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A Tale of Two Ports: Extending the Bertrand Model Along the Needs of a Case Study

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1. Introduction

Competition between container terminals may occur if they serve the same hinterland or handle transshipment for container flows with the same origin and/or destination. In this study we focus on the first case. Competition may take place both between terminals located within the same port and those located in different ports. Disregarding terminal charges for container handling and storage, different container terminals will rarely be perfect substitutes from a user perspective. They may differ with respect to transport cost for the inland leg, efficiency, level of service in terms of vessel calls, freight rates charged by container lines, etc.

In a competitive situation with few players and an inhomogeneous product or service, 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 to 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 modeled as in the Bertrand equilibrium [1]. Bertrand model is named after Joseph Louis François Bertrand (1822-1900) and was formulated in 1883 by [2] in a review of [3] book in which Cournot had put forward the Cournot model. The model examines the pricing behaviour of interdependent firms in a product market with few rival firms. The idea was developed into a mathematical model by [4].

Our case study deals with the 4 container terminals serving the Pakistani market and is somewhat more complicated than a simple Bertrand situation.

The questions we pose and try to answer are the following:

1. Can the present situation with respect to market shares and container handling fees be interpreted as the outcome of a Bertrand game when we apply our best 'guesstimates' of the parameters of the problem?

2. What are the impacts of the policy pursued by the landlord port in a competitive setting like this? In particular, we are interested in the trade-off between annual rent paid by a terminal and fee on containers handled by the terminal.
3. What can the terminals in the port of Karachi (and Karachi port) in total gain by cooperating (i.e. by forming a coalition)? This potential gain can be the source of a possible cooperative game between the Port of Karachi and the two private terminals.

The rest of the chapter is organized as follows: The following section presents a detailed description of the case study and the information and data available on the terminals. In next section we present a number of research works related to the application of game theory to the port sector. This is followed by the game's solution for the present situation, the rent/unit fee trade-off, the coalition aspect and finally the conclusion.

2. Case studies

Pakistan has the following three major seaports:

- *Karachi Port*, the premier port of Pakistan, is located between the towns of Kiamari and Saddar, close to the heart of old Karachi. It handles about 75% of the entire national trade.
- *Port Muhammad Bin Qasim* is Pakistan's first industrial and multi-purpose deep sea port. Located in the Indus delta region at a distance of 50 km southeast of Karachi, it is well connected to the whole country through modern modes of transportation.
- *Gawadar Port* has just been constructed as the third port of Pakistan. Situated on the Baluchistan coast, it is about 460 km from Karachi and 120 km from the Iranian border (see Figure 1). This port will not be considered in this research as it has just started its operation.



Figure 1. Location of three ports in Pakistan

2.1. Karachi port

Pakistan has about 1062 km of coastline on the Arabian Sea, spreading from the Indian border to the Persian Gulf. At the time of partition, Pakistan (then West Pakistan) had only one functional deep water port at Karachi which not only catered for the entire seaborne cargo of northern India but also provided a transit trade facility to landlocked Afghanistan.

Cargo handled at the Karachi port since the commencement their operation is shown in the figure 2:

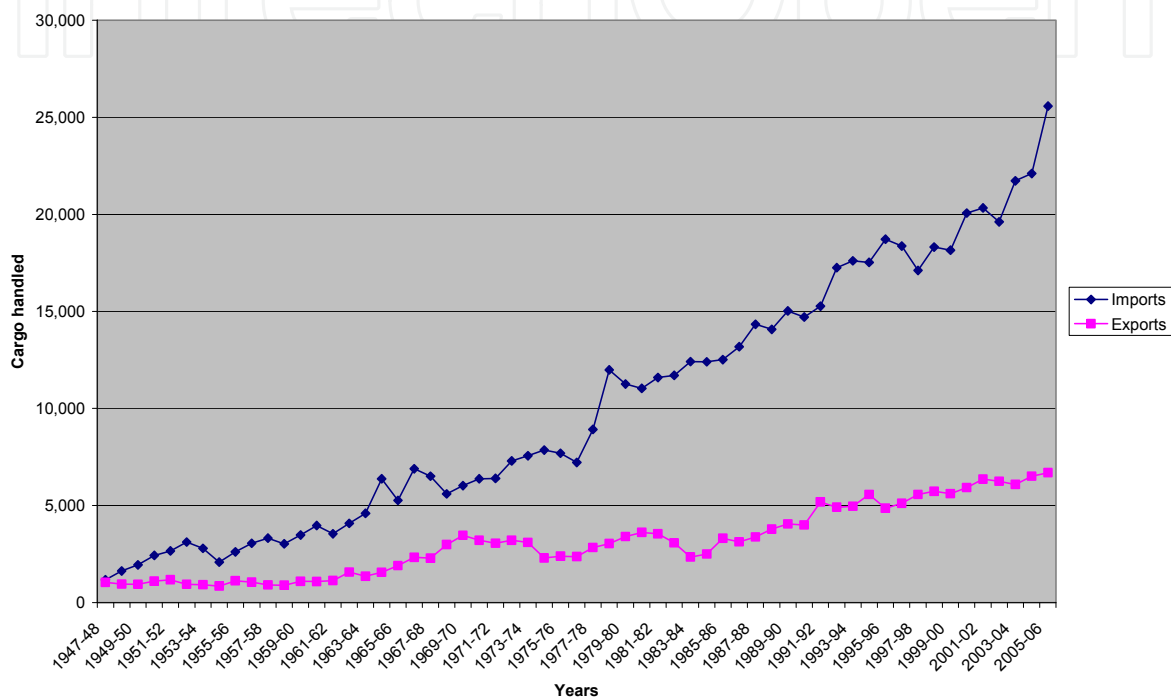


Figure 2. Yearly cargo handling at the Karachi Port since 1947 (independence)

2.1.1. Container terminals at Karachi port

Karachi Port has three terminals:

- Karachi International Container Terminal (KICT): this terminal at Karachi Port has been in operation since 1998. The giant shipping line, APL (American President Line) invested in KICT on a build-operate-transfer (BOT) basis. BOT is the classic case of concessions in which the public sector does not lose ownership of the port infrastructure, and new facilities built by private firms are transferred to the public sector after a specified period of time. Now the terminal has been bought and is managed by Hutchison, Hong Kong.
- Pakistan International Container Terminal (PICT): this terminal at Karachi Port was privatised in August 2002. It was also developed on a BOT basis, specifically build, operate and transfer after 21 years. It is the only container terminal in Pakistan which is sponsored and owned by Pakistanis¹.

¹ See <http://www.pictctrtrack.com/>. Accessed 5th April 2007.

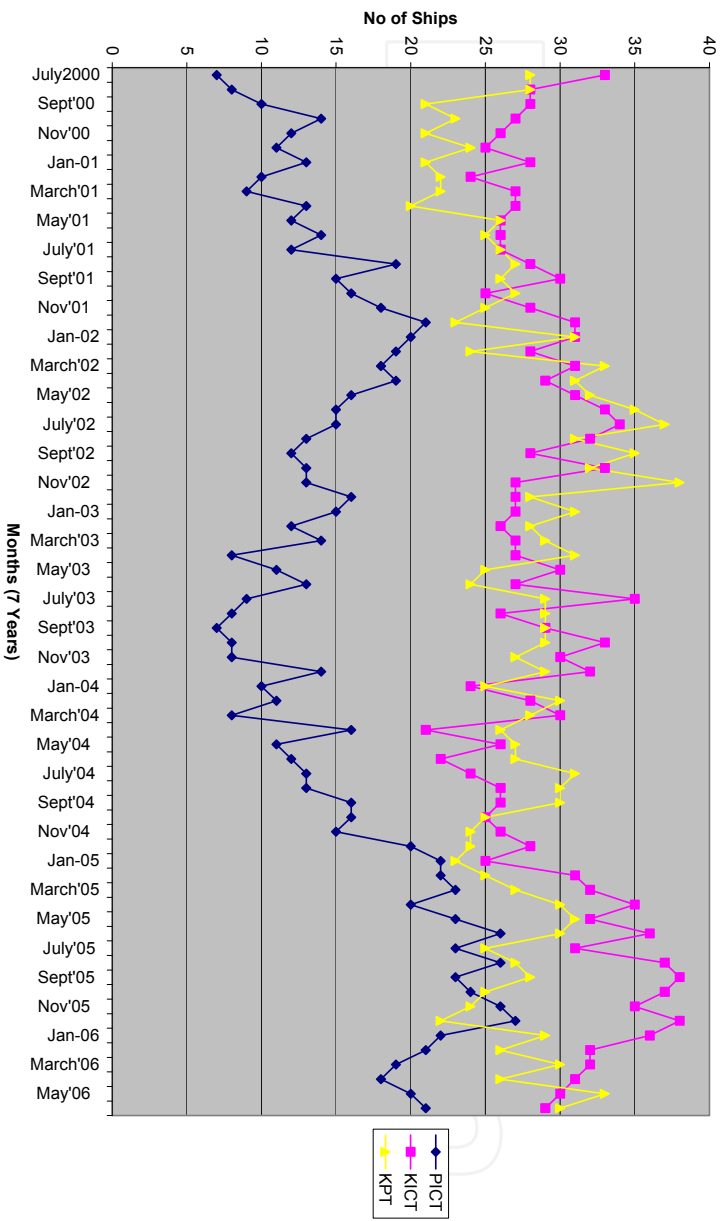


Figure 3. Number of ships handled at three terminals in the Karachi Port

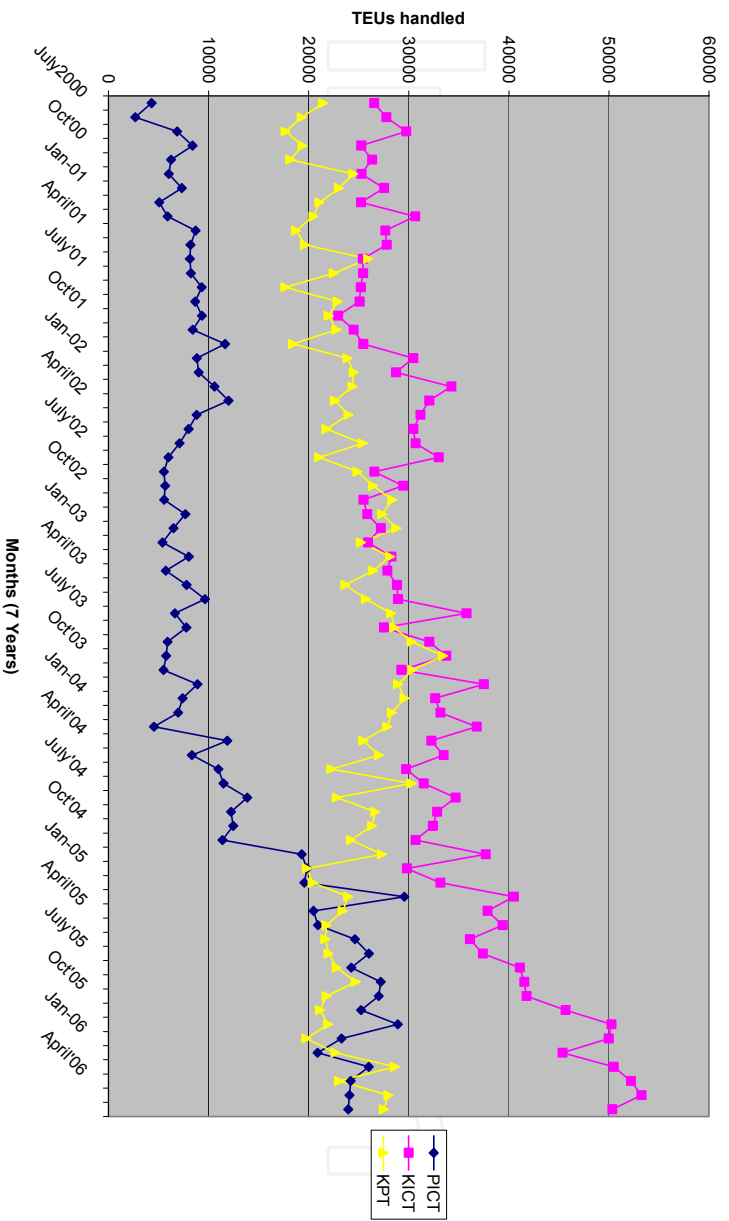


Figure 4. Total TEUs handled at three terminals in the Karachi Port

- KPT ²: this is a conventional terminal with priority berthing for geared vessels, mainly feeders. Unlike KICT and PICT, this terminal does not have modern equipment like gantry cranes to handle containers. Regular container service started at this terminal in 1973.

The total number of ships and total TEUs (Twenty Foot Equivalent Units) handled at the three terminals of Karachi port, for the period July 2000 to June 2006, are shown in the Figures 3 and 4.

2.2. Port Muhammad Bin Qasim

In the past half century of Pakistan's existence, its seaborne cargo handling has increased tremendously; hence the need for another port was felt. This need became a necessity when the Pakistan Steel Mill project was conceived in the 1970s.

Construction of port Qasim, the second sea port of Pakistan, was started in the mid 1970s and completed and opened to shipping in 1990; it has been in operation since then.

Cargo handled at Port Muhammad Bin Qasim, since the commencement its operations, is shown in the Figure 5³:

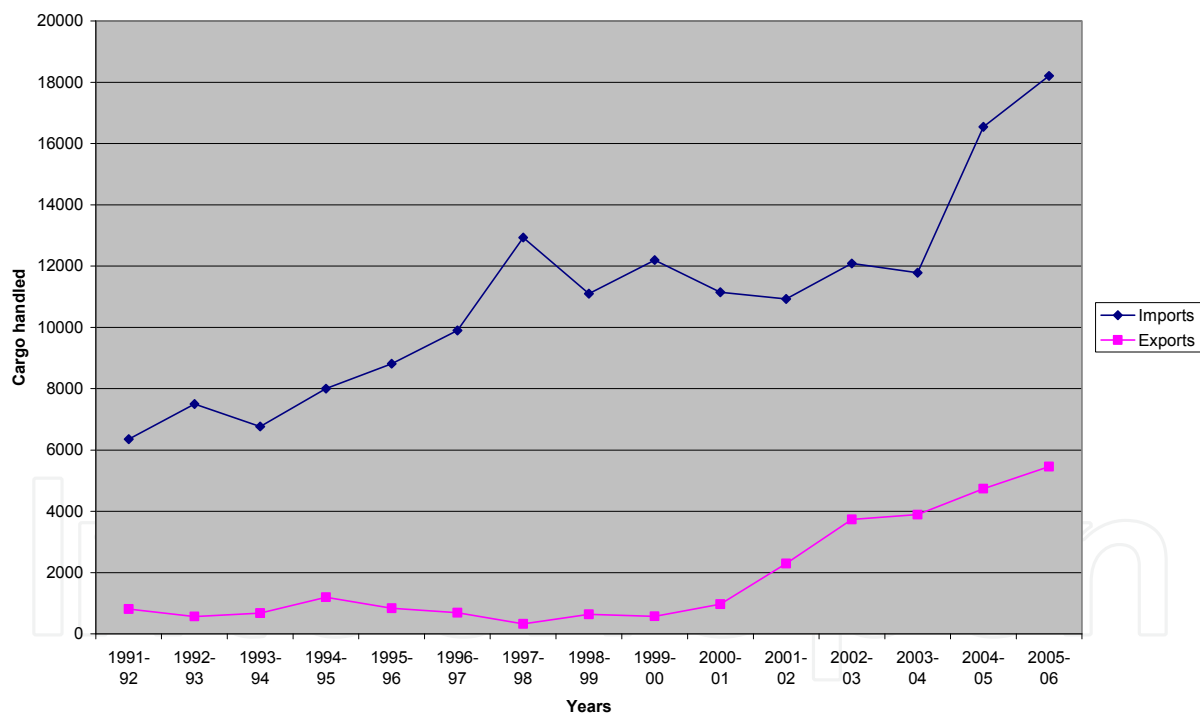


Figure 5. Yearly cargo handling at Port Qasim since 1991

² This public terminal does not have any specific name like KICT or PICT. In the official records of Karachi port authority, it is simply written "Geared Vessels", probably because only geared vessels call at this terminal. For simplicity it is mentioned as KPT in this paper. Moreover, as this terminal is owned by the port authority, both the port and KPT are referred to as KPT.

³ The data used in the graph for Karachi Port was provided by Karachi Port Authority, while the data for Port Qasim is available online at <http://www.statpak.gov.pk/depts/fbs/publications/yearbook2007/transport/20.3.pdf>
<http://www.paksearch.com/Government/STATISTICS/bulletin00/Transport/TC1.html> Accessed 15 July, 2008.

2.2.1. Terminal at Port Muhammad Bin Qasim

Port Muhammad Bin Qasim has only one container terminal known as Qaim International Container Terminal (QICT). It was built at Port Muhammad Bin Qasim on a build-own-operate (BOO) basis. In the case of BOO, parts of the seaport are transferred to the private operators for development. Initially, Maersk invested in QICT, which has now been bought by Dubai port investors. This terminal was incorporated in 1996 and is located approximately 45 km from Karachi.

Figure 6 shows the performance, in terms of handling container lines, of all four terminals of the two ports. Since 2003, QICT has been the biggest terminal in terms of throughput of ships and containers. Although KPT lacks modern equipment it handles a considerable number of ships and containers. The reason is that feeder and geared vessels tend to prefer this terminal due to its low handling charges. Moreover, only KPT has sheds to store goods de-stuffed from containers.

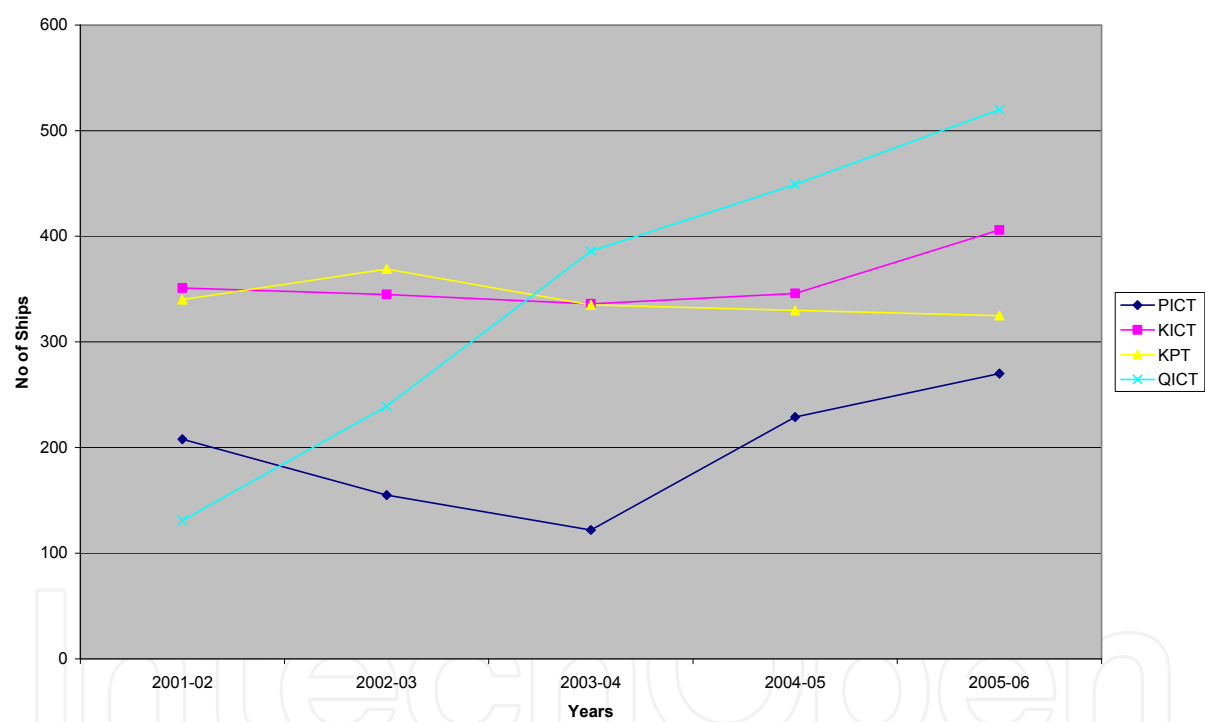


Figure 6. Total traffic handled at two ports in Pakistan

2.3. Cost structure of the two ports

The port of Karachi faces high fixed costs as compared to Port Muhammad Bin Qasim. The reason for this is that Karachi Dock Labor Board (KDLB), which was established to provide regular work and income for dock workers, was previously employed on a casual basis. Up to 2006, there were 3673 dock workers, but the government closed down KDLB in December 2006. KDLB adds significantly to the cost. Firstly, the cargo handling companies are obliged to employ unnecessary KDLB staff and in most cases, pay unnecessary incentive payments.

Secondly, the cargo handling companies have to pay a 'cess' (i.e., a levy) to provide minimum salaries for KDLB staff when they are not 'working' and medical, as well as other, benefits. Moreover, the KDLB impairs competition between the KPT and Port Qasim Authority as the latter does not have a Dock Labor Board.⁴ In short, KDLB has contributed to the increase in the fixed cost of Karachi port as compared to Port Muhammad Bin Qasim.

The costs of container operations at Qasim are lower than they are at Karachi, because they do not have to pay for a dock labor board and they pass only 60 percent of the wharfage charges back to the PQA. These savings reduce costs by about US\$29 per TEU (US\$17 for the dock labor board and US\$12 for the lower wharfage) compared with KPT. On the other hand, QICT has the additional costs of inland transport to/from Karachi and the cities to the north: the weighted average additional land transport cost of using Qasim rather than the KPT is about US\$31 per TEU. The net result is that Qasim suffers from a cost disadvantage of about US\$2 per TEU, which is trivial in relation to total costs and the importance of service quality.

2.4. Performance indicators of the two ports

Pakistan's ports now rate quite highly on the two most important performance indicators: handling speeds are generally up to international standards and tariffs are only slightly higher by international standards.

2.4.1. Handling speeds

The ship–shore handling speeds for containers at Karachi is 25 moves per crane/berth hour, while at Port Qasim it is 22–24 moves per crane/berth hour. However, at the conventional terminal at Karachi port, productivity is lower at about 17 moves per crane hour. But it has the advantage over private terminals in terms of services, which are reported to be about US\$30 per TEU less expensive than those at the KICT and QICT.

2.4.2. Tariffs

Total container handling charges at Port Karachi's specialized terminals are rather on the high side by international standards. They are estimated at US\$113 per twenty foot (not mentioned for individual terminals). There are two main reasons for the relatively high charges. Firstly, the shipping lines impose several additional charges including, in some cases, a shipping surcharge whose justification is now no longer clear. Secondly, a 'terminal handling charges' (THC) is effectively charged twice: (i) by the shipping line and (ii) by the container terminal. If the THC were charged only once, the cost would be around US\$88 per TEU, which is more in line with international charges, including those in Indian ports. Handling charges for Port Qasim are US\$105.

⁴ See <http://www.brecorder.com/index.php?id=483970&currPageNo=1&query=&search=&term=&supDate> Accessed 20 April, 2007.

Port entry charges are high at both Karachi and Qasim. The combined KPT charges on ships for port entry, tugs, pilotage and berth hire amount to about US\$0.82 per GRT (gross registered tons). This would be equivalent to US\$26 per TEU on the assumption of a 35,000 GRT ship handling 1000 TEU. Although these charges are well above international benchmarks, they are not significantly higher than at the main Indian ports. However, they are over five times higher than those at the dominant container transshipment ports of the region of Colombo, Dubai and Shalala. The KPT is aware that their charges are high and has reduced the average port entry cost from over US\$1 per GRT to US\$0.82 in the last year.

The PQA's port entry charges are slightly lower than those of the KPT. The combined charges on ships for port entry, tugs, pilotage and berth hire at PQA amount to about US\$0.72 per GRT. These tariffs contribute to large financial surpluses for the KPT and the PQA. They deter lines from calling with large ships, as these are the main reason for the Pakistan Port surcharge. The PQA reduced port charges by 15 percent in May 2005.

2.5. Ports' finances

Both ports make excessive profits. The KPT's budget revenues of US\$140 million for 2004–05 are more than twice as high as their budgeted costs. A surplus at this level is unusual in the port industry, as is the very high level of income from investments (43 percent). The PQA also makes a large profit, with operating revenue of US\$32.1 million compared with operating costs of US\$21.2 million in the fiscal year 2003. This shows that about 40 percent of the net surplus comes from income from investment, property and storage while about 60 percent comes from operations⁵.

2.5.1. Revenue from private container terminals to port authorities

According to the agreement with KPT, KICT pays \$6.03 per move to KPT, while PICT pays \$12.54 per move⁶. Similarly, according to the lease agreement (30-year renewable lease) in 1994, QICT pays a flat rent of Rs 48 million per annum, a wharfage of Rs 400 per TEU, a 5 per cent royalty of the load on/load off revenue on cargo exceeding 150,000 TEUs to PQA per annum⁷.

The average market share (in terms of TEUs handled) for all terminals, calculated for the years 2001–2006⁸, and handling charges, obtained with the help of questionnaire⁹ are given in Table 2-1.

⁵ See Transport Competitiveness in Pakistan: Analytical Underpinning for National Trade Corridor Improvement Program, 2006. *World Bank report available online at* http://www-wds.worldbank.org/external/default/WDSPContentServer/WDSP/IB/2006/08/14/000160016_20060814091138/Rendered/PDF/36523.pdf Accessed 25 April, 2008.

⁶ Source of information is personal interview with authority at Karachi Port Trust.

⁷ See <http://www.pakistaneconomist.com/database2/cover/c98-21.asp> Accessed 25 April, 2008.

⁸ Data about TEUs handled by all three terminals at Karachi port was obtained from port authority. While data for QICT is collected from official website of terminal www.qict.net Accessed 20 April, 2007.

	<i>QICT</i>	<i>KICT</i>	<i>PICT</i>	<i>KPT</i>
Market Share	31%	32%	13%	23%
Handling Charges	76\$	94\$	69\$	54\$

Table 1. Market share & handling charges

3. Game theory, the model

3.1. Game theory

Game theory was created by Von Neumann and Morgenstern in their classic book *The Theory of Games and Economic Behavior*, published in 1944. Game theory provides a framework for the study of the interactions of decision-makers whose interests are related, though distinctly different, and whose actions jointly determine all outcomes. There are several different ways of characterizing a game, generally not equivalent to one another; however, they all have certain elements in common. The common elements are the set of decision-makers, called *players*, the rules and regulations concerning the possible decisions that each decision maker can choose, sometimes called the *set of strategies*, and rules and regulations governing the way that the players' decisions are related to the reward or payoffs they receive [5].

According to [6], the theory of games can be divided into two distinct approaches: the *strategic* or *noncooperative* approach and *coalitional* or *cooperative* approach. In noncooperative game theory players treat each others as competitors and each individual's payoff is affected by the strategies chosen by the other players. When choosing a strategy, a player therefore picks one that yields his most preferred outcome given the strategies chosen by the others. This behaviour implies rationality. Nash equilibrium is the result of rational play: each player's strategy is an optimal response to what he believes the other players will do, and the belief is correct, while cooperative game theory is concerned with those situations in which players can negotiate before the game is played about what to do in the game. Moreover, it is assumed that these negotiations can be concluded by the signing of a *binding* agreement. Under these conditions, the precise strategies available in the game will not matter very much. What matters is the *preference* structure of the game, since it is this that determines what contracts are feasible [7].

In Oligopoly models, one side of the market typically consists of either price or quantity setters, with price takers on the other side. With homogenous products, the Cournot model is most often chosen to describe market interaction, and with differentiated products, the Bertrand model is usually applied. For each of these static, simultaneous-decision models of oligopoly, there is a sequential-decision counterpart. These sequential-decision models are the progeny of von Stackelberg's strategic analysis of quantity setting [8]. Stackelberg models rely on leadership by one of the rivals. Originally, von Stackelberg extended the

⁹ Questionnaires filled by shipping agents working for foreign principals at Karachi city of Pakistan [See 14] . We have not been able to verify that the average charge reported in the questionnaires corresponds to the actual average charge per container for the respective terminals.

Cournot model to include leadership behavior [9]. That is, the Stackelberg leader's output choice influences the output choices of its rivals, and the Stackelberg leader chooses output in full recognition of its followers' reactions. Von Stackelberg's insight can readily be adapted to the Bertrand pricing model [8]. In this paper, our focus is on Bertrand price model application to a service industry that consists of four container terminals.

3.2. Related literature

Research related to the application of game theory to ports is very limited. [10] developed a game-theoretic best response framework for understanding how competing ports will respond to development at a focus port, and whether the focus port will be able to capture or defend market share by building additional capacity. They applied this model to the investment and competition currently occurring between the ports of Busan and Shanghai. Unlike the analyses on which port expansion plans are typically based, the authors explicitly account for the incentives and opportunities for fellow competitors to respond to investments (or the threat thereof) or to defend or appropriate market share through a game-theoretic response framework. However, the authors did not apply a two-stage Bertrand competition model. They instead, in order to develop a game-based analysis of Busan and Shanghai port development policies, abstracted from the pricing game, focusing instead on strategy in the development game given the observed or projected prices.

[11] applies the Hotelling location model to inter-port competition. They use this model to develop a framework for linking the strategic interdependence between ports' and potential terminal providers' investment desirability. Moreover, considering the importance of the role of the users' cost in selection of a port, the authors explicitly include it in the model in order to examine how changes in the users' cost affect potential operators' decisions. However, the users' cost consists here of port dues charged by the port authority and the service fee of the service providers.

[12] considers both the quantity of competition and price of competition between ports and examines the interaction between hinterland access conditions and port competition. Competition between ports is treated as competition between alternate intermodal transportation chains, while the hinterland access conditions are represented by both the corridor facilities and the inland roads. When ports compete in quantities, an increase in corridor capacity will increase the port's own output, reduce the rival port's output and increase the port's own profit. On the other hand, an increase in inland road capacity may or may not increase the port's own output and profit, owing to various offsetting effects. Finally, inland road pricing may or may not increase the port's own output and profit.

[13] analyses the interaction between the pricing behaviour of the ports and optimal investment policies in port and hinterland capacity. They use the framework of a two-stage game in capacities and prices. The main focus here is on a governance structure where capacity decisions are public, but pricing decisions are private. The game is analysed by backwards induction. The authors obtained the following results. First, profit-maximizing ports internalise hinterland congestion in so far as it affects their customers. Second,

investment in port capacity reduces prices and congestion at both ports, but increases hinterland congestion in the region where the port investment is made. Investment in a port's hinterland is likely to lead to more port congestion and higher prices for port use, and to less congestion and a lower price at the competing port. Third, the induced increase in hinterland congestion strongly reduces the direct benefits of extra port activities. Finally, imposing congestion tolls on the hinterland road network raises both port and hinterland capacity investments.

[14] applies a two-stage game that involves three container terminals located in Karachi Port in Pakistan. In the first stage, the three terminals have to decide on whether to act as a singleton or to enter into a coalition with one or both of the other terminals. The decision at this stage should presumably be based on the predicted outcome for the second stage. The second stage is here modelled as a Bertrand game with one outside competitor, the coalition and the terminal in Karachi Port (if any) that has not joined the coalition. Furthermore, three partial and one grand coalition among the three terminals at Karachi Port are investigated. The concepts of "characteristic function" and "core" are used to analyse the stability of these coalitions. And results revealed that one combination does not satisfy the superadditivity property of the characteristic function and can therefore be ruled out. The resulting payoffs (profits) of these coalitions are analysed on the basis of "core". The best payoff for all players is in the case of a "grand coalition". However, the real winner is the outsider (the terminal at the second port) which earns a better payoff without joining the coalition, and hence will play the role of the "orthogonal free-rider".

[15] analyses the effect of the type of concession contracts on port user surplus and on profits of terminal operators (or port authorities) with the help of game theory. Authors have selected three ports in Pakistan to perform this analysis. These ports function as 'landlords' and have signed concession contracts with private container terminal operators. However, the features of the contracts at present are different for each terminal. Four cases are discussed in this article. The first case is the present situation in which authors treat competition between terminals as a Bertrand game in which each terminal non-cooperatively determines charges for container handling and pays fees to port authorities according to the contract. Furthermore, in the second and third cases, a cost benefit analysis is conducted by solving the Bertrand model. The results reveal that in the long run it is profitable for the Karachi Port to establish a same fixed fee contract with its private terminals. However, users are better off in a situation where a percentage fee concession contract would be adopted instead.

[16] introduces a game theory model to study the scale of container terminals in combination with the market size in order to examine how they affect terminal competition. The starting point is the landlord port management system with long-term concessions agreements shaping the formal relationships between the port authority (who owns the land) and the private terminal operators (who use the land for terminal activities). The model was applied to Karachi and Qasim ports in Pakistan. Results show that the perspectives of port authorities and terminal operators on the balance between economies of scale and intra-port competition are different. Port authorities have a preference for a

number of small terminals inside their ports in view of stimulating intra-port competition. Terminal operators prefer to operate in ports with the smallest number of large terminals (one terminal if possible - monopoly setting).

3.3. The model

3.3.1. *The demand for container terminal services*

The present model treats the competition among terminals as a Bertrand game and also uses the outcome of the Bertrand game to investigate the payoff (profit) for the concerned entities. The Bertrand game is a natural choice in this setting. In the container terminal industry, competitors offer similar but, from the perspective of individual customers, not quite homogeneous services. To detail the structure of the Bertrand game, the demand function of each service provider must be made explicit.

The term “terminal users” is applied to the agents who pay the cost of container freight and handling, and make the choice of which terminal to use. Different ports and terminals can rarely be considered as perfect substitutes from a user perspective. In addition to the terminals’ charges for handling and storing containers, the user will have additional costs, or other user costs (OUC). The components of OUC include the following:

- Inland transport (such as rail and truck) costs for transporting containers to and from terminals within Pakistan.
- Freight rates charged by container lines, in particular any surcharges related to port and terminal efficiency.
- Costs related to transport time, including the cost of container lease or rental. Container lease cost is included in this component because, with the increase in transport time, the lease period will also increase, which will result in increased costs.

The difference between the first and third components is that, in the first case, cost refers to what users pay for inland transportation of containers, while in the third case, cost refers to the costs they have to bear because of the time spent in transporting containers.

Even if terminal charges are equal, differences in OUC may lead to different market shares for competing terminals. On the other hand, differences in OUC may result in persistent differences in terminal charges and market shares even in a competitive setting. The present model assumes that OUC is composed of two components, one that is independent of the volume of containers handled by each terminal, and one that is an increasing function of the volume handled (and decreasing in rated capacity). The rationale for a variable component of OUC is two-fold:

1. The spatial aspect: Marginal customers will, on average, have longer transport distances and higher transport costs to the terminal than the average customer.
2. When the volume of containers approaches or exceeds the rated capacity, different types of delays are likely to increase. Some delays may affect the ship turnaround time and subsequently the freight rates due to congestion surcharges by shipping lines, while other types of delays may affect the dwell time of containers in port.

A counteracting force may be that the level of service for vessel calls will improve with the volume of containers handled. For surface and air transport, this aspect is generally referred to as the Mohring effect [17]. [18] uses the throughput share of the port to capture the Mohring effect. However, in this case with constant capacity, it can be expected that both 1 and 2 will have a stronger negative impact on OUC than the positive Mohring effect. In general, the user cost function for terminal “ i ,” OUC (i), has the following form:

$$OUC(i) = C0_i + f\left(\frac{X_i}{CAP_i}\right) \quad (1)$$

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.

In the numerical implementation of the Bertrand model, the market share of each terminal is determined by an aggregate multinomial logit model, and the demand for all terminals combined is a function of the logsum from the logit model.

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.

The utility functions of terminals are given as follows:

$$U_i = a_i + b \{ p_i + OUC_i \} \quad (2)$$

Where U_i is the “utility” of terminal i $i = KICT, PICT, KPT, \text{ and } QICT$

p_i is price charged per unit by terminal i $i = KICT, PICT, KPT, \text{ and } QICT$

OUC_i = other user cost at each terminal i $i = KICT, PICT, KPT, \text{ and } QICT$

b is the co-efficient of price charged by terminals and a_i is the alternative specific constant for terminal i ;

a_{PICT} and $a_{KPT} = 0$, while a_{KICT} and $a_{QICT} > 0$.

The alternative specific constant is included in the utility functions for KICT and QICT, to capture the attributes that enable these terminals to obtain high market shares compared to their competitors. As is apparent from Table 1, the average market share of these two terminals is high compared to PICT and KPT.

As KPT is owned by Port Authority, the port and KPT are treated as one economic entity in the model, and no distinction is made between handling charges and fees. What matters for KPT is the combined revenue from fees paid by the private terminals, and profits from their own terminal’s operation.

The market share of terminal “ i ” is given by the following logit expression:

$$Q_i = \frac{e^{U_i}}{\sum_j e^{U_j}} \quad i = KICT, PICT, KPT \text{ and } QICT \quad (3)$$

The logsum is defined by

$$LS = \ln(\sum_j e^{U_j}) \quad (4)$$

Total aggregate demand (in TEUs) for all the players is thus given by

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

where A and θ are constants and $0 < \theta < 1$,

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

$$X_i = X \cdot Q_i \quad i = KICT, PICT, KPT, \text{ and } QICT \quad (6)$$

Therefore, the demand faced by a terminal will depend on handling charges (including unit fee) and OUC for all terminals. The private terminals will keep the handling charge, but the revenue from fees is transferred to the Port Authority. Individual demand is elastic because 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.

3.3.2. Revenue/profit for terminals

The operating surplus of the terminal “i” is the following:

$$\Pi_i = (p_i - w_i - c_i) \cdot X_i \quad (7)$$

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 unit fee is a percentage of the handling charge, the surplus is alternatively given by

$$\Pi_i = (p_i \cdot (1 - \delta_i) - c_i) \cdot X_i \quad (8)$$

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

The profit for KPT (including Port Authority) is taken as

$$\Pi_3 = (p_3 - c_3)X_3 + w_1X_1 + w_2X_2 \quad (9)$$

where 1= KICT, 2= PICT and 3= KPT.

For any contract between the Port Authority and a private terminal operator that will be viable in the long run there must be;

$$\Pi_i = (p_i - w_i - c_i) \cdot X_i \geq \text{annual rent}(i) \quad (10)$$

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 model to get numerical solutions because it never becomes binding in this model.

Insofar as w_i (or δ_i) will influence the outcome of a game between competing terminals, that is, the total revenue ($p_i \cdot X_i$), a contract that specifies the magnitudes of δ_i and annual rent constitute an important strategic decision for a Port Authority that attempts to maximize total revenue.

In a competitive situation with few players and an inhomogeneous 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 modeled as Bertrand equilibrium [1].

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 zero. Therefore, in order to find the best reply for player i , it is necessary to differentiate its profit function with respect to p_i and set the derivative equal to zero. The Bertrand Nash equilibrium is characterized by the first-order conditions:

$$\frac{\partial \Pi_i}{\partial p_i} = 0, \quad i = KICT, PICT, KPT \text{ and } QICT \quad (11)$$

The profit function, say, for terminal 1 is given by:

$$\Pi_1 = (p_1 - c_1) \cdot X_1 \quad (12)$$

since

$$X_1 = Ae^{\theta_{LS}} Q_1 \quad (13)$$

By substituting the value of X_1 in equation (12) one gets

$$\Pi_1 = (p_1 - c_1) \cdot Ae^{\theta_{LS}} Q_1 \quad (14)$$

$$\Pi_1 = p_1 \cdot Ae^{\theta_{LS}} Q_1 - c_1 \cdot Ae^{\theta_{LS}} Q_1 \quad (15)$$

By taking the derivative of equation (15) and setting it equal to zero, we get

$$\frac{\partial \Pi_1}{\partial p_1} = Ae^{\theta_{LS}} Q_1 + p_1 \frac{\partial (Ae^{\theta_{LS}} Q_1)}{\partial p_1} - c_1 \frac{\partial (Ae^{\theta_{LS}} Q_1)}{\partial p_1} = 0 \quad (16)$$

$$\frac{\partial \Pi_1}{\partial p_1} = Ae^{\theta LS} Q_1 + (p_1 - c_1) \frac{\partial (Ae^{\theta LS} Q_1)}{\partial p_1} = 0 \quad (17)$$

By taking the log of the equation (13) we get

$$\ln(X_1) = \ln(A) + \theta LS + U_1 - LS \quad (18)$$

$$\frac{\partial \ln(X_1)}{\partial p_1} = \frac{\partial X_1}{\partial p_1} \cdot \frac{1}{X_1} \quad (19)$$

or

$$\frac{\partial X_1}{\partial p_1} = \frac{\partial \ln(X_1)}{\partial p_1} \cdot X_1 \quad (20)$$

By taking the derivative of equation (18) with respect to P_1 we get:

$$\frac{\partial \ln(X_1)}{\partial p_1} = \frac{\theta}{\sum_j e^{U_j}} \cdot \frac{\partial (\sum_j e^{U_j})}{\partial p_1} + \frac{\partial U_1}{\partial p_1} - \frac{1}{\sum_j e^{U_j}} \frac{\partial (\sum_j e^{U_j})}{\partial p_1} \quad (21)$$

$$= \frac{\theta}{\sum_j e^{U_j}} \cdot e^{U_1}(b) + b - \frac{1}{\sum_j e^{U_j}} \cdot e^{U_1}(b) \quad (22)$$

$$= \theta b \frac{e^{U_1}}{\sum_j e^{U_j}} + b - \frac{e^{U_1}}{\sum_j e^{U_j}} \cdot b \quad (23)$$

since $Q_1 = \frac{e^{U_1}}{\sum_j e^{U_j}}$

By substituting the value of Q_1 in above equation we get:

$$\frac{\partial \ln(X_1)}{\partial p_1} = \theta b Q_1 + b - b Q_1 \quad (24)$$

$$= b(\theta Q_1 + 1 - Q_1) \quad (25)$$

By substituting equations (13) and (25) in equation (20) we get:

$$\frac{\partial X_1}{\partial p_1} = Ae^{\theta LS} Q_1 [b(\theta Q_1 + 1 - Q_1)] \quad (26)$$

By substituting equation (26) into equation (17) we get:

$$\frac{\partial \Pi_1}{\partial p_1} = Ae^{\theta LS} Q_1 + (p_1 - c_1) [b(\theta Q_1 + 1 - Q_1)] Ae^{\theta LS} Q_1 = 0 \quad (27)$$

$$Ae^{\theta LS} Q_1 + (p_1 - c_1) [b(\theta Q_1 + 1 - Q_1)] Ae^{\theta LS} Q_1 = 0 \quad (28)$$

$$Ae^{\theta LS} Q_1 \{1 + (p_1 - c_1) [b(\theta Q_1 + 1 - Q_1)]\} = 0 \quad (29)$$

By solving the above equation for p_1 we get:

$$p_1 = c_1 - \frac{1}{b(\theta Q_1 + 1 - Q_1)} \quad (30)$$

This is the implicit reaction curve (pricing rule) for player 1 (i.e. KICT). The reaction function cannot be given on a closed form in this model. The prices of the other players enter via Q_1 , as can be seen in (2) and (3). Similarly, reaction curves for the other three terminals can be derived. Solving these reaction functions yields the Nash equilibrium in prices.

3.3.3. Cooperative Game with external competitors

In the case of cooperative game, three terminals within Karachi port can establish different combinations of coalition. In this case, the profit function for each terminal will be different from equation (10). For instance, if all the terminals at Karachi port decided to work under one decision unit, then the profit function of the coalition, for instance, for KICT will be as follows:

$$\Pi_1 = [X_1(p_1 - c_1) + X_2(p_2 - c_2) + X_3(p_3 - c_3)] \quad (31)$$

This will give 3 conditions, one for each price.

Again Bertrand Nash equilibrium is characterized by the first-order conditions, thus by taking the derivative of equation (31) and setting it equal to zero we get the condition:

$$\begin{aligned} \frac{\partial \Pi_1}{\partial p_1} = & \frac{\partial(Ae^{\theta LS} Q_1)}{\partial p_1} (p_1 - c_1) + Ae^{\theta LS} Q_1 + \frac{\partial(Ae^{\theta LS} Q_2)}{\partial p_1} (p_2 - c_2) \\ & + \frac{\partial(Ae^{\theta LS} Q_3)}{\partial p_1} (p_3 - c_3) = 0 \end{aligned} \quad (32)$$

From Equation (26) we have:

$$\frac{\partial(Ae^{\theta LS} Q_1)}{\partial p_1} = Ae^{\theta LS} Q_1 [b(\theta Q_1 + 1 - Q_1)]$$

The third (and fourth) term is the cross derivatives.

$$\frac{\partial(Ae^{\theta LS}Q_2)}{\partial p_1}(p_2 - c_2) = Ae^{\theta LS}Q_2[b(\theta Q_1 - Q_1)](p_2 - c_2)$$

This should give us:

$$\frac{\partial \Pi_1}{\partial p_1} = Ae^{\theta LS}Q_1[b(\theta Q_1 + 1 - Q_1)](p_1 - c_1) + Ae^{\theta LS}Q_1 + Ae^{\theta LS}Q_2[b(\theta Q_1 - Q_1)](p_2 - c_2) + Ae^{\theta LS}Q_3[b(\theta Q_1 - Q_1)](p_3 - c_3) = 0$$

Now:

$Ae^{\theta LS}Q_1$ Cancels out, leaving

$$[b(\theta Q_1 + 1 - Q_1)](p_1 - c_1) + 1 + Q_2[b(\theta - 1)](p_2 - c_2) + Q_3[b(\theta - 1)](p_3 - c_3) = 0 \quad (33)$$

This is the reaction curve for KICT when all 3 terminals have formed a coalition within Karachi Port. Similarly, reaction curves for other two terminals can be derived. Moreover, in this case we have not considered the fee paid by private terminals to Karachi port in the profit function because this is a matter of internal transfers within the coalition. Similarly in other combinations of coalition, fee of that terminal will not be included in the profit function which will become the partner with KPT.

3.3.4. Assumptions about the parameters of the model

3.3.4.1. Assumed value for b

b is the coefficient of price at ports or cost for customers (shipping lines). In other words, this is the coefficient of price of the choices faced by decision makers. There is only one research, by [19] in which this value has been estimated, by discrete choice methodology, taking any port as a case study. [19], estimated a logit model for container terminal selection by shipping companies on a dataset for the 4 terminals treated here and obtained a statistically significant parameter of -0.0624 for the container handling charge (in US\$). Therefore, based on this value we assume that the value for price parameter, in our model, is -0.050.

3.3.4.2. Assumed value for a

In general terms, Equation (2) can be written as by dividing utility into two additive parts. For instance, for two alternatives, A and B, the utilities can be written as follows:

$$U_{An} = V_{An} + \varepsilon_{An} \quad \text{and} \quad U_{Bn} = V_{Bn} + \varepsilon_{Bn} \quad \text{where} \quad n = 1, \dots, N. \quad (34)$$

where N is the number of decision makers (or users); V_{An} and V_{Bn} are the systematic (or representative) components of the utility of A and B; and ε_{An} & ε_{Bn} are the random parts and are called the disturbance (or random components). a is the alternative-specific constant

and reflects the mean of $\varepsilon_{Bn} - \varepsilon_{An}$; that is, the difference between the utilities of alternatives A and B when “all else is equal”. The values of alternative specific constant for QICT, KICT and Gwadar terminal are arbitrary chosen.

3.3.4.3. Assumed value for cost

The basis of all port tariffs should be short-run marginal cost, which measures the resources used up by supplying a unit of port service. However, strictly setting a price equal to the marginal cost is best only in a perfectly competitive free economy or in an efficient socialist economy [20].

For the marginal costs of terminals, the average cost of PICT for 2005 is calculated. Figures are obtained from the annual report of the terminal¹⁰. The terminal’s operating cost is Rs 695,915,000 divided by total containers handled in 2005, i.e. 206,764 TEUs, which gives an average cost of US\$ 57. On the basis of this figure, the marginal costs for the three private terminals are assumed.

3.3.4.4. Assumed value for θ

Demand for port calls, port trans-shipment and supplementary service is derived from demand for the goods involved and is thus a function of economic growth, industrial production and industrial trade [21]. Thus, a change in price and other attributes of one terminal will shift the traffic to that terminal from other terminals. It will not much affect the total demand, but will affect the market share of all four terminals. That is why the value for θ is quite low.

3.3.4.5. Input Parameters

Tables 2 and 3 provide information about the input parameters used in the model. The values of the log sum parameter and price parameter are assumed on the basis of the literature review. The values of user cost constants are also assumed; a high value is set for KPT because this is a conventional terminal and does not have modern equipment like gantry cranes to handle containers. Moreover, the user cost for QICT is set at US\$ 7 because it suffers from a cost disadvantage of about US\$ 2 per TEU as compared to KICT and PICT. The values for marginal costs for private terminals are explained in previous section. However, the values for marginal cost for KPT and Gwadar Port are assumed and arbitrary chosen. Data about capacity is collected from the official website of each terminal.¹¹

After completion of the **Makran Coastal Highway**, Gwadar Port will be connected to Karachi; however, it is still located far from the industrial area, which is why the user cost is set at \$ 9. Moreover, although the terms of a 40 year concession agreement between **Gwadar Port Authority and PSA Gwadar Ltd.**, are not publicly available, on the basis of available information, for instance, provision of 40 years tax holiday from the government of Pakistan, we will assume that it pays 3% as a royalty for cargo exceeding 200,000 TEUs.

¹⁰ Available online at <http://www.pictctrack.com/docs/annualreport.pdf>. Accessed 25 April, 2008.

¹¹ See www.qict.net, <http://www.kpt.gov.pk/>, <http://www.kictl.com/>, <http://www.pictctrack.com/>. Accessed 20 April, 2007.

KPT charges Rs 445 per square meter from KICT. The total area for KICT is 218,300 square meters. Thus, the annual rent is: $218,300 \times 445 = \text{Rs } 97,000,000$ or \$ 1616 in thousands. Similarly, KPT charges Rs 473 per square meter from PICT. The total area for PICT is 210,000 square meters. Thus, the annual rent is: $210,000 \times 473 = \text{Rs } 99,000,000$ or \$ 1659 in thousands. QICT pays a flat rent of Rs 48,000,000, or \$ 800 in thousands, per annum to Port Qasim authority.

<i>Level of Demand (A)</i>	<i>Logsum parameter (θ)</i>	<i>Price parameter (λ)</i>
1550,000	0.010	-0.050

Table 2. General parameters of demand

	<i>QICT</i>	<i>KICT</i>	<i>PICT</i>	<i>KPT</i>	<i>Gwadar</i>
Alt.spec. constant (α_i)	0.1	0.5	0	0	0.3
User cost constants in \$ ($C0_i$)	7	5	5	40	9
Marginal cost in \$ (c_i)	50	55	55	27	48
Capacity (CAP_i)	600,000	525000	400,000	300,000	675,000
Terminal fee ¹² in \$ (w_i, δ_i)	5%of price	6.03	12.54		3% of price
Annual rent (In 000 US\$)	800	1616	1650		

Table 3. Terminal specific parameters

The chosen form of the user cost function is shown below:

$$OUC(i) = C0_i + 0.5 \left(\frac{X_i}{CAP_i * 0.8} \right)^4 \quad (35)$$

This function implies that the user cost starts to rise sharply when throughput exceeds 80% of rated capacity.

With these parameters, the Bertrand equilibrium is defined by the system of non-linear equations that can be solved numerically by an equation solver to give equilibrium rates for container handling and the market shares.

4. Bertrand solution

With the available information, a model consisting of equations 1, 2, 3, 12, 30, 33 (for each terminal) and 5 is solved using an equation solver. In other words by solving the equilibrium of the Bertrand game we can get the pricing rule set by the players, which will yield the Nash equilibrium.

¹² Source of information for unit fee and annual rent is personal interview with authority at Karachi port and for port Qasim see <http://www.pakistaneconomist.com/database2/cover/c98-21.asp> Accessed 25 April 2008.

4.1. Independent terminals with fee (present situation)

In this case, we take the present contracts between port authorities and private terminals as fixed and assume that each terminal sets the handling fee so as to maximize operating surplus. Each terminal operator has full information and knows the reaction of the other operators to its own actions.

Results obtained for the present situation, which is when private terminals are paying fees to the port authorities are depicted in Tables 4 and 5. If we compare market shares presented in Table 4, with actual market share (See Table 1), we found that they are close to the actual figures.

	<i>QICT</i>	<i>KICT</i>	<i>PICT</i>	<i>KPT</i>
Equilibrium Price US\$/TEU	81.60	90.10	91.90	53.20
User Cost US\$/TEU	7.40	5.80	5.30	41.40
Market share	0.30	0.31	0.18	0.21
Profit (In Mill US\$)	12.4	13.8	6.6	14.3 ¹³

Table 4. Bertrand equilibrium ($\lambda=-0.05$)

<i>Total Demand in 1000s TEUs</i>	1502
<i>Combined profit Karachi Port (Terminal 2-4) In Mill US\$</i>	34.7

Table 5. Total demand for two ports & combined profit for the Karachi port

In order to analyse the effect of fees on the overall profit of the port of Karachi, we assume that port authorities do not charge fees from private terminals. Results presented in Tables 6 and 7 show that this results in low prices for all players and consequently low profit for QICT and KPT. This is similar to what has been described in international trade: the suggestion that government intervention can raise national welfare by shifting oligopoly rents from foreign to domestic firms. The crucial point is that the home firm can increase its profits by persuading foreign firm to charge a *higher* price than the Nash equilibrium. To do this, it must commit to a higher price than would be optimal. To achieve this, government must impose an export tax [22]. Similarly, in this situation, ‘fee’ charged by port authorities, plays the same role as played by ‘government tax’ in international trade.

	<i>QICT</i>	<i>KICT</i>	<i>PICT</i>	<i>KPT</i>
Equilibrium Price US\$/TEU	77.60	84.20	80.90	51.20
User Cost US\$/TEU	7.30	5.90	5.70	40.70
Market share	0.28	0.32	0.23	0.18
Profit (In Mill US\$)	11.5	13.9	9.0	6.4

Table 6. Bertrand equilibrium without fee

¹³ Including fees paid by KICT and PICT

<i>Total Demand in 1000s TEUs</i>	1506
<i>Combined profit Karachi Port (Terminal 2-4) In Mill US\$</i>	29.3

Table 7. Total demand for two ports & combined profit for the Karachi port

4.2. Independent terminals with fees and less elastic price

A crucial assumption in the numerical model is the price parameter in the logit model. In order to test for the sensitivity of this assumption, we change the value of this parameter from -0.05 to -0.03 . Tables 8 and 9, show the results with less price sensitive demand.

	<i>QICT</i>	<i>KICT</i>	<i>PICT</i>	<i>KPT</i>
Equilibrium Price US\$/TEU	99.40	109.50	109.00	70.40
User Cost US\$/TEU	7.30	5.90	5.40	41.60
Market share	0.28	0.32	0.20	0.21
Profit (In Mill US\$)	18.6	23.3	12.4	20.6

Table 8. Bertrand equilibrium ($\lambda=-0.03$)

<i>Total Demand In 1000s TEUs</i>	1522
<i>Combined profit Karachi Port (Terminal 2-4) In Mill US\$</i>	56.4

Table 9. Total demand for two ports & combined profit for the Karachi port

Not unexpectedly, it turns out that less sensitive demand results in higher handling charges and higher profits for the terminals, but moderate changes in market shares. However, less price sensitive demand, in general, will outweigh the higher handling charges, which increase the value of the logsum and leads to higher total demand.

4.3. Rent/fee trade-off

As can be seen from Table 2, the fee per TEU paid by PICT to Karachi port authority is about twice the fee paid by KICT. The reason for this is not clear, but it probably reflects the fact that the PICT contract has more recently been negotiated. In the long run – when contracts have to be renewed – it is reasonable to assume that Karachi port authority will charge the same fee from both private terminals.

Annual rent paid by private terminals to the landlord port has to come out of operating profit. Now profit for the Karachi port will have 3 sources, the profit from KPT as a terminal, the transfer from container handling at KICT and PICT and the annual rent. According to Figure 7, Karachi port can maximize its profit by increasing the fee up to the level \$75. However, it can maximize the combined profit of all terminals by charging the fee up to \$40. So it might actually be profitable to set the fee so as to maximize combined profit and extract some of the profit from KICT and PICT as annual rent. However, the port might still do better by maximizing the combined profit, taking away all competition within the Port of Karachi, i.e. a duopoly.

4.4. Coalition/Duopoly

In this section, a hypothetical situation is created in which all three terminals at Karachi Port have formed a coalition. Hence they work under one single decision unit. The reason for forming a coalition may be two-fold. Firstly, as a coalition, the terminals in Karachi Port will increase their market power and the game is transformed to a game of duopoly. Secondly, by forming a coalition they may increase the combined capacity which will result in reduction in average waiting time. The reason is that before a coalition, there are three queues at three independent terminals (servers), but after formation of a coalition, there will be one queue and three servers. This will cause a decrease in average waiting time for existing customers. Moreover, it will also increase their efficiency and reduce total cost.

Results presented in the Tables 10 and 11 show that this coalition results in high profit for all cooperating units as well as for their competitor.

	<i>QICT</i>	<i>KICT</i>	<i>PICT</i>	<i>KPT</i>
Equilibrium Price US\$/TEU	83.00	102.00	102.00	74.00
User Cost US\$/TEU	8.50	5.30	5.10	40.10
Market share	0.42	0.28	0.17	0.12
Profit (In Mill US\$)	18.1	20	12.2	8.6 ¹⁴

Table 10. Bertrand equilibrium – Duopoly

<i>Total Demand in 1000s TEUs</i>	1495
<i>Combined profit Karachi Port (Terminal 2-4) In Mill US\$</i>	41

Table 11. Total demand for two ports & combined profit for Karachi port

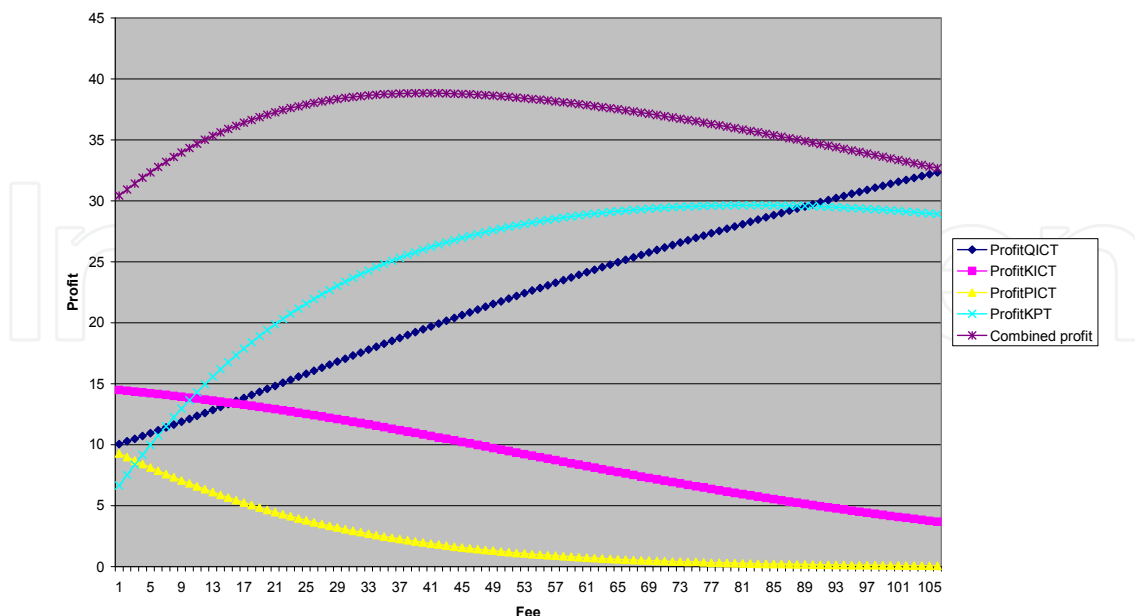


Figure 7. Relation between fee and profit of terminals

¹⁴ Excluding fee from KICT and PICT

4.4.1. Addition of Gwadar port as a player

Gwadar port, due to political conflicts, at present handles very small volume of cargo. However, in the long run when this port will be fully functional, it is expected that due to geo-political importance Gwadar port will tend to capture transit traffic to/from Iran, Afghanistan and China. In addition, Gwadar port will also compete, for Pakistani trade that presently goes through Karachi and Port Qasim.

Thus we have included Gwadar port as a player to analyze how the additional player may influence the formation of coalition or duopoly.

	<i>QICT</i>	<i>KICT</i>	<i>PICT</i>	<i>KPT</i>	<i>GWD</i>
Equilibrium Price US\$/TEU	76.50	90.90	90.90	62.90	77.70
User Cost US\$/TEU	7.30	5.10	5.10	40.10	9.20
Market share	0.27	0.22	0.13	0.09	0.28
Profit (In Mill US\$)	9.2	11.8	7.2	5.1	11.7

Table 12. Bertrand equilibrium - Duopoly

<i>Total Demand in 1000s TEUs</i>	1507
<i>Combined profit Karachi Port (Terminal 2-4) In Mill US\$</i>	24.1

Table 13. Total demand for two ports & combined profit for the Karachi port

In this situation, according to results presented in Tables 5-9 and 5-10, formation of coalition will not benefit that much to the Karachi port as did in first case.

5. Discussion and policy implications

Whether working independently or forming a coalition, which is a feasible proposition for terminals operating in the same port, is a question addressed in this analysis. We presented the Bertrand solution of the present situation prevailing at two ports, as well as two hypothetical situations. Market shares and handling fees in the present case, obtained by the Bertrand model, are quite close to the actual figures. Hence, they confirm the validity of the proposed model.

A comparison of the first and second case shows that the Nash equilibrium results in high prices for all terminals, when they are charged with fee by port authorities and are working independently. This increase in price is more for PICT and KICT as compared to QICT, because they have to pay a high fee to the port authority. As a result of this, profit of PICT has decreased. Nevertheless overall profits of the Karachi port have increased.

This situation is similar to what has been described in international trade where the suggestion is that government intervention can raise national welfare by shifting oligopoly rents from foreign to domestic firms. The starting point of this debate was several papers by [23, 24], who showed that the government policies can serve the 'strategic' purpose of altering the subsequent incentives of firms, acting as a deterrent to foreign competitors.

Further, [25] have extended the application of strategic trade policy to the Bertrand competition, with firms (home and foreign) taking each others' prices as given.

Each firm's best responses describe a reaction function that is upward sloping. The Nash equilibrium is at the point where two curves intersect. The crucial point is that the home firm can increase its profit by persuading foreign firm to charge a *higher* price than at the Nash equilibrium. To do this, it must commit to a higher price than would be optimal. To achieve this, government must impose an export tax.

A situation similar to the international trade exists in this case. Reaction functions for the two ports are drawn into the price space (see fig. 8). Nash equilibrium is at point N where two curves intersect with each other. Now Karachi can increase its profit only by moving northeast along the Qasim reaction function. This can be achieved when the port authority imposes fees on the private terminals, forcing them as well as their competitor to raise their prices and to earn greater profits.

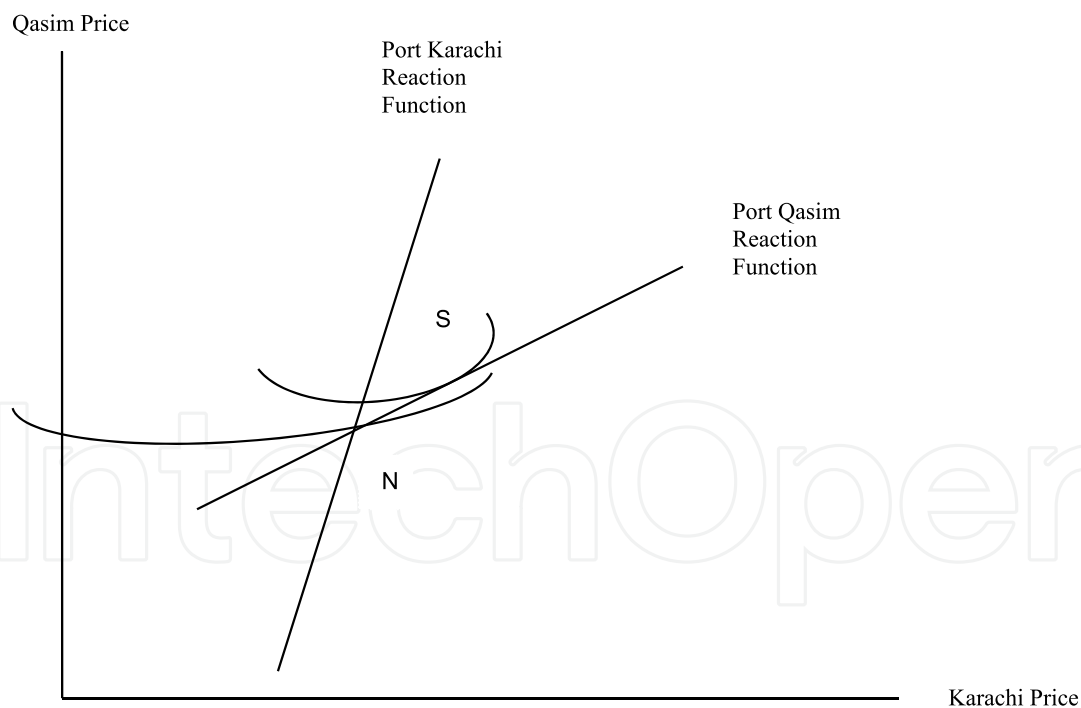


Figure 8. Reaction functions for two ports

We also analyzed the situation with less sensitive price. All the terminals can earn excess profit by charging high prices in this situation even when they are working independently. However, the situation can become more favourable if three terminals at Karachi port work under one single decision unit, creating the situation of duopoly. However, considering revenue only as unit of analysis for port performance is not appropriate. Other factors should also be considered which contribute to the overall efficiency of both ports. For instance, as mentioned earlier as a result of forming a coalition, the combined capacity at Karachi port will be greater as compared to the capacity of individual terminals. This will result in the reduction in the average waiting time of existing customers.

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