiso port authority can negotiate new terminal fee for the two private terminals and it will concession the T2 with a higher terminal fee than TPSV. Actually, it is requested to pay the same fee as PC is paying, 0.97 US$ per TEU. In addition, EPV is assumed to be able to increase the terminal fee of TPSV to the same amount of 0.97 US$ per TEU. Results are shown in the table below.

<table>
<thead>
<tr>
<th>Table 8 – Bertrand equilibrium with 4 terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV (TPSV)</td>
</tr>
<tr>
<td>Equilibrium Price (US$/TEU)</td>
</tr>
<tr>
<td>User Cost (US$/TEU)</td>
</tr>
<tr>
<td>Users’ Surplus</td>
</tr>
<tr>
<td>Market share</td>
</tr>
<tr>
<td>Profit (in Mill US$)</td>
</tr>
<tr>
<td>Total Demand (in 1000s tones)</td>
</tr>
<tr>
<td>Profit of EPV</td>
</tr>
<tr>
<td>Combined profit of Valparaiso Port (in mil US$)</td>
</tr>
<tr>
<td>Combined profit (Ter. 3-4) S. Antonio Port (in mil US$)</td>
</tr>
</tbody>
</table>
4.3.3.5 Discussion

The request of higher terminal fee by the EPV results in higher profits for itself as now it gets 10 mill US$ from concession fee. It also results in higher prices requested for the users and consequently user cost for the both terminals of port of Valparaiso than in the previous case. For both terminals, the higher prices lead to a decrease to their profits. Their customers now have to pay higher prices which leads to loss of some of them and reduction of their profits.

However, in general both ports are in better position now. The combined profit of the two terminals, TPSV and T2, in previous case, was 326.6 mill US$ while now combined profit of two terminals is 329.1 mill US$. The market shares of competing terminals of port of San Antonio stay the same. Profits for both terminal operators in S. Antonio port are increasing. S. Antonio’s combined profit has increased. Demand for both ports decreases.

### 5. Conclusions and Policy Implications

Empresa Portuaria Valparaiso (EPV) is considering of carrying out an international tendering process with the objective of selling the concession to construct, operate and maintain Terminal 2 (T2) of Valparaiso port.

In this paper, a game theoretic model was developed in order to provide support to the port authority of Valparaiso (EPV) in deciding on the configuration of its container terminal plots T1 and T2. The decision of EPV to concession T2 is already made. The dilemma faced by EPV is the following: is it best to opt for one big terminal, named as TPSV2, or two separate ones, TPSV and T2. Thus, the discussion is between the two cases, case 1 and 2 and the analysis of the results of the four sub-cases.

The most obvious parameter for EPV to check is its profits. When deciding to give away T2, EPV loses revenues from the operation of this terminal. After the concession agreement, EPV’s only revenue is going to be the terminal fee that it will receive from the terminal operator(s). In this case, its profits are higher when it charges a higher terminal fee per TEU. No matter whether EPV concessions T2 to the same or a different terminal operator than TPSV, it
receives higher profits when it charges higher than today’s terminal fee to its terminal operator(s). In our specific example and under the specific assumptions we made on the values of the terminal fees, EPV gets higher profits when it concessions T2 to a different terminal operator than TPSV and charges the same higher fee to both terminal operators. Therefore, from a strictly economic perspective, the best scenario for EPV is to introduce intra-port competition and concession two independent terminals. In reality, EPV has more goals than profit maximization that end up in satisfying conflicting interests of different stakeholders involved.

The terminal operators of Valparaiso port are the most important group of stakeholders. The first customer of EPV is the current terminal operator, TPSV from which it gets its revenue. Keeping TPSV satisfied is in its best interest. Satisfaction for the use of TPSV is translated into profit maximization and TPSV’s profits are higher when it operates a large terminal. In the case that TPSV concessions T2, its profits and its market share increase as it becomes the only terminal operator of the Valparaiso port. Valparaiso port will not have to worry too much about the monopoly power of TPSV2 in its port as it will continue to get strong external competition by the terminals in San Antonio port. Therefore, the terminal operator of TPSV will always opt for the large terminal. In the examples examined in this paper, TPSV2 will be better off when EPV concessions T2 to TPSV2 keeping the terminal fee at the same levels as in the present situation. This is quite obvious since TPSV2 now controls a bigger terminal but continues to pay the same terminal fee.

The second most important customer for EPV is the new operator (if any) of T2. By definition, the operator of T2 prefers the second case of having two independent operators in Valparaiso. In particular, for the operator of T2 it is better when EPV charges lower terminal fees so this operator can get higher profits.

The third group of interest is the customers of the Valparaiso, the users of its terminals. The user surplus for users of Valparaiso port is negative in all cases. In the case of one terminal operator the negative values are much higher than the case of two different terminal operators. This means that, due to higher prices, users are worse off in the case that the port has one terminal operator. Thus, we expect that users would choose to be served by the terminals in ports with a lot of small terminals in order to maximize their surplus.

The findings of our model are in line with the hypothesis introduced in earlier work (Kaselimi et al., 2011c) that port authorities encourage container terminal development at less than terminal operators' preferred scale. Valparaiso port acting as a typical landlord port authority would prefer two smaller terminals inside its port in order to stimulate intra-port competition. The TPSV terminal operator prefers to operate in ports with the smallest possible number of terminals (ideally one terminal) so as to benefit from economies of scale and a certain level of market power.

Welfare maximization for the region is another goal that Valparaiso port has to take into account along with the need for a high competitiveness of the port as a whole and its terminals in
view of attracting new customers/users and keeping existing ones satisfied. In that sense, Valparaiso has to examine its combined profit or market share for both terminals TPSV and T2. Combined profits are higher when the terminals are under the same management and especially when terminal fees are higher. The market share of Valparaiso port is higher (i.e. 51%), when the two terminals are separated and especially when the terminal fee is kept low.

In addition, the market share for the competing port of San Antonio is lower, i.e. 50%, when the two terminals of Valparaiso port are separated and so are its profits.

The final decision lays in the hands of Valparaiso port which depending on its objectives, specific strategy and priorities will decide and act accordingly.
Acknowledgements

The authors would like to thank Port Authority of Valparaiso that supported this research. Special thanks to mr. Enrique Piraino for making available the data, their guidance and their valuable comments throughout the research. However, the views and opinions expressed by the authors do not necessarily state or reflect those of the ports and terminal operators concerned.
References


UNITE (2003) *Unification of accounts and marginal costs for Transport Efficiency*. Project funded by the EC under the Fifth Framework Transport RTD.


Appendix

The Demand for container terminal services

Computation of user cost function
Following the reasoning of Mohring effect, the user cost function for terminal ‘i’, OUC (i), has the form:

\[ OUC(i) = C0_i + f\left(\frac{X_i}{CAP_i}\right) \]  \hspace{1cm} (A.1)

where \( C0_i \) is the fixed component, \( X_i \) is the volume handled by terminal ‘i’ and \( CAP_i \) is the rated capacity of terminal ‘i’. \( f \) is an increasing function of the ratio.

Computation of utility functions and market share

The utility functions used have the following simple form:

\[ U_i = a_i + b\{p_i + OUC_i\} \]  \hspace{1cm} (A.2)

where \( U_i \) is the ‘utility’ of terminal ‘i’, \( p_i \) is charge per TEU in terminal ‘i’ including fee to Port Authority, OUC = other user cost at each terminal, \( b \) is the co-efficient of price at terminals; \( a_i \) is the alternative specific constant for terminal ‘i’. The market share of terminal ‘i’

\[ Q_i = \frac{e^{U_i}}{\sum_j e^{U_j}} \]  \hspace{1cm} (A.3)

is given by the logit expression:

\[ LS = \ln\left(\sum_j e^{U_j}\right) \]  \hspace{1cm} (A.4)

The logsum is defined by:
<table>
<thead>
<tr>
<th>Table A1 – Bertrand equilibrium when TPSV &amp; T2 under one management (MC=70)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P.V.</strong></td>
</tr>
<tr>
<td><strong>TPSV2</strong></td>
</tr>
<tr>
<td><strong>Equilibrium Price (US$/TEU)</strong></td>
</tr>
<tr>
<td><strong>User Cost (US$/TEU)</strong></td>
</tr>
<tr>
<td><strong>Users’ Surplus</strong></td>
</tr>
<tr>
<td><strong>Market share</strong></td>
</tr>
<tr>
<td><strong>Profit (in Mill US$)</strong></td>
</tr>
<tr>
<td><strong>Total Demand (in 1000s tones)</strong></td>
</tr>
<tr>
<td><strong>EPV’s profit</strong></td>
</tr>
<tr>
<td><strong>Combined profit of Valparaiso Port (in mil US$)</strong></td>
</tr>
<tr>
<td><strong>Combined profit S. Antonio Port (in mil US$)</strong></td>
</tr>
<tr>
<td><strong>Logsum</strong></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Table A2 – Bertrand equilibrium when TPSV &amp; T2 under one management (MC=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P.V.</strong></td>
</tr>
<tr>
<td><strong>TPSV2</strong></td>
</tr>
<tr>
<td><strong>Equilibrium Price (US$/TEU)</strong></td>
</tr>
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<td><strong>User Cost (US$/TEU)</strong></td>
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<tr>
<td><strong>Users’ Surplus</strong></td>
</tr>
<tr>
<td><strong>Market share</strong></td>
</tr>
<tr>
<td><strong>Profit (in Mill US$)</strong></td>
</tr>
<tr>
<td><strong>Total Demand (in 1000s tones)</strong></td>
</tr>
<tr>
<td><strong>EPV’s profit</strong></td>
</tr>
<tr>
<td><strong>Combined profit of Valparaiso Port (in mil US$)</strong></td>
</tr>
<tr>
<td><strong>Combined profit S. Antonio Port (in mil US$)</strong></td>
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<tr>
<td><strong>Logsum</strong></td>
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</tbody>
</table>

*Source: own compilation*