PORT PRIVATIZATION, EFFICIENCY AND COMPETITIVENESS: SOME EMPIRICAL EVIDENCE FROM CONTAINER PORTS/TERMINALS

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Summary

It is widely believed that ports form a vital link in the overall trading chain and, consequently, port efficiency is an important factor for a nation to achieve international competitive advantage (Tongzon, 1989; Chin and Tongzon, 1998). In addition, most port authorities think that increasing private sector participation in the ownership and operation of container ports (terminals) can help them improve their operation efficiency. These are the reasons that port privatization becomes one of the most obvious phenomena in current port industry. Therefore, it is indispensable to identify both the relationship between the ownership structure and port efficiency, and the relationship between port efficiency and port competitiveness.

In the first part, the effect of private sector participation in port industry on port efficiency is examined. Although there are many empirical studies focusing on the subject of port performance and efficiency, there is scant literature that has attempted to quantitatively examine the effect of ports' ownership structure on port efficiency. This paper is intended to fill this gap in the current literature by establishing a simultaneous equation model proposed by Battese and Coelli (1995) to measure the port efficiency level and identify the relationship between the ownership structure and port efficiency to show whether the port privatization is a useful strategy for ports to gain a competitive advantage.

The second part identifies the determinants of port competitiveness, including the effect from port efficiency. A linear regression model is applied to examine the effects of the determinants of the port competitiveness. I first use the method based on principal component analysis (Fruchter, 1967) to establish the port competitiveness index and justify the total throughput of the ports/terminals as the proxy for the port competitiveness. Then, I run a regression of the total throughput on the determinants of the port competitiveness to study the effects from the determinants of port competitiveness.

Given the fact that the phase of development, which the trend of port privatization has reached within Asian port sector, is currently unique within the world's port industry (Cullinane and Song, 2001), 50 container terminals located at Asian ports were initially selected to carry out this empirical study. Questionnaires requesting data for the year 1999 on port performance were sent out to these selected terminals. However, due to the limited responses from the above terminals, I extend the sample to some European and American container terminals (Top 50 of world container ports/terminals) to satisfy the requirement both on availability of enough data and on the random characteristic of the selected samples since there is almost no fully privatized container terminal in Asia.

Based on the sample of selected container terminals around the world, the results of this study are able to provide some policy implications for port authorities and port operators that are now considering what extent of private sector participation in port functions is the best for them to achieve port operation efficiency and what factors are most important for them to improve their competitiveness vis-à-vis competitors.

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Chapter One

Introduction

1.1 Background

In recent years, the market environment in which ports operate has changed significantly, especially the development of vertical and horizontal integration in the international maritime transport chain. Shipping companies in particular have taken the initiative in this trend, which results in an increase in the market power of the large shipping companies over the other service providers, such as port authorities. Port authorities have realized that the competitiveness is very important for them to win the business and that the speed of container handling and consequent vessel turn around time is a crucial issue in terms of competition. In addition, many port authorities and port operators think that increasing private sector participation in ownership and operation of container ports (terminals) can help port authorities improve their operation efficiency. Therefore, port privatization becomes one of the most obvious phenomena in the current port industry.

1.2 Objective of the Study

In order to justify the above phenomena and opinion in the existing port industry, it is indispensable to conduct theoretical and empirical research to identify both the relationship between ownership structure and port efficiency, and the relationship between port efficiency and port competitiveness.

Based on different data sources from ports or terminals all over the world, many studies have focused on the subject of port performance and efficiency. Conventionally, port efficiency is estimated using partial indicators of productivity in the port system, for example, studies by Talley (1994), Tongzon (1995), Jara, Cortes, Vargas and Martinez (1997), and Fernandez, De Cea and Fernandez (1999). While all these studies generate useful insights on the performance of ports, they do not yield an assessment on the overall efficiency of port operations. The increasing demand for a method to obtain the general efficiency figure for ports has resulted in the application of more quantitative methods, such as Data Envelopment Analysis (DEA) and Stochastic Frontier Model. Martines, Diaz, Navarro, and Ravelo (1999) and Tongzon (2001) apply different models based on DEA method to study the relative efficiency of Spanish ports and international ports respectively. Another method, Stochastic Frontier Model, is used by Coto, Banos, and Rodriguez (2000) and Estache, Gonzalez and Trujillo (2002) to examine the technical efficiency of ports from Europe and Mexico respectively.

Although all these studies have investigated the overall efficiency of port system, they just compare the efficiency level among ports based on different port ownership structures, instead of having attempted to quantitatively examine the effect of ports' ownership structure on port efficiency. However, port privatization is a worldwide leading trend in port reform taken by almost all port authorities, so it is indispensable to quantify the relationship between ownership structure and port efficiency. This paper is intended to fill this gap in the current literature by establishing a simultaneous equation model proposed by Battese and Coelli (1995) to measure the port efficiency level and identify the relationship between ownership structure and port efficiency to show whether the port privatization is a necessary strategy for ports to gain competitive advantage. It is widely believed that the port efficiency level is one of the most important factors that influence the competitiveness of ports, but it is definitely not the only variable that determines ports' competitiveness. Some variables, such as port charges and service reliability, are also essential for ports to compete with other rivals. For example, PSA Corporation has lost its biggest client, Maersk, due to no discount for port charges. However, there is scant literature that has mentioned the measurement of port competitiveness and quantitatively studied the determinants of ports' competitiveness. Using a method named principal component analysis, this study will establish port competitiveness index and justify the total throughput of a port as a good proxy for the port competitiveness. Then a linear regression model will be used to study the effects of the determinants of port competitiveness, such as port efficiency, port charges and service reliability, on port competitiveness.

1.3 Significance of the Study

The empirical results of this study will be able to provide some policy implications for port authorities and port operators. First, it will tell us whether port privatization has a positive effect on port operation efficiency, and if has, what is the best extent of private sector participation in port functions. Secondly, the results will show the importance of port operation efficiency for port authorities and port operators to obtain competitive advantages. Finally, this study will also identify other significant factors that determine the port competitiveness.

1.4 Organization of the Study

The remainder of this paper is organized as follows. Chapter 2 provides an overview of maritime industry. Chapter 3 gives a detailed review of the existing literature related to port efficiency and port competition. Chapter 4 describes the derivation of the data and develops methodology that will be used in this study. Chapter 5 presents the empirical results of this study. Conclusions are made in Chapter 6.

Chapter Two

Overview of Maritime Industry

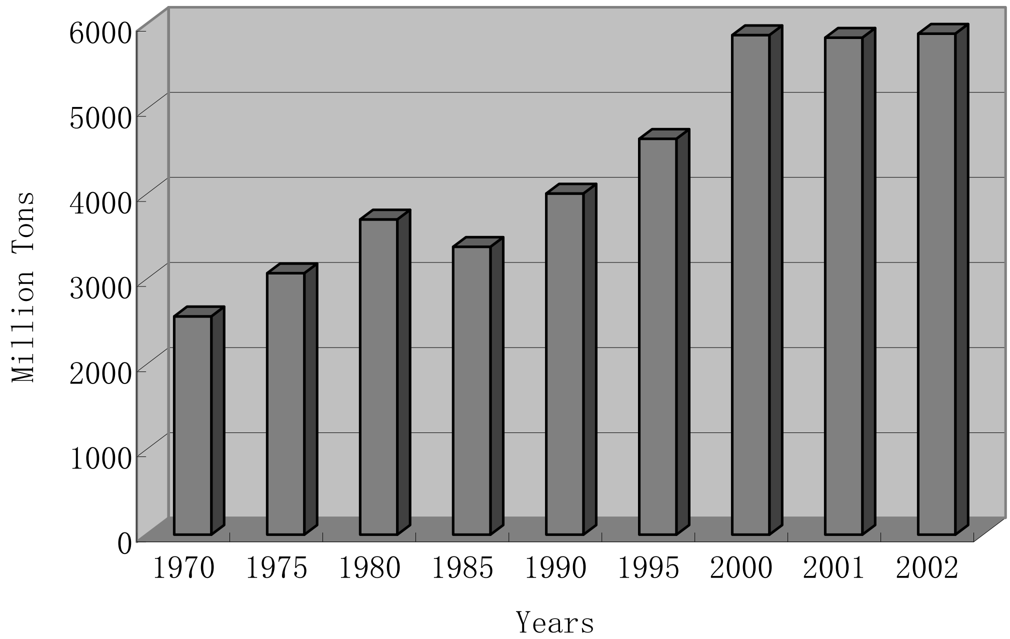
During the past decades, the market environment in which seaports operate has changed dramatically. World seaborne trade increased by almost 40% (UNCTAD, 2003), liner shipping was the one that grew fastest in all shipping sectors, and containerization was definitely the most desirable trend for the development of international trade transportation.

2.1Trends in Seaborne Trade

With the globalization of the world economy, the growth rate of world commodity trade has exceeded that of world output for many years. Since seaborne trade accounts for almost 80% of international trade, it is clear that seaborne trade became one of the great economic success stories in the last three decades, growing from 2.57 billion tons to 5.88 billion tons between 1970 and 2002. In close correlation to the development of world output, global maritime trade expanded at around 3.2 percent per annum between 1990 and 2002. As world economic activity increased from 1.2 percent in 2001 and to 1.9 percent in 2002, seaborne trade followed this pattern by increased from –0.5 percent in 2001 to 0.8 percent in 2002 (UNCTAD, 2003).

Figure 2.1

International Seaborne Trade for Selected Years



Sources: Review of Maritime Transport (various issues).

Although this trend looks simple, there was a significant variance between the growth levels recorded by the main commodity and shipping modes. Bulk trade grew on average at rate of 5.2% per year, with seaborne liquid bulk trade rising by an average of just 3.3% and dry bulk trade by 9.5%. Liner trade, however, rose annually at an average rate of 11.1%. While non-containerized general cargo volumes growing by only 0.8% annually, containerized cargo, clearly the most dynamic sector of global seaborne trade over the period, registered an average growth of 24.8% (UNCTAD, 2003). In 1980, the cargo shipped by containers is just about 3% of international seaborne trade by weight. But after container transport grows rapidly, the balance of

1.6 billion tons of dry cargoes is increasingly being carried in containers along the liner trade routes and the share by weight is 27.2% in 2002 (UNCTAD, 2003). Thus, containerization is a major and increasingly important sector of not only maritime activity, but also of world trade and the entire global industrial structure (Peters, 2001).

2.2 Developments in Container Shipping

Container lines have gone through several organizational phases in order to seek for profitability. At the beginning of containerization it was the consortia concept which dominated the industrial structure either with or without joint marketing, before there was a swing towards independent operations in the 1980s as lines looked to assume sole control of operations, sales, asset ownership, and in many cases pricing (Peters, 2001). At the end of 1980s, it is widely accepted that huge investment needed in this industry to keep the pace with the increase in cargo flows denies the possibility of this approach.

Nowadays the globalization of manufacturing drives carriers towards both vertical and horizontal integration. On the one hand, integration and outsourcing generate new opportunity for the participants in the transport chain, especially shipping lines who have viewed themselves as major actors in the logistics business. Many shipping firms (e.g. Maersk/Sealand, APL, NYK) have extended their transaction from container shipping to value-added services such as local transport, customs clearance and supply chain management services to be adaptable to the emergence of the door-to-door philosophy. In order to become the main logistical partner of the manufacturer, shipping lines have also expanded their scope to include terminal operations in terms of dedicated terminal and liner owned agency.

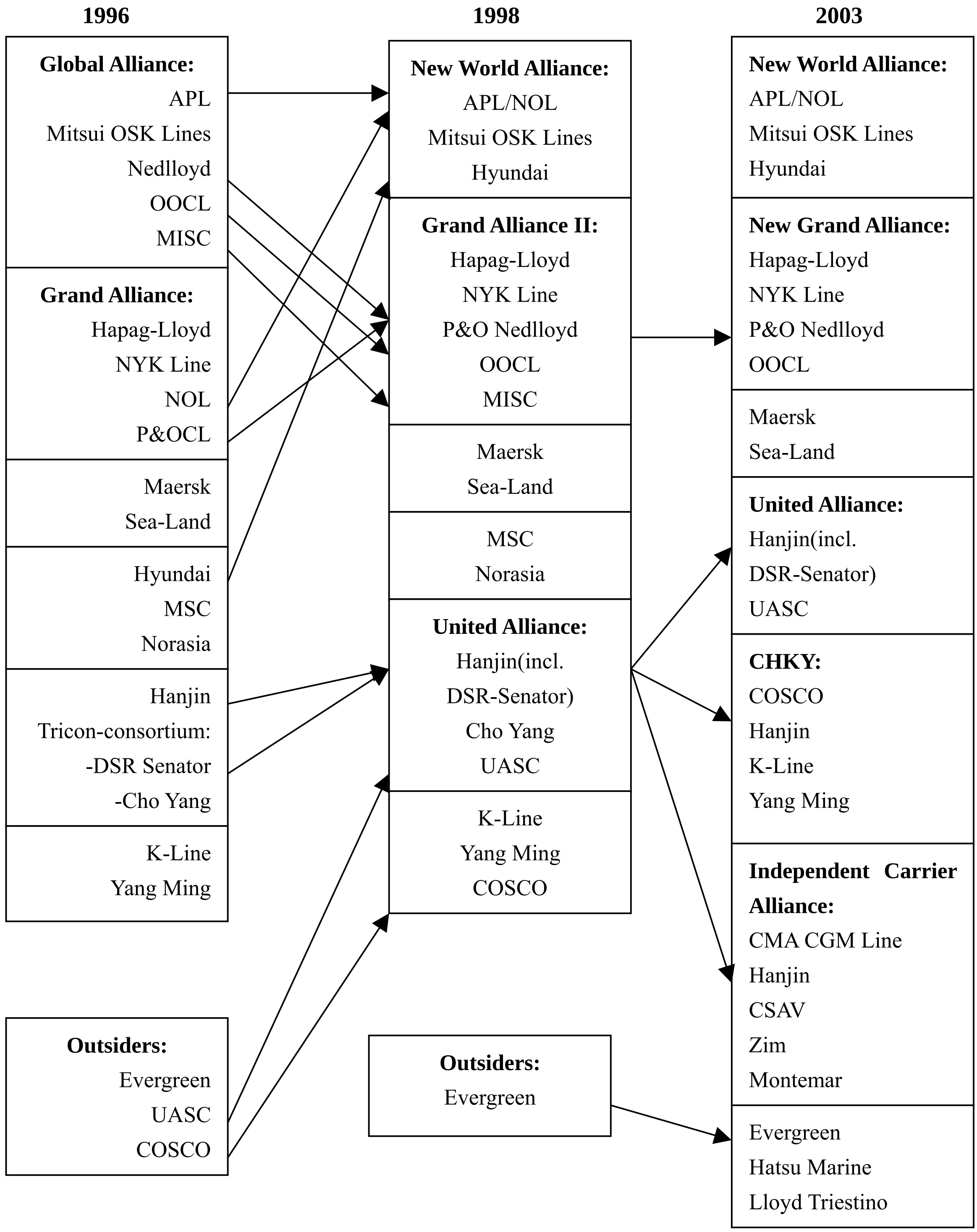
On the other hand, since it becomes apparent that the freight rate is unlikely to increase considerably in future due to certain amount of overcapacity produced by shipping companies, cost reduction is considered as the main measure to achieve a higher margin than that of competitors. Almost all carriers believe that an increase in the scale of operation is a useful way to cope with their public enemy, operational cost. Thus, the formation of strategic alliances and equity partnerships becomes one of the most significant developments in the container shipping industry over the last decades. For example, most of the top 20 carriers are involved in multi-trade strategic alliances (e.g. New World Alliance of APL/NOL, MOL and Hyundai; United Alliance of Hanjin and UASC; Grand Alliance of Hapag-Lloyd, NYK, P&O Nedlloyd, OOCL and MISC, see Figure 2.2), and mergers and take-over in liner shipping are well documented (e.g. P&O Nedlloyd in 1977 and Maersk SeaLand in 1999). This tendency offers the prospect of cooperation among shipping companies on everything, even including marketing and administration when acquisition happened. The main benefit they have obtained from these strategies is the increased usage of ship capacity through sharing ship capacity mutually, which will explicitly help shipping companies to achieve cost savings in the end. Therefore, carriers view shipping liner alliance as one of the most effective strategies in dealing with a business environment that is characterized by serious pricing pressure. These strategic alliances have resulted in a concentration of power on the demand side of port services, and finally transfer the serious competition from liner services to port authorities and port operators.

2.3 Reform of Port Authorities

2.3.1 Seaports

Seaports are areas where there are facilities for berthing or anchoring ships and where there is the equipment for the transfer of goods from ship to shore or ship to ship. A port mainly has civil engineering features, administrative functions and operational functions. Within a port area, there are usually several terminals. Terminals focus more on operational functions while a port also has other features and functions as mentioned above. The performance of operational functions is the most important criterion for shipping lines to select the port because operation efficiency decides the turn around time of a ship at the port. Since port operation is largely concerned with the physical transfer of goods between sea and land, the physical inputs in the port operation process, such as terminal quay length, terminal surface, and number of quay cranes, determine the efficiency level of port operations. For example, the terminal quay length decides the type of ships that this terminal can handle. The larger the ship is, the more efficient the handling equipments will be used. Similarly, the terminal surface determines the space for cargo transfer and storage, and insufficiency of terminal areas will cause the congestion problem. Obviously, the quay crane is the key handling equipment used to transfer the container from ship to shore or vice versa.

Figure 2.2: Major Liner Alliances and Co-operation Agreements



Source: 1996 & 1998 – Notteboom and Winkelman (1998)
2003 – http://www.joc.com/gta/steamship_all.shtml

2.3.2 Port Reform

The successive changes occurring in international transport market in the last 20 years, from a segmented modal approach towards a much more integrated transport concept tailored to better meet the pressing needs of customer industries, are resulting in increasing pressure on ports to adapt their role and function to this more demanding operational environment (Juhel, 2001). It is obvious that the increased horizontal and vertical integration in the shipping industry entitles carriers a stronger bargaining power vis-à-vis port authorities and port operators. At the same time, institutions with abundant experience in container terminal management are intended to enlarge their roles in logistics service by taking over terminals in different ports all over the world to construct their own port service network (see Table 2.1). These and related trends in market environment in which international transport operates cause the port authorities and port operators into devising various ports' reform strategies.

Table 2.1: Top Five Global Container Terminal Investors/Operators (million teu/% share of world container port throughput , 2002)

Terminal Operator	Million TEUs	% Market Share
Hutchison Port Holdings (HPH)	36.7	13.3
PSA Corporation	26.2	9.5
APM Terminals	17.2	6.2
P & O Port	12.8	4.6
Eurogate	9.5	3.5

Source: The Annual Review of Global Container Terminal Operators (2003) by Drewry Shipping Consultants Ltd.

A key claim made with respect to organizational reforms is that the transformation of ownership from public to private sector will improve cost efficiency as well as general welfare (Yarrow, 1986; Vickers and Yarrow, 1991). Since it is believed that the participation of private ownership, even with no change in competitive situation, will sharpen managerial incentives and replace defective bureaucratic monitoring hierarchies (Liu, 1995), the role of the private sector has expended dramatically in many important economic sectors over recent decades. Ports have not been immune from this tendency, and port privatization is deemed by many port authorities as the most helpful way to increase operation efficiency which, in turn, will assist them to gain competitive dominance.

Although port authorities have benefited from some extent of privatization, such as leasing of port assets, concession, management contract and joint venture, the evidence suggests that the full privatization of ports will be counter-productive due to the particular nature of port investment. United Kingdom is the only country that has advocated and indeed practiced such a laissez-fair policy that involves the outright sale of port land, combined with a transfer of utility and regulatory function to the private sector (Baird, 2000). However, the main problem of this full privatization is that the private investor has no more funds to finance the purchase of new facilities and equipments after paying for all the port’s properties. Consequently, there is not obvious case that efficiency level of privatized port is much higher than that of public port in UK since significant improvement on operation infrastructure has not happened yet even after port privatization. Most forms of privatization, with exception of the outright sale method adopted in the UK, have the potential to bring about positive outcomes with respect to port investment, port competition, port planning and control, and port organization. For example, PSA, a public port authority under the Government of Singapore, was transformed to an independent and private entity in 1997. Meanwhile, a new statutory board, MPA, was established to manage and administrate PSA Corporation through the regulation of essential port and marine services and facilities. In Korea, the government body, Ministry of Maritime Affairs and Fisheries leases the terminals to the Korea Container Terminal Authority (KCTA) without payment. The KCTA then introduces private terminal operators to manage and operate these terminals. As to the port privatization in China, we can find that Chinese government prefers to use the form of joint venture to introduce the private sector in the terminal operations, such as Shanghai Container Terminals Limited (SCT) and Yantian International Container Terminal.

Comparing the results from port privatization in the UK and the above Asian countries, it shows that full port privatization will impede the improvement on port performance while some extent of private sector participation can increase the efficiency level, which implies that the extent of private sector intervention in port sector has an inverted U-shaped effect on port operation efficiency.

2.4 Summary

In recent years, the market environment, in which the port authorities operate, is well-marked by the development of vertical and horizontal integration in the international maritime transport chain. Shipping companies in particular have been taking the initiative in this trend, which results in an increase in the market power of the large shipping companies over the other service provider, such as port authorities. However, as expected, the port authorities are responding to the changing environment after they realized the risk of losing their major clients, large shipping companies. Most port authorities believe that the introduction of private sector participation in port operation and management will help them improve their performance and gain the competitive advantages. This is the main reason that port privatization becomes the most obvious phenomena in the existing port industry.

Chapter Three

Literature Review on Port Efficiency Studies

3.1 Introduction

In recent years, the conception of efficiency and performance in production has been widely used in published empirical research papers, which focus on a broad variety of industries, including the port industry. Before reviewing the existing literature related to port efficiency measurement, it is necessary to provide a brief introduction to modern efficiency measurement.

The most commonly used efficiency measures, proposed by Farrell (1957) upon the work of Debreu (1951) and Koopmans (1951), are technical efficiency, allocative efficiency and economic efficiency. Technical efficiency can be defined as that which reflects the ability of a firm to obtain maximal output from a given set of inputs. Allocative efficiency is concerned with the ability of a firm to make use of the inputs in optimal proportions, given their respective prices and the production technology. Integrating these two measures will provide a measure of total economic efficiency.

Methodologically, there are four principal methods for measuring the above different kinds of efficiencies, namely, least-squares econometric production models, total factor productivity (TFP) indices, data envelopment analysis (DEA), and stochastic frontiers. The above four methods can be categorized according to at least two criteria. First, a distinction can be made between whether they recognize inefficiency or not. The first two methods are always chosen for time-series data and offer measures of technical change and/or TFP. Both of these two techniques implicitly assume that all firms are fully efficient. The latter two methods, on the other hand, are usually applied to data on a sample of firms (at one point in time) and provide measures of relative efficiency among those firms. Hence these latter two methods do not assume that all firms are fully efficient. However, multilateral TFP indices can also be used to compare the relative productivity of a group of firms at one point in time. Also DEA and stochastic frontiers can be used to measure both technical change and efficiency change, if panel data available (Battese, Coelli and Prasada, 1998). The second classification is to note that the first and last methods involve the econometric estimation of parametric functions, while the second and third methods do not postulate a particular functional boundary.

Since efficiency ratings are a powerful management tool for port authorities and port operators, efficiency measurement is also introduced to port performance and competition studies. As to the methods that have been employed to address the subject of port performance, traditionally studies on port efficiency measurement attempt to adopt a multitude of indicators to measure partial productivity or partial out/input ratios such as TEU/crane, ship calls/berth, etc. Although partial productivity measures are helpful for valuing certain aspects of port performance, they do not allow to asset the general efficiency of port production. Thus, DEA and stochastic frontiers, which can be used to measure overall productive efficiency, are widely applied in later port performance research. These three major methods and related literature that have paid more attention to port industry will be discussed in the following section.

3.2 Review of the Literature

The subject of port efficiency has been investigated in many empirical studies that have applied a broad range of methods. Almost all these approaches used to measure efficiency of seaports can be classified into two main groups. The first focuses on partial indicators of productivity in the port system. The second introduces more quantitative methods, such as DEA and Stochastic Frontier Models, to measure the overall efficiency of the seaports.

3.2.1 Partial Indicators Method

The first group of literature estimates the port's efficiency by using a multitude of partial indicators. Many port authorities publish their annual reports by adopting this approach. The more academic research applying this method to focus on inter-port comparison was first suggested by Talley (1994) and Tongzon (1995). They both made use of comparable indicators to measure and compare the efficiency level of selected ports with similar characteristics. Heaver (1995) and the Australian Productivity Commission (1998) carry out further research to study how inter-port competition can be accelerated through comparison of a set of productive indicators among ports.

Although partial productivity measurement is useful for evaluating certain aspects of ports efficiency, their main shortcoming is their partial view which does not yield an analytically consistent approach to the joint contribution of the various inputs to overall efficiency (Estache, Gonzalez and Trujillo, 2002). For example, although a container terminal can be very efficient in terms of the container handling rate (TEU/Hour), this does not consequentially mean that this container terminal utilizes all inputs efficiently in general to produce output. It is possible that other factors are used inefficiently, which will definitely degrade the overall efficiency level of this container terminal.

The increasing demand for a method to obtain the general efficiency figure for ports has resulted in the application of more quantitative methods, such as Data Envelopment Analysis (DEA) and Stochastic Frontier Model. The preferences of the methods adopted in port performance research are evenly distributed between Data Envelopment Analysis and Stochastic Frontier Model. The literature applying these two techniques to investigate port efficiency will be reviewed in the next two subsections.

3.2.2 Data Envelopment Analysis Method

Data Envelopment Analysis (DEA) involves the use of linear programming methods to construct a non-parametric frontier over the data. Efficiency levels are then calculated relative to this frontier. The conception of this method was advocated by Farrell (1957), but only a few scholars paid attention to this paper in the following two decades. Mathematical programming methods, suggested by Boles (1966) and Afriat (1972) to achieve the task, did not receive much attention until the term data envelopment analysis (DEA) initially appeared in the paper by Charnes, Cooper and Rhodes (1978).

The application of Data Envelopment Analysis (DEA) in port industry to measure port efficiency and performance was first proposed by Roll and Hayuth (1993). They think that seaports are complex service organizations and there is a long list of outputs and inputs characterizing the operations of ports. Due to this complexity of factors affecting port efficiency, it is difficult to determine the efficiency and the extent to which a port's resources are fully exploited in achieving the goals.

DEA is considered as one of the most suitable tools for measuring port efficiency by Roll and Hayuth (1993) who think that DEA has some advantages compared with traditional approaches. For example, it enables coinstantaneous analysis of multiple outputs and multiple inputs and enables the inclusion of environmental and other qualitative factors, which are highly important to evaluate performance; it can recognize the possibility of different but equally efficient combinations of outputs and inputs (in different proportions); and it does not require an explicit a priori determination of relationships between outputs and inputs, or the setting of rigid importance weights for the various factors.

In order to demonstrate the applicability of the DEA technique in port industry, they construct a hypothetical numerical example data with four outputs and three inputs where the performances of 20 ports are compared. They show that DEA is a promising and easily adaptable method for obtaining the relative efficiency ratings of port and it is possible for a series of secondary research to provide a deeper insight into port performance and point out potentials for improvement.

Martines, Diaz, Navarro, and Ravelo (1999) and Tongzon (2001) build on the work of Roll and Hayuth (1993) through applying the DEA approach to actual performance data from selected ports. Martines et al. (1999) study the relative efficiency of the 26 Spanish Port Authorities during the period of 1993-1997, 5 actual observations for each port, which permits the comparison among the ports in each group as well as the evolution of both each group and every port over time. In order to reach conclusive results from the application of the DEA approach, they divide all the ports into three homogeneous categories in accordance with a complexity criterion given by port size and the composition of the output vectors. Based on the opinion of Jara-Diaz et al. (1996) that port activity exhibits increasing economies of scale given the importance of fixed costs, they choose one of the basic models of Data Envelopment Analysis (DEA) technique, the BCC model (Banker et al., 1984) that takes into account economics of scale.

The results of the above study show that different evolutionary modes in terms of relative efficiency exist among three groups. The ports with greater complexity have higher efficiency level and have gone closer to the frontier during the periods. This is not the same situation to the medium complexity group whose growth rate of the efficiency level during the investigated period was smaller. The worst one is the ports with smaller complexity, which show an even negative evolution direction. In all three groups, the ports that locate on the frontier, or close to it, attribute their relative advantage position to the ceaseless improvement in their input management, given certain level of outputs. Finally, the study of the slack levels shows that the highest inefficiencies are generally due to excess capacity, even if the effect of this aspect is different among three groups.

Another paper by Tongzon (2001) extends the comparisons of port efficiency to an international scope. Since ports form a vital link in the overall trading chain and, consequently port efficiency is an important contributor to a nation's international competitiveness (Tongzon, 1989; Chin and Tongzon, 1998), it is necessary to monitor and compare ports in terms of overall efficiency not only within a nation but also from an international aspect.

Tongzon (2001) applies data envelopment analysis (DEA) to make international comparisons of port efficiency among four Australian and twelve other international container ports. He chooses two outputs and six inputs to characterize the daily port operation activities. The first output used is the total throughput handled per year in terms of TEU and the second output measures the number of containers moved per working hour per ship. On the other hand, the number of berths, cranes and tugs are used as the capital input, the terminal area of ports as the land inputs, and the number of employees as the labor input. In addition, another variable, the amount of delay time, is employed to indicate how well working time is being used.

Since there is no clear-cut evidence on the returns to scale of the port production function, both the CCR model (Charnes, Copper and Rhodes, 1978) and the Additive model (Charnes, 1985), representing constant returns to scale and variable returns to scale respectively, are employed to study the port performance basing on the cross-sectional data from 16 international container ports. Due to the small sample size from data constraints, the results show that there are more efficient ports than inefficient ones. To resolve this problem, only the first output is used in both models. Although there is some difference between the result of the CCR model and that of the Additive model, the main findings show that a port's efficiency level has no clear relationship with its size and its function (hub or feeder) and that the inefficiency is almost due to the underutilization of inputs of container berths, terminal area and labor.

3.2.3 Stochastic Frontier Model

Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) independently propose the stochastic frontier production function, in which an additional random variable characterizing the measurement error is added to the non-negative random variable that represents inefficiency. The Stochastic Frontier Production method employs econometric techniques where efficiency is measured relative to a frontier production function, which is statistically estimated.

Liu (1995) bases on the stochastic production function to calculate technical efficiency and compare the influence of public and private ownership on inter-port efficiency differences. Since he uses a model available for panel data, three different estimation methods, Within, generalized least squares (GLS) and maximum likelihood (ML), can be applied to test the correlation of inefficiency with the independent variables and the distribution assumption. Basing on the observations of output and inputs for 28 ports in the UK, he finds that there is no problem of heteroskedasticity and no correlation between the inefficiency term and independent variables, capital (total turnover) and labor (total wage payment).

In addition, from the regression result of obtained efficiency on the ownership dummies and variables representing other potential efficiency determinants, Liu (1995) fails to identify that the ownership has a significant effect on the port performance. As an alternative, Liu (1995) uses ML again to estimate the stochastic frontier model with the ownership dummy, and then compares ML estimates of deviation of inefficiency with the former one. However, the deviation does not change too much, which means that ownership, as an extra regressor, is not significant in the frontier production function.

Coto, Banos, and Rodriguez (2000) cover the efficiency problem in port industry by using a stochastic frontier cost function to estimate the economic efficiency of Spanish ports through a panel of data of 27 Spanish ports from 1985-1989. A likelihood ratio is applied to compare a Cobb-Douglas function with the translog one, and it is found that the latter better represents the technology according to the data. With the aim of determining whether the fixed effect model or the random effect model is suitable, the Hausman test is used, which can identify any correlation between the fixed effects and exogenous variables. The test result shows that such correlation exists and only the fixed effect model is consistent.

In order to study the effect of port size and the type of management on the efficiency, they run a regression of the indices of economic efficiency on a dummy variable, which takes one if the ports are autonomous, and zero otherwise, and on the number of linear meters of depth over 4m of the quays as an indicator of the size of each port. The result indicates that the size is insignificant when explaining economic efficiency and the ports in the category of autonomous ports is less efficient than the rest.

Notteboom, Coeck and van den Broeck (2000) use the Bayesian Stochastic Frontier Model, developed by van den Broeck, Koop, Osiewalski and Steel (1994), to compare the efficiency level of a set of 36 European container terminals, supplemented with four Asian container ports. First, they use an econometric method to estimate the baseline model without composed error, i.e. all inefficiency levels are zero. Then, they assume that the inefficiency term is a gamma distribution with shape parameter j (j=1, 2, 3; Erlang models) and apply the BSFM software to obtain the posterior regression coefficients. At last, the results of these three models are pooled to averaging out the model uncertainty.

After comparing the efficiency levels among the studied terminals, they find that very large terminals seem to have efficiency levels of at least 0.75 and smaller container terminals situated in large ports attain also relatively high efficiency levels. The analysis also shows that container terminals located in hub ports are on average more efficient than those in feeder ports and that no relationship is found between the type of ownership, operations of a terminal and the efficiency level.

Estache, Gonzalez and Trujillo (2002) illustrate the efficiency effects of the Mexico's 1993 Port Reform by using a panel of data of 44 observations from 11 independent Port Administrations spanning over four years, 1996-1999. Basing on the maximum likelihood method relying on the FRONTIER package, version 4.1, they test two functional forms for a stochastic production frontier function, the Cobb-Douglas and the translog. The dependent variable used is the total volume handled at terminals and the input variables are capital (the length of docks) and labor (the number of workers). From the statistical result, they find that the coefficients for the capital and labor factors for the function forms estimated, Cobb-Douglas and translog, are significant and have the expected signs but other coefficients for the translog are not significant. The efficiency scores based on the statistical results show that the reform of decentralization and privatization taken at Mexico' ports has generated large short-term improvements in the average performance of the port industry.

Cullinane, Song and Gray (2002) employ a port function matrix proposed by Baird (1995, 1997) to analyze the administrative and ownership structures of major container ports from Asia. Both the cross-sectional and panel data versions of the stochastic frontier model are then used to assess the relative efficiency of the above Asian container ports. The main difference in the results of the cross-sectional model and panel data model is the significant improvement in the efficiency level of Kobe in the latter model, which is attributed to the abnormal effect of its earthquake upon the data collected and the results produced by the following studies.

Basing on their appraisal of the obtained efficiency levels of selected ports from the above two models, Cullinane, Song and Gray (2002) think that there does seem to be some support for the opinion that privatization should have some relation with the improvement in productivity efficiency. This empirical study, however, does not provide convincing evidence to show the link between the degree of privatization and the level of port efficiency. Nevertheless, some persuasive inference can be drawn from the analysis that the ports with larger throughput seem to have certain performance advantage over their smaller competitors.

3.3 Summary

Both the application of the DEA method and the application of the Stochastic Frontier method to port efficiency measurement have provided reasonable way to make inter-port comparisons of their performance. However, they both have some advantages over the other. The DEA method can measure port efficiency levels with multiple outputs and inputs while the Stochastic Frontier Model allows only one output. In addition, DEA method does not need an explicit pre-determination of relationships between outputs and inputs. On the other hand, the Stochastic Frontier Model takes into account of the statistical noise, such as measurement error, weather and strike, but DEA method assumes all deviations from the frontier are due to inefficiency. Furthermore, certain statistical tests of hypotheses can be carried out in a stochastic frontier analysis.

Another significant difference between DEA method and Stochastic Frontier Model is that econometric techniques have a strong policy orientation and mathematical programming approaches have a much greater managerial decision-making orientation

(Aigner and Schmidt, 1980; Fare et al., 1994; Lovell, 1995). The policy orientation is more related to the national activities, which focuses on the overview of the whole industry, while managerial decision-making orientation pays more attention to company level issues, e.g. providing relative comparison among the companies. The policy orientation of econometric approaches is more suitable for the study of worldwide port privatization phenomena in this paper, especially since port privatization is a kind of government policy and these approaches have a more solid grounding in economic theory (Forsund et al., 1980; Pitt and Lee, 1981; Bauer, 1990). Another reason to choose the Stochastic Frontier Model is that it incorporates the inefficiency effects in the production function, which will help us directly identify the effect of port privatization on port operation efficiency.

The stochastic frontier model used in this thesis will be discussed in detail in the next chapter. In addition, the following chapter will also cover the method of the port competitiveness measurement and the investigation of port competitiveness determinants since almost no empirical research has been done on this topic.

Chapter Four

Methodology and Data

4.1 Methodology

A stochastic frontier production function proposed by Battese and Coelli (1995) is used to measure the efficiency levels of selected ports and examine the relationship between the port efficiency level and certain qualities of port, such as ownership structure and port size.

Moreover, two different methods are used to study the determinants of port competitiveness. First, principal component analysis is employed to construct the index of the port competitiveness, which will be used to justify the total throughput as the proxy for the port competitiveness. Then, I run a regression of the total throughput on the determinants of the port competitiveness and examine the causal relationship between the determinants and the total throughput.

4.1.1 Stochastic Frontier Model

Since the stochastic frontier production function was independently constructed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), there have been numerous research efforts to extend and apply this model. The basic model for the stochastic frontier production function is as follows:

$$\ln(Y_{it}) = x_{it}\beta + v_{it} - u_{it} \qquad i = 1, 2, \ldots, N, \; t = 1, 2, \ldots, T. \qquad (1)$$

where $\ln(Y_{it})$ denotes the nature logarithm of the output for the i-th firm at time t;

x_{it} is a $(K+1)$-row vector, whose first element is "1" and the remaining elements are the nature logarithms of the K-input quantities used by the i-th firm at time t;

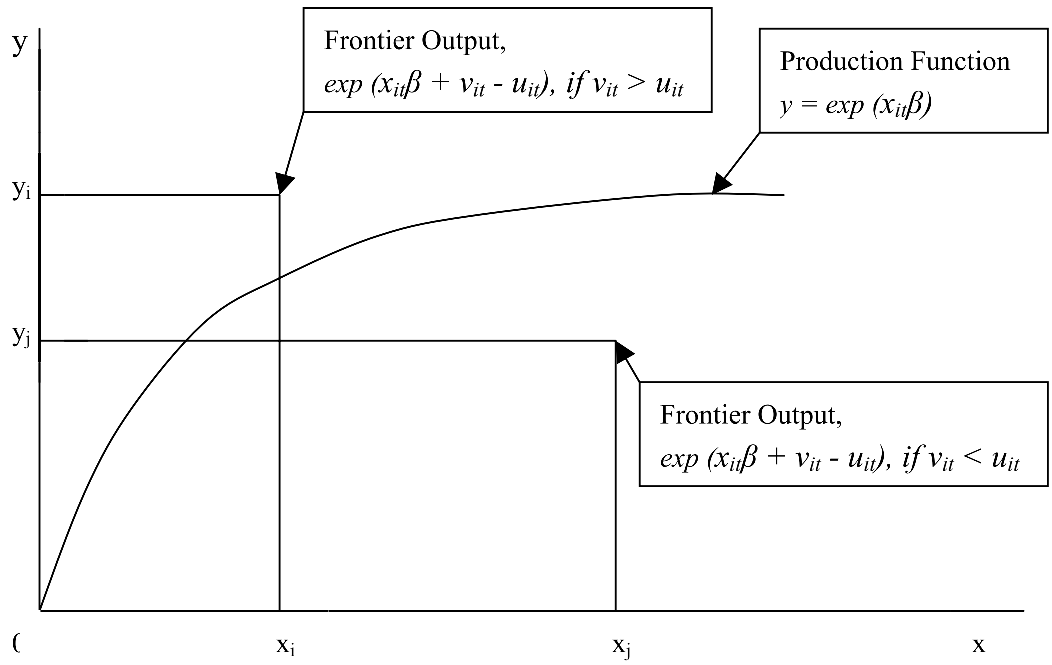
$\beta = (\beta_0, \beta_1, ..., \beta_k)'$ is a $(K+1)$-column vector of unknown parameters to be estimated;

v_{it} represents a symmetric disturbance term accounting for random variation of the production function across firms, such as measurement error and the effects of exogenous shock beyond the control of the economic units (e.g. weather, strike or luck); and

u_{it} is a non-negative random variable, representing the technical inefficiency in production of firms in the industry involved.

The basic features of the stochastic frontier production function are illustrated in two dimensions in Figure 4.1. The inputs are represented on the horizontal axis and the outputs on the vertical axis. The deterministic component of the frontier model, $y = \exp(x\beta)$, is drawn assuming that diminishing returns to scale apply. The observed inputs and outputs for tow firms, *i* and *j*, are presented on the graph. The firm *i* uses the level of inputs, x_i, to produce the output, y_i. The observed output value of firm *i* is indicated by the point marked with the arrow above the value of inputs, x_i. If the corresponding random errors are greater than the corresponding inefficiency effects, the observed outputs may be greater than the deterministic part of the frontier, such as the firm *i* (i.e., $lnY_{it} > x_{it}\beta$ *if* $v_{it} > u_{it}$). Otherwise, the observed output should locate below the deterministic part of the frontier.

Figure 4.1: The Stochastic Frontier Production Function



Initially, the above stochastic frontier model is developed for cross-sectional data. However, this model for cross-sectional data suffers from two difficulties. One is that certain distribution assumption should be made for both inefficiency term and statistical noise term. The other is the required assumption that the input variables and inefficiency term must be independent. Although many empirical studies have shown that the first assumption is not a very strict one for data, Liu (1995) and Cullinane, Song and Gray (2002) argue that the second assumption may well be violated since if a firm knows its level of inefficiency, this should affect its input decision. The model they used in port studies is inefficiency time-invariant stochastic frontier model proposed by Battese and Coelli (1988), which is as follows:

$$\ln(Y_{it}) = x_{it}\beta + v_{it} - u_i \qquad i = 1, 2, \ldots, N, \ t = 1, 2, \ldots, T. \qquad (2)$$

where the crucial difference between model (1) and model (2) is the absence of the subscript *t* of *u* in the latter, and thus *u* captures firm-specific time invariant variables omitted from the production function. After employing the model (2) to obtain the efficiency level, Liu (1995) goes further by regressing efficiency estimates on the ownership dummies to investigate the role of ownership as one of the potential sources of inter-port efficiency differences.

However, the time-invariant efficiency model also involves some difficulty. The assumption that technical efficiency effects are time-invariant is more difficult to justify as T becomes larger. One would expect that managers learn from their previous experience in the production process and their technical inefficiency effects would change in some persistent pattern over time (Battese, Coelli and Prasada, 1998). Furthermore, there is a contradiction between the two stages in Liu (1995). In the first stage, Liu (1995) assumes that u_i is independently and identically distributed as half-normal. But in the second stage, he specifies a regression model for those predicted inefficiency effects, which contradicts the assumption of identically distributed inefficiency effect in the first stage.

In order to solve these problems, a simultaneous estimation method, proposed by Battese and Coelli (1995), will be used in this study. The first equation is the stochastic frontier production function for panel data,

$$Y_{it} = exp\ (x_{it}\beta + v_{it} - u_{it}) \tag{3}$$

where Y_{it} denotes the production at the t-th observation (t=1, 2, …, T) for the i-th firm (i=1, 2, ……, N);

x_{it} is the nature logarithms of input variables;

v_{it}s are assumed to be iid $N\ (0, \sigma_v^2)$ random errors, independently distributed of the u_{it}s;

u_{it}s are non-negative random variables, denoting the technical inefficiency of production, assumed to be independently distributed, and obtained by truncation of the nominal distribution with mean, $z_{it}\delta$, and variance, σ^2;

The second equation is the regression of the inefficiency effect, u_{it}, on the variables that explain this inefficiency,

$$u_{it} = z_{it}\delta + W_{it}, \tag{4}$$

where z_{it} is a $(1xM)$ vector of observable explanatory variables;

δ is an $(Mx1)$ vector of unknown scalar parameters to be estimated (which would generally be expected to include an intercept parameter); and

W_{it} is defined by the truncation of the nominal distribution with zero mean and variance, σ^2, such that the point of truncation is - $z_{it}\delta$. These assumptions are consistent with u_{it} being a non-negative truncation of the N ($z_{it}\delta$, σ^2)-distribution.

Obviously, this model is a simplification, which does not account for possible correlation structures among random errors (the v_{it}s), associated with particular firms or time periods. Nevertheless, certain adjustments can be made to alleviate some difficulties of this model. The cross-sectional data instead of panel data will be employed to this study, which can avoid the serial correlation among random errors. In addition, if we use a pure cross-sectional analysis, we are unlikely to get unbiased estimators since inefficiency term is unlikely to correlate with input choices in the same period, the problem argued by Liu (1995) and Cullinane, Song and Gray (2002).

The method of maximum likelihood is proposed for simultaneous estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects. The likelihood function is expressed in terms of the variance parameters, $\sigma_s^2 = \sigma_v^2 + \sigma^2$ and $\gamma = \sigma^2/\sigma_s^2$. The ratio of the observed output for the *i*-th firm at time *t*, relative to the potential output, defined by the frontier function, given the input vector, x_{it}, is used to define the technical efficiency (TE) of the *i*-th firm at time *t*:

$$TE_{it} = y_{it} / exp\ (x_{it}\beta + v_{it}) = exp\ (x_{it}\beta + v_{it} - u_{it}) / exp\ (x_{it}\beta + v_{it}) = exp\ (-u_{it})$$

$$= exp\ (-z_{it}\delta - W_{it})$$

The technical efficiency of the *i*-th frim involves the technical inefficiency effect, u_{it}, which is unobservable. The best predictor for u_{it} is the conditional expectation, given the value of v_{it} -u_{it}:

$$E\,[exp(u_{it})|(v_{it}-u_{it})] = \{exp[-\mu_{*} + 1/2*\sigma_{*}^{2}]\}\{\varphi[(\mu_{*}/\sigma_{*})-\sigma_{*}]/\varphi(\mu_{*}/\sigma_{*})\},$$

$$where\ \mu_{*} = [\sigma_{v}^{2}\, z_{it}\delta-\sigma^{2}(v_{it}-u_{it})]/(\sigma_{v}^{2}+\sigma^{2})$$

$$\sigma_{*}^{2} = \sigma_{v}^{2}\,\sigma^{2}/(\sigma_{v}^{2}+\sigma^{2})$$

The empirical results based on these methods are shown in chapter 5.

4.1.2 Determinants of Port Competitiveness

In order to study the effects of the determinants of port competitiveness, we should first justify the indicators of port competitiveness. Since the environment in which ports operate has changed dramatically, ports are affected by various new forces driving global competition, including the far reaching unitization of general cargo, the rise of mega-carriers, the market entry of logistics integrators, the creation of network linkages among port operators, the development of inland transport networks etc. (Notteboom and Winkelmans, 2001). In this context, eight key determinants of port competitiveness are proposed based on the existing literature (e.g. Peters, 2001, Tongzon, 1995, Notteboom and Winkelmans, 2001). These determinants include:

1. Port (terminal) operation efficiency level
2. Port cargo handling charges
3. Reliability
4. Port selection preferences of carriers and shippers

5. The depth of the navigation channel
6. Adaptability to the changing market environment
7. Landside accessibility
8. Product differentiation

Port (terminal) operation efficiency level

Since carriers view ships' time at ports as an expensive commodity, the speed of container handling and consequent vessel turnaround time is a crucial issue in terms of competition for port authorities and port operators (Peters, 2001). Thus, substantial productivity improvements are generally required to enable ports to meet the stringent service requirements of their customers and to obtain competitive advantages. Productivity is a measure of the efficiency of port or terminal operations, and accounts for the amount of resources usually required to perform a given task in a given time. Therefore, the level of efficiency can represent how quickly containers are handled and how quickly vessels are turned around at ports. The higher the efficiency level of a port or terminal operations, the more the port users are likely to choose it as their port of call, which, in turn, will make the port take up more market shares.

Port cargo handling charges

The price of goods or services is always an important factor that the consumers will consider when selecting products with similar characteristics. This rationale will also happen, or even more likely, to the services provided by port authorities or port operators since carriers or shippers think that port charges or dues constitute a significant part of their total transportation costs. In addition, carriers are also confronted with severely competitive environment in shipping market and must pursue the ways to reduce the total shipping costs to gain competitive advantages. Nowadays, port charges become a major source for shipping lines to cut down total operation costs. Therefore, they usually prefer the ports that can offer relative lower service charges, which means that a port with lower charges is more competitive than his rivals, holding other factors constant. Since the cargo handling services are most important for port users in terms of total charges, these charges significantly affect a port's competitive position (Trujillo and Nombela, 1999).

Reliability

That price is an important factor for producers to attain more market shares does not mean that price can decide all things. Reliability of port operations also influences a port's performance (Tongzon, 1995), which in turn will affect the choices of shipping lines and shippers. Reliability means a steady and predictable performance adapted to shipping lines schedules. If a port authority or port operator always makes delays during operation process due to strikes, equipment breakdown, weather, etc, shipping companies and shippers will suffer huge loss due to these kinds of unreliability.

Definitely, carriers and shippers will give up this kind of ports even if the producers provide the most attractive price among their competitors.

Port selection preferences of carriers and shippers

Globalization of industry is fast breaking down the traditional practice, whereby shipping companies favor certain ports. Increasingly, carriers and shippers are showing less loyalty to specific ports. Ports face the constant risk of losing important clients, not because of deficiencies in port infrastructure or terminal operations, but because the client has rearranged its service networks or has engaged in new partnerships with other carriers (Notteboom and Winkelmans, 2001). Thus, this variable is not fully correlated with port specific variables, such as efficiency and reliability, so it should be included as an independent port competitiveness indicator.

The depth of the navigation channel

To accommodate trade growth and to offer economies of scale in a highly competitive market, many shipping companies intend to upsize the container ship, from Panamax to Post-Panamax, or even to the Super Post-Panamax. Increasingly large tonnage, especially of vessels deployed in the container shipping market, will have significant effects on port competition. These huge size container ships are always used among loading centers or hub ports, the kind of port that most port authorities want to be to enhance the amount of total throughput. In many cases, however, the insufficient water depths in access channel and port basins prevent some ports from being a transshipment center (Peters, 2001).

Adaptability to the changing market environment

The market environment in which ports operate has changed significantly, and this continuous process of change raises the question about the role of port authorities. A successful port must constantly be prepared to adopt new roles in order to cope with the changing market environment (Notteboom and Winkelmans, 2001). For instance, in order to improve terminal operation performance and to integrate door-to-door transport, many shipping lines want to expand their scope to include terminal operation. If port authorities can not realize the importance of this trend, they will lose certain competitive advantages. That Port of Singapore Authority (PSA) has recently lost its two most important clients is a convincing example. Thus, seaports that will succeed in the 21st century will be those that are "consumer led", who really understand customer needs.

Landside accessibility

Originally, ships loaded and discharged their cargoes in towns or cities where producers and consumers are located. Expansion of land transport systems has altered things somewhat. The days when ships were forced to call at city terminals blocked in on the landside by congested city street are long gone. New remote coastal terminals with good landside connections, and ports strategically located close to the main global trade lanes, increasingly offer carriers and shippers a more appropriate option (Fleming and Baird, 1999). Efficiency of inland transport to serve an increasing, and most often disputed hinterland, has become a critical factor of the ports' potential future, as well as of overall trade growth prospects. Since ports have become a prominent node in integrated logistics chains, quick and safe access to port facilities from an inland transport system becomes a basic requirement for port users to evaluate their port selection options.

Product differentiation

In general, port authorities and port operators can obtain competitive advantages by either cost saving or product differentiation. Cost saving implies that a port tries to achieve competitive advantage by providing the low-cost port services, which has been indicated by the variable of *Cargo Handling Charges*. A differentiation strategy aims at providing specific port services in market niches distinct from those provided by other ports, offering greater value to the port users. This is so-called economies of scope. If a port authority or port operator has some specific competencies that are inimitable and durable, it is easier to achieve competitive advantages than his competitors (Notteboom and Winkelmans, 2001).

As one of the objectives of this study is to examine the effects of the determinants of the port competitiveness, we should now find out one indicator to represent the port competitiveness after identifying the determinants of port competitiveness. Most academicians and professionals consider the total throughput as a good criterion to measure the port competitiveness. Since this characteristic (port competitiveness) is not linked with only one indicator, we attempt to measure the port competitiveness by developing a composite index, named port competitiveness index (PCI), which can be used to justify the assumption that the total throughput is a good proxy for the port competitiveness.

The main limitation of the traditional technique of constructing a composite index from a number of indicators is that usually the subjective and fixed weights are distributed to individual indicators, which actually vary over time and space. To solve this problem, we apply the well-known Principal Component Analysis to obtain the port competitiveness index. Principal component analysis was originated by Pearson (1901) and later developed by Hotelling (1933). The application of principal components is discussed by Rao (1964), Cooley and Lohnes (1971), and Gnanadesikan (1977). Excellent statistical treatments of principal components are found in Kshrisagar (1972), Morrison (1976), and Mardia, Kent, and Bibby (1979).

The essential principle of this method is to compute *k* principal components given a data set with *k* numeric variables. Each principal component is a linear combination of the original variables, with coefficients equal to the eigenvectors of the correlation or covariance matrix. The eigenvectors are customarily taken with unit-norm. The principal components are sorted by descending order of the eigenvalues, which are equal to the variances of the components. Principal component one is used in this study to construct the port competitiveness index since the first principal component is the linear combination of the original variables that explains the largest percentage of the total variance. The equation is as follows:

$$PCI_i = \sum W_k X_{ik} \qquad (5)$$

where PCI_i (Principal Component One) represents port competitiveness index of the i^{th} port, W_k denotes the weights of k^{th} indicator and is chosen automatically by program to form a linear combination of the original variables that explains largest percentage of the total variance, and X_{ik} is unit free value of the k^{th} indicator for the i^{th} port. The port competitiveness for each container port/terminal can be calculated by using the above equation.

Then we can use the above port competitiveness index to justify the total throughput of container ports/terminals as a good proxy for the port competitiveness (shown in Chapter 5) and run a linear regression of the total throughput on the determinants of the port competitiveness:

$$PC_i = f\,(X_{ik};\ \alpha) \qquad (6)$$

where PC_i represents the total throughput of port i. The determinants of port competitiveness are entered in the model as the independent variables. The coefficients on these independent variables represent the effects of determinants on port competitiveness.

4.2 Data

4.2.1 Data for Stochastic Frontier Model

Seaports are complex service organizations and port output can be multi-dimensional depending on the objective that ports want to achieve. There is a long list of outputs characterizing the operations of ports, such as cargo handling, warehousing, and towage. Also, modern ports tend to diversify beyond traditional logistics activities into value-added logistics services, namely repacking, assembly and repair. However, due to the restriction of stochastic frontier model and unavailability of data, we will identify only one output in this study. Since our focus is on the container terminals, the total throughput in terms of TEUs is a good measurement for the output of a container terminal.

To produce the above output and to facilitate port operations, certain kinds of inputs are required. Dowd and Leschine (1990) argued that the productivity of a container port/terminal depends on the efficient use of land, labor and capital. Expert information reveals that the input-factors: the terminal quay length, the terminal surface and the number of quay cranes can be used as relevant variables directly affecting container terminal efficiency (Notteboom et al., 2000). It can be noted that labor is not mentioned as the direct input factor. However, expert information shows that there is a considerably fixed relation between the number of quay cranes and the number of dock workers on a container terminal (Marconsult, 1994). Hence, we use the terminal quay length, the terminal surface and the number of quay cranes as the input factors.

In the technical inefficiency effect model (equation 4), some quality characteristics of container terminals are used to explain the inefficiency differences among the selected units. Ownership structure is the most desired one to be included in this model. Since few ports could be identified with pure private or public ownership structure, this study uses the extent of private sector participation in container ports/terminals rather than 0-1 dummy variable to distinguish different ownership structures. We will refer to a port function matrix proposed by Baird (1995, 1997) to analyze port ownership structure. The port function matrix is used as follows:

Table 4.1

Extent of Private Sector Participation in Port Functions

Function / Extent	Regulator	Landowner	Operator
0/3	Public	Public	Public
1/3	Public	Public	Private
2/3	Public	Private	Private
3/3	Private	Private	Private

Sources: Baird (1995, 1997).

For example, if the private sector has participated in all these three port functions, such as port of Felixstow, the extent of port privatization is 1, indicating a fully private port. As to the PSA Corporation, the private sector has entered the operator function and there is a joint venture between private sector and public sector in the landowner function. In this case, the extent of port privatization is 0.5 (1.5/3). If there is no private sector in any of these three port functions, such as port of Dubai, the extent of port privatization is 0, implying a fully public port.

In addition, to capture the inverted U-shaped effect of ownership structure on port operation efficiency, not only the linear form but also the square form of this index is employed in the technical inefficiency effects model. Another port attribute, the size of port, which is often considered to be related to port efficiency, is also included in technical inefficiency effect model. This variable is defined by using a dummy variable to distinguish whether the total throughput of the observation exceeds one million TEUs or not.

4.2.2 Data for Determinants of Port Competitiveness

Since some determinants of port competitiveness are very difficult to measure directly, we should first find some proxies for them. Average delayed time of ships at port is used as the proxy for the reliability of port services, which is the difference between the actual berth time and the planned berth time, consistent with the method used by Tongzon (1995).

Port selection preferences of carriers and shippers are measured by the total number of direct-call liner services at the ports/terminals. If there are many shipping liners selecting certain port as their call port, implying that the carriers prefer to have their ships called at that port. So this proxy can represent, to some extent, the carriers' preferences when selecting the port of call.

Another variable, adaptability to the changing market environment, we will measure it by the extent, to which certain port/terminal satisfies the demand of their customers. Since the most important change in the maritime transport market environment is the concentration of the power on the demand side of port services, this proxy can capture the adaptability of ports to the changing market environment.

As to the product differentiation, we use the investment in marketing of ports/terminals as the proxy since port authorities and port operators usually think out the new service product through marketing activities.

4.2.3 Data Collection

Given the fact that the phase of development, which the trend of port privatization has reached within Asian port sector, is currently unique within the world's port industry (Cullinane and Song, 2001), 50 container terminals located at Asian ports were initially selected to carry out this empirical study. At the first stage, the values (Year 1999) of physical variables are obtained from Containerization International Yearbook. For the variables (e.g. extent of privatization, cargo handling charges, average delayed time, marketing investment) that are unavailable from the secondary sources, questionnaires are sent out to these selected terminals. However, due to the limited responses from the above terminals, we extend the sample to some European and American container terminals (Top 50 of world container ports/terminals) to satisfy the requirement both on availability of enough data and on the random characteristic of the selected samples since there is almost no fully privatized container terminal in Asia. Finally, we obtained the response from 25 container ports/terminals. Although the sample is small, these container ports/terminals have different features in terms of port privatization and port performance. For example, there are full private/public ports, e.g. Felixstow from the UK and Dubai from UAE. In addition, in this study, there are also many other container ports/terminals that are partially privatized. Thus, the research outcomes can provide some valuable policy implications for port authorities and port operators.

Due to the business secret and some technology difficulties, they do not provide the data for cargo handling charges, average delayed time and marketing investment. At the second stage, questionnaires are sent out to some major shipping lines to obtain their assessment on the adaptability to the changing market environment and landside accessibility of selected container ports/terminals, which are measured in five categories: excellent (5), good (4), fair (3), poor (2), very poor (1). Table 4.2 only presents a summary of production variables and inefficiency effect variables. The simple statistics for the determinants of ports/terminals competitiveness are showed in

Appendix I.

Table 4.2

Summary Statistics for Variables in the Stochastic Frontier Production Function

Variables[a]	Mean	Median	Min	Max	S.D.
Y	1579706.44	810439.00	239967.00	15944793.00	3092111.45
X_1	1538.28	1000.00	300.00	10205.00	2033.72
X_2	72.48	40.00	4.56	339.00	80.90
X_3	14.08	8.00	3.00	118.00	22.85
z_1	0.40	0.00	0.00	1.00	0.50
z_2	0.49	0.50	0.00	1.00	0.22

[a]Y is defined as the terminal output as measured by annual container throughput in TEUs. X_1 is defined as the terminal quay length in meters. X_2 is defined as the terminal area in hectares. X_3 is defined as the number of quay cranes used at the terminal. z_1 is defined as the port size, which is dummy variable. z_2 is defined as the private participation in terminal functions.

4.3 Model Specification

Following the literature in the field, we test two functional forms for the stochastic frontier production function, a Cobb-Douglas and a Translog. The estimates are based on the maximum likelihood method relying on the FRONTIER package, version 4.1. The stochastic frontier production function to be tested is:

$$ln(Y_i) = \beta_0 + \beta_1 ln(X_{1i}) + \beta_2 ln(X_{2i}) + \beta_3 ln(X_{3i}) + \beta_4 ln(X_{1i})^2 + \beta_5 ln(X_{2i})^2 + \beta_6 ln(X_{3i})^2$$

$$+ \beta_7 ln(X_{1i})\, ln(X_{2i}) + \beta_8 ln(X_{1i})\, ln(X_{3i}) + \beta_9 ln(X_{2i})\, ln(X_{3i}) + v_i - u_i$$

where the technical inefficiency effects are assumed to be defined by

$$u_i = \delta_0 + \delta_1 z_{1i} + \delta_2 z_{2i} + \delta_3 z_{2i}^2 + W_i$$

where *ln* denotes the natural logarithm;

Y_i = the total throughput in terms of TEUs of container port (terminal) *i*;

X_{1i} = the terminal quay length in meters of port (terminal) *i*;

X_{2i} = the terminal surface in hectares of port (terminal) i;

X_{3i} = the number of container quay cranes used by port (terminal) i;

z_{1i} = the size of port (terminal) i, which is the dummy variable to distinguish whether the total annual throughput of the observation exceeds one million TEUs or not.

z_{2i} = the extent of the private sector participation in port (terminal) i;

v_i, u_i and W_i are as defined in the previous section.

The test on functional forms can be carried out by the generalized likelihood-ratio method, which works as follows:

$$LR = -2\{ln[L(H_0)]-ln[L(H_1)]\},$$

where $L(H_0)$ and $L(H_1)$ are the value of the likelihood function under the null hypothesis (H_0: $\beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$) and the alternative ($H_1$) respectively.

The models for the investigation on determinants of port competitiveness are as follows:

$$PCI_i = W_1 X_{i1} + W_2 X_{i2} + W_3 X_{i3} + W_4 X_{i4} + W_5 X_{i5} + W_6 X_{i6} + W_7 X_{i7} + W_8 X_{i8}$$

$$PC_i = \alpha_0 + \alpha_1 X_{i1} + \alpha_2 X_{i2} + \alpha_3 X_{i3} + \alpha_4 X_{i4} + \alpha_5 X_{i5} + \alpha_6 X_{i6} + \alpha_7 X_{i7} + \alpha_8 X_{i8} + \varepsilon_i$$

where PCI_i is the port competitiveness index for port i;

PC_i is the total throughput in terms of handled TEUs by port i;

X_{i1} = efficiency level for port (terminal) i;

X_{i2} = cargo handling charges of port (terminal) i;

X_{i3} = reliability of port (terminal) i (delayed time);

X_{i4} = the number of direct-call liner services at port (terminal) i;

X_{i5} = the depth of the navigation channel of port (terminal) i;

X_{i6} = adaptability to the changing market environment of port (terminal) i;

X_{i7} = landside accessibility of port (terminal) i;

X_{i8} = products differentiation of port (terminal) i (investment in marketing).

Applying two softwares, SAS and Eview, respectively to the above two models, we can obtain the effects of determinants of port competitiveness that are shown in the next chapter.

Chapter Five

Empirical Results

5.1 Stochastic Frontier Model

Because of limitation on data, we just use the Cobb-Douglas production function directly to investigate the relationship between the port efficiency and port specific characteristics. The maximum-likelihood estimates of the parameters of the frontier model, defined by equations (3) and (4), were obtained for the 25 selected container ports/terminals (Table 5.1) by using the computer program FRONTIER 4.1 (Coelli, 1996). The empirical results are shown in Table 5.2, from which we can notice that the input variable, the terminal surface, is not used directly in the production function. Suppose given a certain number of the quay length, it must incur congestion problem in the terminal area and decrease the productivity if there is no enough space for container storage and container flow. Thus, the relative measurement of the terminal surface to the quay length, ($X_2*10000/X_1$), is more accurate to be viewed as the input of container operation production. The same rationale is applicable to another input, the number of quay cranes. Here the relative measure of this input variable, (X_3/X_2), is used in the production function instead of the absolute value. These kinds of transformations are consistent with those used by Notteboom et al. (2000).

Table 5.1: Productive Efficiency of Selected Container Ports/Terminals

Container Port/Terminal	Country	Efficiency Level(Rank)
1.Hongkong Terminal 1/2/5/8(west)	China	99.392(2)
2.Manila International Container Terminal	Philippines	80.543(15)
3.PSA	Singapore	99.393(1)
4.Shekou Container Terminal	China	83.989(11)
5.CSX Tianjin Container Terminal	China	69.174(25)
6.Chiwan Container Terminal	China	72.991(24)
7.Yantian Container Terminal	China	99.194(8)
8.Yokohama Terminal MC-1/2	Japan	78.492(18)
9.Hongkong Terminal 3	China	99.317(6)
10.ESCO Terminal B3	Thailand	76.708(20)
11.Hongkong Terminal 8(east)	China	99.361(5)
12.LCB1 Terminal B1	Thailand	79.350(17)
13.Felixstow	UK	99.380(3)
14.Dubai	UAE	98.655(10)
15.Voltri Terminal	Italy	78.092(19)
16.Gamman Global CT-Busan	South Korea	79.982(16)
17.Gamman Hanjin CT-Busan	South Korea	82.906 (13)
18.Gamman Hyundai CT-Busan	South Korea	83.356(12)
19.Gamman Korea Express CT-Busan	South Korea	81.864(14)
20.Jasungdae CT-Busan	South Korea	99.310(7)
21.Shinsundae CT-Busan	South Korea	99.369(4)
22.Klang Port Container Terminal	Malaysia	73.998(23)
23.Klang Container Terminal	Malaysia	75.453(22)
24.Centerm	Canada	76.615(21)
25.Burchardkai	German	99.027(9)
Average		86.636

Table 5.2
Maximum-Likelihood Estimates for Parameters of the Stochastic Frontier and Inefficiency Model

Variables	coefficient	standard-error	t-ratio
Stochastic Frontier			
Constant	2.354	0.988	2.382**
$\ln X_1$	0.777	0.087	8.943 ***
$\ln(X_2{*}10000/X_1)$	0.804	0.383	2.098*
$\ln(X_3/X_2)$	1.015	0.291	3.488***
Inefficiency Model			
Constant	0.463	0.215	2.152**
Z_1	-0.639	0.187	3.417***
Z_2	-0.666	0.793	0.839
Z_2^2	0.415	0.843	0.492
Variance Parameters			
$\sigma_s^2=\sigma^2+\sigma_v^2$	0.015	0.007	2.225**
$\gamma\equiv\sigma^2/(\sigma^2+\sigma_v^2)$	0.186	0.503	0.370
Log-likelihood function	17.740		

Note: t-ratios are absolute values. Approximate critical values for the t ratios are: 10%=1.753(*), 5%=2.131(**), 1%=2.947(***). ln=natural logarithm.

Table 5.3
Statistics for Hypotheses Tests of the Stochastic Frontier and Inefficiency Model

Null Hypothesis	Likelihood ratio test	Critical Value χ^2(5%)	Decision
No Inefficiency ($\gamma=\delta_0=\delta_1=\delta_2=\delta_3=0$)	10.903	10.371[a]	Reject
No Inefficiency Effect ($\delta_1=\delta_2=\delta_3=0$)	10.902	7.81	Reject
Ownership Effect ($\delta_2=\delta_3=0$)	9.824	5.99	Reject

Note: [a]A mixture of χ^2 distribution (Kodde and Palm, 1986)

5.1.1 Hypothesis Tests

Table 5.2 shows that all three inputs have a positive effect on production, which conforms to a priori expectation. The coefficients of the quay length and the relative measurement of the number of quay cranes are both statistically significant at the 5% level, while the coefficient of the relative measurement of the terminal surface is statistically significant at 10% level. From the values of these three coefficients, we can see that the most important input of container operation production is the relative measurement of the number of quay cranes, which is the most pivotal equipment employed in the container handling process. The estimates of the parameters in the inefficiency effect equation and the economic interpretation will be discussed later. Estimate of γ is 0.186, implying that only 18.6% of total variability is associated with technical inefficiency of production, and it is not significantly different from zero. This result is mainly due the fact that most of selected container ports/terminals are from top 50 container ports around the world and there is not much technical inefficiency difference among them.

Hypotheses tests associated with the inefficiency effects are presented in Table 5.3. The null hypotheses are tested using likelihood-ratio tests:

$$LR = -2\{ln[L(H_0)]-ln[L(H_1)]\},$$

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null hypothesis (H_0) and the alternative (H_1) respectively. We also apply the one-sided generalized likelihood-ratio test, suggested by Coelli (1995), to examine the presence of inefficiency effect, u_i. In this case, if H_0: $\gamma=\delta_0=\delta_1=\delta_2=\delta_3=0$ is true, the generalized likelihood-ratio statistic, *LR*, has asymptotic distribution which is a mixture of chi-square distributions (Coelli, 1995a), the critical value of which can be obtained from Kodde and Palm (1986).

The null hypothesis that there is no technical inefficiency ($\gamma=\delta_0=\delta_1=\delta_2=\delta_3=0$) is rejected, indicating that γ is joint significant with four estimates of the parameters in the inefficiency effect equation (δ_0, δ_1, δ_2 and δ_3) at 5% level although the γ is not separately significant in Table 5.2. In addition, the null hypothesis that all the coefficients of the explanatory variables in the inefficiency model are equal to zero ($\delta_1=\delta_2=\delta_3=0$) is also rejected, implying that port ownership structure and port size can explain the difference of inefficiency levels among the selected container ports/terminals. Furthermore, two coefficients on ownership variables (δ_2 and δ_3) are also joint significant at 5% level though they are not separately significant in Table 5.1, indicating that the effect of port ownership structure on port operation efficiency is statistically significant.

5.1.2 Technical Inefficiency Effects

The estimate of the coefficient of port size in the inefficiency effect model is both negative and significant, showing that ports with larger size are more efficient than the smaller ones. This result is consistent with the rationale of economies of scale and informs the port authorities and port operators that increasing the total number of containers handled can improve the operation efficiency. The negative relationship between the port size and operation inefficiency also implies that the container handling ability of most of container ports/terminals is surplus and the underutilization of inputs of quay length, terminal surface and quay cranes.

The negative sign of the estimate of the coefficient on port privatization (z_{2i}) implies that there is a positive relationship between technical efficiency and privatization in port industry. However, the coefficient of the square form of port privatization (z_{2i}^2) is positive, implying an inverted U-shaped relationship between technical efficiency and privatization. Since these two variables related to port privatization are jointly statistically significant, the inverted U-shaped effect of private sector participation on port efficiency is statistically significant.

The results show that the best extent of private participation in container ports/terminals is 0.80 ($\delta_2/2\delta_3$), which is between the Private/public (0.67) and the Private (1.00) mode. The results indicating the relationship between the extent of private sector participation in port functions and port efficiency is very important for policy purposes. For example, if a port authority wants to increase its operation efficiency, the results show that one effective way is to introduce private sector in some port functions. If a port authority, who has introduced the private sector in some port functions, wants to maximize the positive effect from port privatization, the above empirical results suggest that the port authority had better let the private sector fully participate in landowner and operator functions and take part in some regulatory activities.

5.2 Determinants of Port Competitiveness

The results of the principal component analysis are presented in Appendix I. The principal component 1 (PRIN1), explaining around 44% of the total variance, is used to calculate the ports/terminals competitiveness index and has the following coefficients:

$$PRIN1 = 0.53\ EFF + 0.25\ DEP + 0.52\ NDC + 0.58\ LAN + 0.24\ ADA$$

The efficiency (EFF), port selection preferences of carriers and shippers (NDC) and landside accessibility (LAN) are most important to the port competitiveness. The container ports/terminals competitiveness index is showed in Figure 5.1, in which the order of the container ports/terminals is the same as in Table 5.1.

Although the above weights on each variable from the PCA method can represent the effects of determinants on container ports/terminals competitiveness, we can not carry out the hypothesis test based on this program. In order to see the statistical significance of these coefficients, we should find a proxy for container ports/terminals competitiveness and run a regression of it on those determinant variables. From Figure

5.2, we can see that the natural logarithm of the total throughput (TEUs) of container ports/terminals is a good proxy for container ports/terminals competitiveness, consistent with the assumption mentioned in the previous chapter.

Figure 5.1: Container Ports/Terminals Competitiveness Index

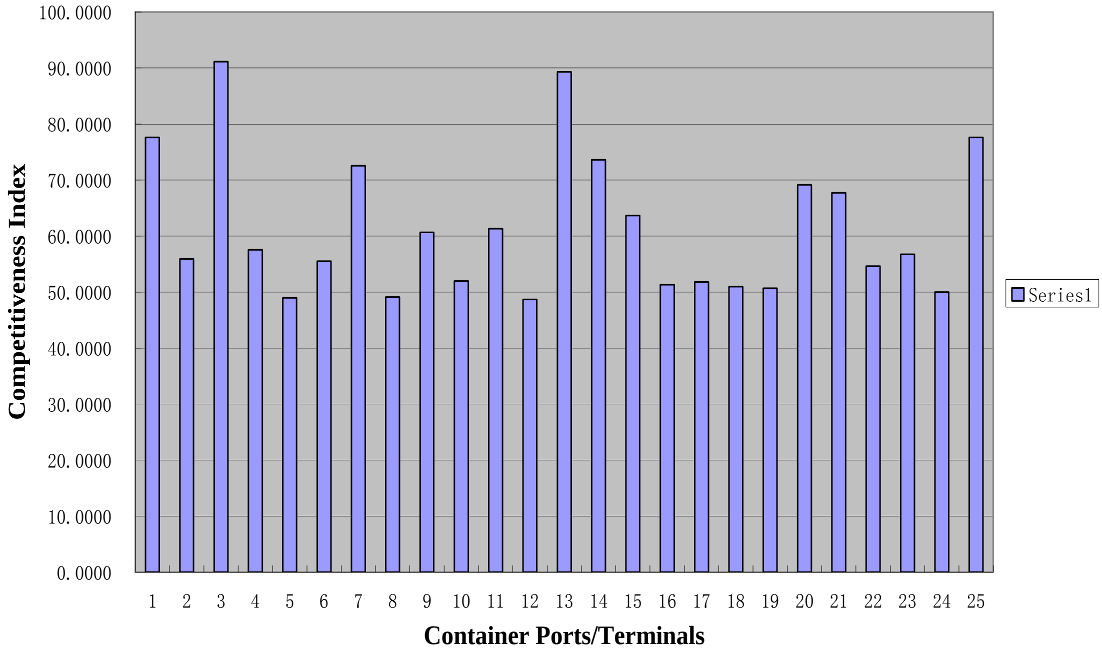
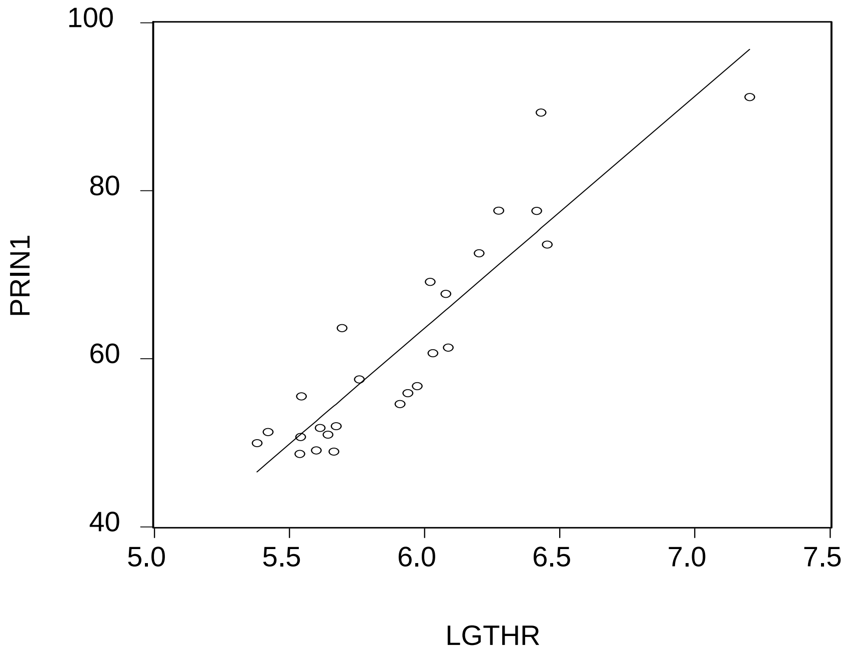


Figure 5.2: PRIN1 (Competitiveness) vs. LGTHR (lgthroughput)



The results of the regression are showed in Table 5.4. The White Test points to an absence of heteroskedasticity in the regression model and the Jarque-Bera statistics justifies the normality of the residuals. Therefore, the estimates are consistent with the postulations prescribed by the OLS regression model.

Table 5.4: Determinants of Container Ports/Terminals Competitiveness

Dependent Variable: the natural logarithm of ports/terminals throughput

Variables	coefficient	t-ratio	p-value
Constant	-7.118	-1.450	0.1633
ln (EFF)	3.433	4.239	0.0004
ln(DEP)	-0.747	-0.493	0.6277
ln(NDC)	0.355	4.722	0.0001
ln (LAN)	1.650	1.691	0.1072
ln (ADA)	3.336	3.035	0.0068
R-squared	0.8497		
F-test	21.489		0.0000
White Test			0.2713
NORM	0.066		

Note: White Test is the test for functional mis-specification. NORM is the Jarque-Bera test for the normality of the residuals. ln = natural logarithm.

All the signs of the coefficients except that of depth support the theoretical hypotheses. We can ignore the strange result on the coefficient for the depth of port navigation channel since the estimate is statistically insignificant in spite of its negative effect on ports/terminals competitiveness. The variable landside accessibility has the right sign but is statistically insignificant. There are three variables statistically significant at 1%

level, ports/terminals operation efficiency, number of direct-call liner services and adaptability to the changing market environment. And the largest effects are from two variables. One is ports/terminals operation efficiency, which has the highest coefficient, implying that operation efficiency is most important for port authorities and port operators to increase their competitiveness. This result is consistent with the results in Tongzon (1995), in which the port operation efficiency was found the most important factor to port performance measured by the total throughput in terms of TEUs. Another important determinant is adaptability to the changing market environment, whose coefficient is quite close to that of the port efficiency, indicating that port authorities can not ignore the importance of this variable while they are trying to increase the port operation efficiency.

The aforementioned findings provide empirical support for the argument that port competitiveness is determined by some factors, some of which are beyond the control of the port authorities and operators such as the port selection preferences of carries and shippers that are decided by their service network instead of port performance. However, two most statistically significant variables, operation efficiency and adaptability, can be controlled by the port operators. We can easily understand their importance in determining the ports/terminals competitiveness since these two variables represent the quantity and the quality of the services provided by ports/terminals operators respectively.

Chapter Six

Conclusions

6.1 Summary of the Study

As I mentioned in the first chapter, there are two major research purposes for this study. First, to further justify the relationship between port privatization and port efficiency since there is no consistent conclusion on this problem. Second one is to construct the port competitiveness index and investigate the determinants of port competitiveness.

To find out the accurate relationship between port privatization and port efficiency is very important. On the one hand, most port authorities assume there is a positive relation between these two factors and they consider port privatization as a necessary measure to improve operation efficiency. On the other hand, however, there is no clear-cut answer based on the existing empirical study. Applying more appropriate methodology and model specification, this study gives us a satisfied result: the effect of port privatization on port efficiency is inverted U-shaped, consistent with the argument proposed by Baird (2000).

However, this is not the end of the story since the final target of port authorities is to achieve competitive advantages. Is port operation efficiency very important to determine port competitiveness? The second part of this study gives us the answer. Using Principal Component Analysis, port competitiveness index is constructed and justifies the total throughput as a good proxy for port competitiveness. Then a linear regression model is used to examine the effect of determinants of port competitiveness, including port efficiency. The results show that the port operation efficiency and the adaptability to the customers' demand are the key factors that influence port competitiveness.

6.2 Implication of the Study

The obtained empirical results provide some valuable policy implications for port authorities. First, it shows that the introduction of private sector participation in the port industry is useful to improve the operation efficiency. However, on the other hand, full port privatization is not an effective way to increase the operation efficiency, which means that this relationship is not a linear positive one. Then, what extent of private sector participation can maximize the operation efficiency? This study gives us the answer. The best extent of private participation in container ports/terminals is between the Private/public (0.67) and the Private (1.00) mode, implying that the port authority had better let the private sector fully participate in landowner and operator functions and take part in some regulatory activities. In other words, port authorities have to introduce the private finance, operation and management in the place of state funds and administration while they remain in place as regulators.

Secondly, it is found that the operation efficiency is very important for port authorities and port operators to gain the competitive advantages, implying that partial port privatization is a quite effective way to help port authorities to win the game in the serious port competition. And it also implies that the customers of port services, shipping lines, pay more attention to the port operation efficiency when selecting the port services.

Finally, the results show that another most important factor determining port competitiveness is the adaptability to the customers' demand. Since the port industry is a kind of service industries, it is reasonable that port authorities and port operators should well understand the requirement of their customers and make efforts to meet and exceed customers' expectation. Therefore, seaports that will succeed in the 21st century will be those that are "customer-oriented", who really understand customer needs.

6.3 Limitation of the Study

It is worth noting that this study does not investigate the effects of three justified determinants of port competitiveness, cargo handling charges, reliability and products differentiation due to the unavailability of the data. Running short of these data must constrain the comprehensive analysis of port competitiveness. For example, cargo handling charge is a very common tool for port authorities and port operators to compete with their competitors. Incorporating this variable into the model will tell us how to balance the positive effect from high operation efficiency and the negative effect from high operation charges to achieve the maximum of port competitiveness. Thus, first suggestion is that further study can try to obtain the data of above mentioned variables. Secondly, adding more container ports/terminals into the sample of this study will provide stronger proof to justify the empirical results of this study. Another possible way is to find out other good methodologies that have been used in research work of other industries and apply them to port industry and justify the empirical results of this study.

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APPENDIX I

Principal Component Analysis: results

Simple Statistics

	EFF	DEP	NDC	LAN	ADA
Mean	86.63644000	14.58800000	17.80000000	3.786664000	3.815000000
StD	10.97760604	0.85990310	16.47725705	0.420870703	0.298061639

Correlation Matrix

	EFF	DEP	NDC	LAN	ADA
EFF	1.0000	0.1385	0.4787	0.5300	0.1346
DEP	0.1385	1.0000	0.1133	0.2498	0.0628
NDC	0.4787	0.1133	1.0000	0.5373	0.1081
LAN	0.5300	0.2498	0.5373	1.0000	0.2535
ADA	0.1346	0.0628	0.1081	0.2535	1.0000

Eigenvalues of the Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulative
PRIN1	2.18265	1.23339	0.436530	0.43653
PRIN2	0.94926	0.01232	0.189851	0.62638
PRIN3	0.93694	0.41593	0.187388	0.81377
PRIN4	0.52101	0.11087	0.104202	0.91797
PRIN5	0.41014	.	0.082029	1.00000

Eigenvectors

	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5
EFF	0.525735	-.259184	-.041380	-.752765	0.296748
DEP	0.246172	0.514137	0.803252	0.018467	0.171779
NDC	0.520651	-.335506	-.052435	0.652741	0.433057
LAN	0.576497	0.004148	-.007330	0.081101	-.813021
ADA	0.244083	0.745591	-.591837	0.018861	0.184095

Notes:

EFF: Ports/Terminals Operation Efficiency

DEP: Depth of Navigation Channel

NDC: Number of Direct-call Liner Services

LAN: Landside Accessibility

ADA: Adaptability to the Changing Market Environment