A LONGITUDINAL ANALYSIS OF PORT SYSTEMS IN ASIA

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SUMMARY

Competitive seaports and airports are vital for smooth flow of trade and form the backbone of an economy's prosperity. This dissertation is organized into three distinct but related parts, which together, addresses some of the recent advances in the Asian port systems. Some internal and external factors that favor the developments of hub port are identified in the course of research.

Part 1 examines the changing landscape of the port industry in Asia and the associated implications on port competitiveness. An econometric model is applied to investigate the relative contributions of production elements, scale operations and economic conditions to seaport and airport performances over the recent years, followed by a clustering analysis that groups the ports according to their capital intensities and throughputs after adjusting for differences in the economic environment. In addition to these macro factors, ports are differentiated in terms of natural endowments, technical and operating characteristics that influence their attractiveness to carriers (who ultimately determine the success of ports) and their relationships with other ports. Therefore, a hub port assessment framework is proposed from an explicit formulation of network-based connectivity and cooperation indexes to assess the accessibility of a port and the potential or sustainability of its hub status. Through the service networks of major liner companies, three case studies are conducted to position various ports in the proposed framework. The connectivity index is further integrated with important considerations of port attributes to reveal the underlying port selection behavior, which lends key insights to port operators on possible port improvement areas for sustainable competitiveness. The joint optimal pricing and capacity investments rules for ports pursuing a hub development strategy are established in an analytical model that takes into account of the intrinsic port

qualities and downstream demand characteristics that influence carriers' selection of ports.

Part 2 focuses on the efficiency of major Asian airports. It begins with the illustration of an operations flexibility improvement trend that provides the foundation for greater efficiency at the industry level. A full ranking of individual airports on various dimensions of efficiency is then accomplished by incorporating prices and exogenous factors into the traditional Data Envelopment Analysis (DEA) models.

Part 3 recognizes that the prospects for hub port formation in a regional port system are dependent upon the competitiveness of the overall supply chains in which ports are the nodal points. The Air Cargo Supply Chain Operations Reference (ACSCOR) model, adapted from traditional Supply Chain Operations Reference (SCOR) model, is presented to identify the performance linkages among different levels of the air cargo supply chain. In the light of statistics from Hong Kong and Singapore, correlation analysis is used to study the role of the seaport (which is a traditional mode for international transportation) in this modern age of air transport. Finally, the economic contributions of ports are quantified through accelerator and multiplier models in view of the external influences on supply chain and port performances.

CHAPTER 1

INTRODUCTION

"Traffic means life and prosperity not only for the port but also for the city and region around it. Thus it is inevitable that a dynamic port will seek to attract as much traffic as possible from wherever it can…The port must find ways and means of providing services and facilities that induce maritime interests and shippers in the hinterland to use it in preference to another ports … Failure to provide certain facilities, perhaps because of over-reliance on established reputation, is likely to divert traffic to competing ports that can provide the services and are probably eager to do so." Weigend (1958)

1. Background

Trade is recognized as one of the oldest and most important nexus among nations. An efficient and competitive port is vital for smooth flow of trade and forms the backbone of an economy's prosperity[1]. The modern interdependent world market economy makes trade and ports more important. On recognition that the development of a hub port spurs economic progress, governments and port authorities pump huge investments into port expansions and upgrades of hard and soft supporting infrastructures while implementing customs simplification and cost cutting measures at the same time. Whilst these efforts have helped to attract users and stimulate port traffic, they also trigger inter-port competition defined by Slack (1985) as "…the

[1] Irwin and Tervio (2002) have proven one of the most fundamental propositions of international trade theory, which advocates that trade allows a country to achieve a higher real income than would otherwise be possible.

process of fighting to secure customers, market share or hinterland control, over which a port may have exclusive or partial control".

Over the years, competitions among ports are intensifying due to a number of structural changes that took place in the regional port systems (which include both seaports and airports). First, port hinterlands have ceased to be captive and extended beyond national boundaries as a result of logistics and transport infrastructure improvements. These improvements have led to an overlapping of port hinterlands, which allows shippers to substitute one port for another economically and feasibly. For example, a liner may substitute a port on one coast for a port on another if such substitution contributes to the profit of a vessel's route within the cycle time available under the constraint of same-day service. Similarly, a cargo airline may use a cheaper transit airport in another country in place of the more expensive one so long as the cargo can reach the destination on time. Second, the container shipping and airline industries (i.e., the primary port users) are getting increasingly concentrated through mergers and alliances. When carriers are becoming more footloose and port independent, concentrations strengthen the bargaining powers of carriers vis-à-vis the ports. Coupled with the deployment of larger containerships and aircrafts that resulted in fewer stopovers and less frequent schedules, the move of a large carrier represents a potent traffic volume gain/loss to a port. Third, ports are no longer mere interface points between land and sea or air. As communication technology advancements and trade liberalizations facilitate globalization and stimulate shift in manufacturing activities towards countries with comparative advantage, the roles of ports in the supply chain means that port competitiveness not only directly influences the competitiveness of the country's logistics industry but also the competitiveness of the country as a whole since the success of the chain is recognized as being dependent on each of the parts working together to provide an effective reliable system. Thus, ports have become one of the most dynamic links in international transport networks and uncompetitive ports can wither gains from trade liberalization, export performances and stifles economic growth.

In view of the far reaching consequences of ports, the inter-port competition and its implications on seaport and airport performances in a regional port system warrant an in-depth investigation. While there have been several academic attempts to measure inter-port competition using scientific techniques (other than case studies analysis), comprehensive research on port competition at the global or regional levels have been significantly hindered by the lack of price and demand information[2] on port services across different countries. For studies on port performances, some are oriented towards a variety of operational matters such as berth and gate allocations in seaports and airports respectively and others deal with the more general matters of assessing port competitiveness. In the latter, the absence of information on cross price elasticity between seaport's and airport's services has also hampered an unbiased evaluation of actual performance of an airport against those of the competing airports or the targeted performance set for the airport in the nation's development plans.

1.1 Research Scope and Objectives

This dissertation focuses on the inter-port competition and port competitiveness analysis of both seaports and airports that arise from government efforts to develop their ports into regional or global hub ports within the port systems in Asia. As a whole, Asia has experienced rapid economic growth in the past two decades.

[2] Price information is often confidential and full market demand functions are not available as turn-away traffic is not captured by the systems. Moreover, general cargo rates vary according to the time of year, and between inbound and outbound cargo making accurate price comparisons extremely elusive (Zhang 2003).

Compared to the world gross domestic product (GDP) that is growing at an estimated rate of 4.9 percent in real terms, the aggregate economy of Asia maintains its upward momentum with a 7.3 percent growth rate. Of which, China and India have shown remarkable growth of 11.4 percent and 9.2 percent respectively while Japan and Republic Korea grow by 2.1 percent and 5 percent in 2007. During the same period, the world container port throughput[3] grows by 13.4 percent to over 440 million TEUs. The mainland Chinese ports grew by an average 35 percent. Other Asian ports that have made double-digit gains include Colombo (25 percent), Jawaharlal Nehru (23 percent), Gwangyang (22 percent), Incheon and Ho Chi Minh (19 percent), Tanjung Pelepas and Port Klang (14 percent), Laem Chabang (11 percent) and Bangkok with (10 percent). For air cargo throughput, according to the International Civil Aviation Organization (ICAO), Asia is already biggest market for international air cargo traffic accounting for 37 percent of the world's demand with the China demonstrating the fastest aggregate growth at 35.7 percent followed by Republic Korea at 13.6 percent. In terms of air passenger traffic, the international passenger traffic carried by airlines in the region grows by 6.6 percent accounting for about 28 percent of the total international traffic behind Europe at 40 percent and ahead of North America at 17 percent.

The objective of this dissertation is to analyze the recent developments in the port systems of Asia and provide some insights on port management directed at stimulating port growth. Particularly, we shall conduct theoretical and empirical analysis on: (1) the contributions of production and economic factors to port traffic over the years; (2) the influences of seaport operating aspects, supporting infrastructure and natural endowments on seaport attractiveness and the stability of

[3] Source: Review of Maritime Transport 2007, the United Nation Conference on Trade and Development (UNCTAD)

ports' current positions; (3) port's pricing and capacity investments practices for hub port development; (4) airport operations agility and the different dimensions of airport efficiencies; (5) linkages between port performances in a supply chain; and (6) the economic contributions of ports.

Although the port's policy is chosen for analysis, many aspects of the theoretical and empirical models developed during the course of this research are applicable for analyzing other industries, especially those industries that have characteristics of natural monopoly such as electricity, roads, railroads, telecommunications etc. Our research uses only observational data (as opposed to survey data from questionnaires or interviews) to minimize the level of subjectivity while ensuring the consistency and integrity of these data for a meaningful analysis. The results from this research will not only contribute to the advancement of the theory and methodology for analyzing port development plans as well as economic regulation and deregulation in general, and port's policy in particular, but also help port managers and policy makers by providing analytical results and quantitative evidence on the effects of alternative policies on port's performance and competitiveness. In addition, the implications of the results of these research modules addressed in the dissertation on port policy and strategies for port operators will be analyzed and synthesized.

1.2 Structure of Dissertation

The dissertation is structured into three distinct but related parts. Part 1 is made up of chapters 2, 3 and 4 that address the requirements of hub development in the changing landscape of the Asia port industry and their implications. **Chapter 2** examines the relative contributions of production factors (i.e., physical and human capital) and the economic conditions in the operating environment to seaport and airport performances over the recent years by applying panel data on an econometric model[4] represented by a Cobb-Douglas function. Ports are then divided into clusters based on their traffic volume, capital intensity and economic conditions; and movements between clusters are scrutinized to analyze port dynamics. Other than production and economic factors, ports differ among one another in terms of natural endowments, supporting infrastructure and operating aspects. **Chapter 3** proposes a network-based hub port assessment model, consisting of a novel connectivity and cooperation index, to assess the potential and stability of hub status in upcoming ports and established ports. Wang and Cullinane (2006) stated that port connectivity is generally representative of port competitiveness strength. Expressing the port connectivity index as a function of the technical, operating and economic aspects of seaports, results from this chapter can provide port operators with the key insights on how to improve their port infrastructure and operations. In conjunction with the cooperation index, this chapter further identifies port partners for individual ports so as to strengthen their positions in the international port industry. Using mathematical modeling, **Chapter 4** establishes the joint optimal pricing and capacity investment rules in the context of airports with airlines acting as intermediaries between airport and freight shippers (though most of the results obtained are certainly applicable to sea cargo supply chain with liners and seaports as main players). The model takes into account that an airport, pursuing an air hub development strategy, will enter a regional or global market where it needs to compete against other airports. Varying ownership structures,

[4] Studies by Gong and Sickles (1992) and Oum and Waters (1996) showed that econometric approaches generally produce better estimates of efficiency than mathematical programming when panel data is used and the functional form of the econometric data is well specified. Most poignantly, Cullinane et al (2005) found this to be the case when they compare the results from the applications of both programming and econometric approaches to data from the container port industry. Nonetheless, a mathematical modeling approach is more suitable if analysis is oriented towards greater managerial decision – making (for example, deciding on airport capacity and charges in Chapter 4)

budget constraint, intrinsic qualities of an airport and the demand characteristics from its downstream supply chain partners affect the relative amount of capacity investment an airport will put in and the way an airport seeks to recover its cost. Since each airport is unique in its own way, airports could also assess if it would be more profitable for them to pursue a competitive pricing strategy as a secondary airport especially with the recent re-emergent of low cost carriers.

Part 2, consisting of chapters 5 and 6, focuses on efficiency performances of airports. An efficient airport attracts airlines and increases its air connectivity[5], which facilitate the development of an air hub. Although airport charges account for only 5 to 7 percent of an airline's total operation cost, Gillen and Lall (1997) noted that these airlines operate in highly competitive markets and cannot easily pass airport rate increases onto the freight shippers. As a result, airlines have continually placed pressure on airports to reduce airport charges and make it necessary for airports to increase their efficiency for continual competitiveness. Like any organization in many other industries, operations flexibility represents a basic underpinning that allows swift adjustments of operations for maximum efficiency when scale of productions or factor availability and prices change. By means of Allen-Partial Elasticity, **Chapter 5** measures and analyzes how the substitutability between various factors in aggregate Asia airport industry has transformed over the years. In effect, the results from such analysis give insights on how increasing competitive pressure translates into higher airport operations flexibility (or operations agility) at the industry level. **Chapter 6** uses and extends a variety of Data Envelopment Analysis (DEA) models to present a detailed analysis on individual airport's cost efficiency, broken down into different

[5] Among many, Kasarda and Green (2005) have advocated that nations with good air cargo connectivity have competitive trade and production advantage over those without such capability in the new fast-cycle logistics era.

components such as scale, mix, technical and allocative efficiencies. More specifically, the scale and mix efficiencies measure the ease of airports to change their magnitude of operations and input proportions when traffic volume and price change. The inclusion of the allocative component, together with the technical component, in cost efficiency seeks to assess the importance of intelligent managerial decisions and operations flexibility on an airport's cost operations. An airport is allocative efficient if its management is able to take advantage of the cost differences between inputs by adjusting the input mix when existing technology limits the ability of airport to reduce cost by handling more traffic with lower usage of inputs in the short term. The detailed efficiency decompositions also aid to ascertain the ability of the airport to remain competitive in the short-term as well as in the long term.

Part 3 seeks quantify the economic contributions of airports, taking into considerations of the inter-relationships among seaports and airports, logistics industry and the economic and regulatory environment. While it has often been said that seaports and airports form two major pillars of a competitive logistics hub, there has been little attempt to distinguish the respective roles played by these two kinds of ports. **Chapter 7** explores the presence of complementary seaport and airport functions through an analysis of the logistics industry structure. Following the suggestion from Bichou and Gray (2004) that expansion to frameworks which encompass value-added logistics services would be beneficial in measuring port performance, this chapter also attempts to reconcile the association between the logistics landscape in an economy and the performances of her airport by introducing the Air Cargo Supply Chain Operations Reference (ACSCOR) model. The study is undertaken in the context of Hong Kong and Singapore in view of the observation made by Song and Lee (2005) that logistics services in ports are a contentious issue in port policy and management in Hong Kong and Singapore, for which these mega ports regard logistics services as a key area to support their long-term vision as a hub port. A correlation analysis on key performance indicators within and between different levels in the ACSCOR model is applied to demonstrate the effects of internal airport operating characteristics as well as government policies targeting at the logistics industry and the general economy on an airport performances. Whilst air cargo service demand may be a resultant of economic growth, this study recognizes that air cargo service demand is also a cause of economic growth in itself and seeks to measure the economic contributions of the air cargo business using established multiplier and accelerator models from economic theories.

Finally, **Appendix A** writes up brief profiles for selected seaports and airports in East Asia. Since port performances are shaped by their operating environments, these profiles include an environmental analysis that presents the opportunities and threats facing the countries at large in addition to the strengths and weaknesses inherent in ports. This is the typical strengths, weakness, opportunities and threats (SWOT) analysis often adopted in strategic management studies. **Appendix B** reviews the methodologies that have been employed in past studies on seaports and airports competition and performances. Figure 1-1 below summarizes the external and internal factors, analyzed in this dissertation, which could possibly affect the growth and development prospects of a port.

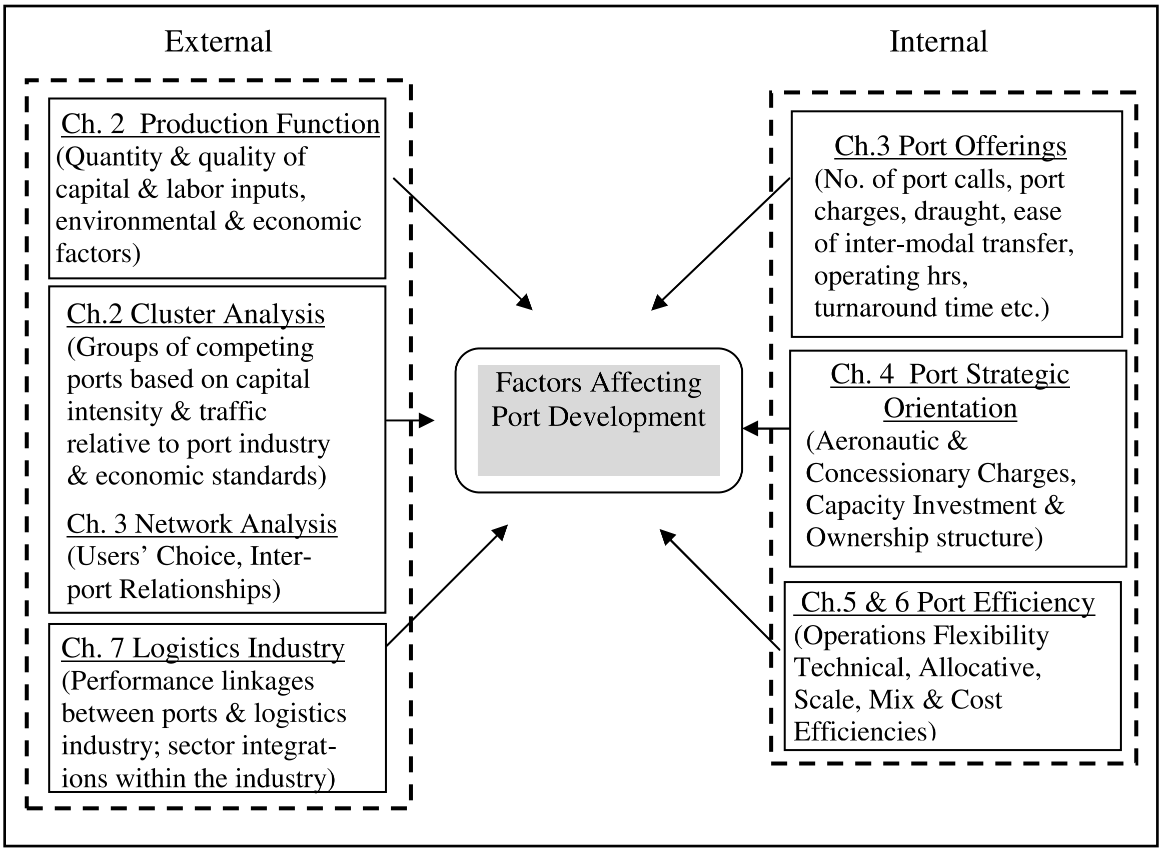

Figure 1-1 Factors Affecting Port Development Examined in the Dissertation

CHAPTER 2

AN EMPIRICAL INVESTIGATION ON THE CARGO TRAFFIC PERFORMANCES OF EAST ASIAN PORTS

2. Introduction

Ports are vital economic assets and generators of increased economic activity in a country. For countries wishing to attract new industries and foreign investments, the presence of seaports and airports offers a strong inducement for companies to set up their businesses in a particular location. The economic activity generated by a port is a result of operations carried out by the port management, port tenants and supporting and complementary businesses. These organizations contribute to their host countries by employing local residents, consuming locally supplied goods and services and by contracting port construction and capital improvements. Ports are also said to be the focal point at which economic benefits of shipping and aviation activities converge. In itself, a port supports the overall development of a country such that taxes on passengers and shippers and income taxes on port employees that are payable to government can be used to finance improvement programs on infrastructure, health care and education. Ports, especially airports, are also at the heart of travel and tourism industry. Tourism strengthens cultural ties between countries, in addition to the creation of many job opportunities in a diverse range of service and manufacturing industries. Other spin off benefits such as reducing cost of trade and movements, attracting new businesses, support for development of new technology and distribution process based on the rapid movement of people and goods.

Beyond the geographical boundaries of a country, ports form a vital link in the overall trading chain and consequently, ports' efficiencies and performances determine a nation's growth and its international competitiveness to a large extent (Rodrigue 1999, Klink and van den Berg 1998, Heilling and Poister 2000). The International Association of Ports and Harbors (IAPH) has seen the world seaborne trade increasing from 2.37 billion tons in 1990 to 5.88 billion tons in 2000, of which container trade increases from 86.5 million TEUs to 209.7 million TEUs. These figures are foreseen to grow further. While it is difficult to translate world seaborne trade values [1] into cargo volume directly, Lagoudis et al. (2006) estimated that over 80 percent of world trade *volume* is carried by the international shipping industry. At the same time, the value of air cargo to the society cannot be underestimated even though the volume of air cargo[2] is significantly smaller than that of sea cargo in terms of weight. The Air Transport Action Group (ATAG) estimated around 40 percent of the *value* of world's manufactured exports is transported by air. Zhang and Zhang (2002) observed that the average annual cargo traffic is growing at 7.9 percent in freight-tonne kilometers of international scheduled services compared to 2.1 percent in domestic services during the last decade. Noting that Asian countries have been experiencing strong growth in the cargo business after recovering from the 1997 financial crisis, the average annual air cargo growth in Asia is expected to lead all

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[1] The trade volume of the world economy are generally reported in terms of monetary statistics and are therefore not comparable with the ports' cargo volume traffic estimates given in tonnes or tonne-miles.

[2] O' Conner (1995) defined the term "air cargo" to include air freight, mail and several types of expeditated small packages. It generally includes almost everything that goes in the cargo compartment on a passenger flight except passenger baggage which is treated as if it is part of the passenger.

other international geographic markets in the next 20 years (Edgar 1995 and Ohashi et al. 2005).

Recognizing that uncompetitive ports and inefficient cargo services slow down economic progress and wither gains from trade, governments in many countries have taken steps to improve their port infrastructure and labor quality, streamline bureaucracy, relax custom administration and so forth in an attempt to speed up cargo processing procedures and enhance efficiency. Nevertheless, the effect of capacity investment in stimulating seaport traffic is equivocal. Citing examples from the over-capacity ports in US, UK and Japan, Helling and Poister (2000), Notteboom and Winkelmans (2001) and Terada (2002) pointed out that there is no evidence that increasing investment alone will enable port authorities to retain or regain greater control over their traffic. On the contrary, De Monie (1995) and Cullinane et al. (2004) recognized the congestion problem in India and the outdated handling equipment in China as one of the major obstacles hindering the port developments. Though increasing capacity and investing in modern equipments in these ports will help to alleviate the problem and improve the competitiveness of ports, the actual problem is more complicated in practice as Song (2002) demonstrated the value of intelligent facilities investment in a port's success. In the airport industry, Oum (1997) saw virtually all governments in Asia seeking to develop new airports or expand their existing airports[3] into continental superhubs for Asia as part of their national strategic plans to transform designated regions in their countries into a global or regional logistics hub. However, Oum (1997, 2008) added that an airport cannot become a superhub unless access to that airport is opened to a large number of carriers.

[3] Major Asian airports have been expanded or under construction in the late 1990s include Changi (Singapore), Kansai (Osaka), Narita (Tokyo), Seoul (New Seoul Airport), Pudong (Shanghai), Chek Lap Kok (Hong Kong), Bangkok, Kuala Lumpur, Macau, Hanoi and Manila.

Concurrently, governments of China, Hong Kong, Malaysia, Singapore, South Korea, and Taiwan had streamlined custom administration to speed up air cargo processing procedures (Tsai and Su 2002).

Whilst evidences showing that ports in proximity grow at drastically different rates[4] challenged the conventional wisdom that geographical superiority is the prime driver of port's growth on port performance, the large performance gaps among ports signal that port development efforts are met with different degrees of success and thereby evoking academic research interests. For seaports, Tongzon (1995) quantified the relative contributions of port location, ship call frequency, port charges and economic activity to the overall port traffic using 1991 data from 23 ports in the Asia Pacific, North America and Europe continents. More recently, also by means of setting up a logarithmic function, Cullinane and Song (2006) examined the relationship between physical capital (namely, quay length, terminal area and number of pieces of handling equipment) and port performance using 2002 data from 74 European ports. In the Asian context, other existing studies such as Haynes et al. (1997), Loo and Hook (2002) and Cullinane et al. (2004) looked at the factors influencing the development of specific ports like Kaohsiung, Hong Kong and Shenzhen respectively. In the airport development literature, Park (2003) Nijkamp and Yim (2001) and Ohashi et al. (2005) presented cross-sectional[5] empirical analyses on some major Asian airports to assess and identify important factors contributing to

[4] According to statistics from the Containerisation Yearbooks, the container throughput in 1986 for Kaohsiung, Hong Kong and Singapore were 2.78 million, 2.77 million and 2.20 million TEUs respectively. By the year 2002, the figures are 8.49 million, 19.14 million and 16.80 TEUs for the three ports.

[5] One limitation of such cross-sectional nature of the analysis stems from the fact that only a snapshot of relative efficiency can be obtained. Port competitiveness and their determinants change over time and, in consequence, there is a need to implement some form of dynamic analysis using longitudinal data. More critically, the lumpy nature of investment in port infrastructure means that cost inefficiency will occur immediately following an investment in facilities that is intended to cater for future growth in their use. Thus, recent or imminent investments are likely to have a significant deleterious impact on measures of relative cost efficiency that are based on cross- sectional data.

an airport competitiveness and success. Park (2003) looked at service, demand, managerial, facility and spatial qualities while Nijkamp and Yim (2001) studied the physical, technological, organizational, financial, ecological aspects in an airport. Ohashi et al. (2005) focused on air cargo transshipment airport and examined the monetary and time cost factors. Meanwhile, Raguraman (1997), Tsai and Su (2002), Zhang (2003) and Lee and Yang (2003) analyzed the air hub development strategy by government and airport authorities in Singapore, Taiwan, Hong Kong and South Korea respectively. As ports are unique to one another in terms of intrinsic characteristics and operating environments, it is difficult to generalize the relative importance of the various constituents in a development strategy on a port's performance from a direct comparison among case studies presented in these papers.

This chapter contributes to the literature by taking a longitudinal approach in its analysis on how the physical and human production aspects of a port and the economic environment that it is operating within will affect the port's performance using panel data that includes major seaports and airports in East Asia. The selection of variables included in the analysis is justified on basis that the presence of key production and favorable economic factors are necessary for actual traffic to materialize. That is, a port must possess production factors in order to supply the output and favorable economic conditions prevail to ensure effective demand for the port's output. Specifically, a separate econometric model, consisting of primary production factors and macroeconomic and regulatory conditions such as capital, labor, GDP, trade volume, bureaucracy and so forth, is presented to explain the determinants of sea and air cargo traffic in the aggregate East Asia seaport and airport industries[6] over time. Empirical investigation will provide estimates for the unknown parameters in the model, measure the validity of the model against the behavior of the observable data and reveal underlying trend[7]on the relative influences of factors under study across time.

Apart from port-specific and national factors, the performances of a port need to be assessed relative to the competition (Loo and Hook 2002). To better understand the dynamics within the Asia seaport and airport industries, the ports under study are then grouped into clusters and the movements of these ports between clusters over the study horizon are analyzed. Compared to the existing studies cited in Appendices B.4.1 and B.4.3 that employ Data Envelopment Analysis (DEA) and Total Productivity Factor (TPF) to examine port efficiency, our clustering analysis depicts port efficiency in terms of capital facilities usage and actualized traffic volume after taking into considerations the differing baseline performances attributable to the diverse sizes and economic conditions present in each of the respective ports. Such cluster analysis reveals market-aggressive ports characterized by exceptional improvements in volume performances and facilities utilizations, and is, hence, useful for identifying potential competitors. To the best of our knowledge, this study is the first attempt to quantitatively group ports into clusters.

[6] The East Asia airport industry is made up of airports in Southeast Asia and Northeast Asia. Southeast Asia includes a group of countries consisting of Singapore Malaysia, Thailand, Indonesia and Philippines while Northeast Asia comprises of Korea, Japan, China, Hong Kong, Macau and Taiwan.

[7] In contrast to snapshot analysis by Tongzon (1995), Cullinane and Wang (2006), Park (2003) and Nijkamp and Yim (2001) etc, trend analysis provides the foresights necessary for sound planning to ensure the airport can continue stand up to the competition in the future. For examples, environmental concerns, limited land for expansion and high financing cost that will result in delays in obtaining the increased capacity. Meredith (1995) noted that governments in many nations are facing increasingly heavy bills for economic development in other areas besides airport development, which requires hefty capital outlay. Knowing the relative influences of the various aspects on airport performances will enable the government to tailor their strategies according to the specifics of their airports and put their limited resources into optimal use.

The rest of the chapter is structured as follows: Section 2.1 develops an analytical representation to model the determinants of port cargo traffic. Section 2.2 presents empirical evidences to verify the precisions of the analytical model and section 2.3 groups ports into clusters. In the light of the observed results, section 2.4 discusses the implications of the findings at the aggregate and disaggregate levels of the Asian port industries and individual ports. Section 2.5 highlights potential limitations and concludes the chapter.

2.1 Model of Analysis

The output of port *i*, denoted as Y_i, is measured using the volume of cargo handled[8]. Two common primary production factors considered are capital (*K*) and labor (*L*).

Capital, *K*, comprises the physical infrastructure and facilities such as length of berths, number of tugs, storage areas etc in the context of seaports. The presence of adequate physical capital avoids costly congestions at the water side. Among others, De Monie (1995) and Cullinane et al. (2004) observed that the insufficient provisions of physical infrastructure such as berths and yards entail long waiting time of ships to load and unload their cargo in Indian and China ports. This results in unnecessary productivity loss due to slow port turnaround, which is one of the key elements considered by port users in the selection of port. Meanwhile, airport capital comprises the physical infrastructure and facilities such as runways, check-in counters, terminal space, gates etc. As stated by the Air Transport Research Society (2005), airports

[8] According to Tongzon (1995) and Ohashi et al. (2005), traffic volume is commonly used as a performance measure in the seaport and airport literature on the assumption that ports are throughput maximizers. Alternatively, a port's economic objective may also be to maximize profits (Talley 2006). Both objectives are equivalent if the port is regarded as a profit-maximizer who is assumed to be a price taker in its input markets (Culliane and Song 2006). That is, input prices are treated as exogenous to the model in this chapter

provide a wide range of services that can generally classified into airside operations[9] and landside operations[10]. An adequate provision of physical capital to ensure smooth running of these two types of operations is essential to avoid costly congestions.

Another production input variable is the size of labor force, *L*. Labor, is required to perform port and non-port related operations effectively and efficiently. Loo (2000) observed that the abundance of labor in China has led to a large-scale relocation of labor-intensive and export-oriented industries into China, which spurred the growth of ports in South China. Alongside, O'Conner (1995) noted that operations at airport terminals are labor-intensive despite much use of complex sorting and conveying apparatus. Labor is required to receive goods at the loading platform; to handle to paper work; to compute and collect the charges; to weigh, sort and allocate each piece to the proper flight; and to provide the proper protection. Even with sophisticated equipment and automation it still requires human effort to load and at the destination, to unload the cargo, as well as to sort it once again and get it into the hands of the recipients. Apart from the large pool of frontline workers, ports also employ management staffs to carry out operations and strategic planning and engineers to implement technological developments to ensure the overall efficiency in the ports.

Noting that labor in different countries is characterized by different degrees of productivity, we introduce a variable *H* to denote the amount of productive services supplied by workers. That is, *H* is the contribution of workers of different skill levels

[9] Airside operations refer to the activities that facilitate the movement of aircraft including runway services, apron services, and the loading and unloading of baggage/ freight.

[10] Landside operations refer to activities associated directly with passengers and freight traffic, covering various stages of processing of passengers' baggage and freight though the respective terminals and onto the aircraft.

to throughput generation. We make the standard assumption that the amount of human capital each worker has depends only on the number of years of education and better educated workers are more productive (Romer 2001). For ease of mathematical representation, our model also assumes that each worker obtains the same amount of education, denoted by *E*. Putting this assumption in notation,

$$H_i(t) = L_i(t)G_i(E) \tag{2.1}$$

where $L_i(\bullet)$ is the number of workers and $G_i(\bullet)$ is a function giving human capital as a function of years of education per worker at port *i*. Equation (2.1) also represents total labor services where *LG(0)* is raw labor and the remainder, *L[G(E)-G(0)]* is human capital. The first derivative, $G'(\bullet) > 0$, is imposed to insure that a worker processes more human capital with higher education. But the second derivative, $G''(\bullet)$, is unrestricted.

While ports are central to international trade that is one of the main drivers of economic growth, global economic growth in itself is also recognized as a key driver for the growth of port service demand. Some of these economic indicators[11] that are likely to lead economic growth as well as port growth are trade volume, national income, political and economic stability and level of bureaucracy. We use the variables X_i and $x_{i,j}$ to represent the aggregate and individual economic forces that determine throughput for given amount of physical capital and labor services. That is,

$$X_i(t) = x_{i,1}(t)x_{i,2}(t)\ldots x_{i,n}(t) \tag{2.2}$$

where $x_{i,j}(t)$ refers to the j^{th} factor of port *i* at time *t*.

[11] Hayuth and Fleming (1994) as well as Zhang and Zhang (2002) cited trade volume as a key force affecting seaport's and airport's cargo traffic. Macroeconomics theory postulates that trade volume is driven by economic factors such as GDP growth, economic stability, level of bureaucracy and so forth.

The multiplicative structure of (2.2) allows for possible interaction among the $x_{i,j}$ terms. For example, higher trade volume may result in or be a result of high GDP.

Having discussed about the various influences of capital, labor and economic conditions on port's cargo traffic, the structural equation for the determination of quantity of throughput generated at time *t* takes the following mathematical form:

$$\frac{Y_i(t)}{L_i(t)} = e^{b_0}\left(\frac{K_i(t)}{L_i(t)}\right)^{b_1}\left(\frac{H_i(t)}{L_i(t)}\right)^{b_2} X_i(t)^{b_3} + \varepsilon \qquad \forall i = 1,2,3 \qquad (2.3)$$

Equation (2.3) is a standard production function which expresses the throughput per worker[12] as a function of capital intensity, labor quality and an exogenous factor (in our case, the aggregate economic performance of the nation). b_1 and b_2 represent the respective returns to scale of capital intensity and labor quality on throughput per worker and e^{b_0} is the shift parameter. If b_1 and b_2 sum to unity, constant return to capital intensity and labor quality is implied. That is for a given nation's economic performance, doubling the inputs will double the amount of cargo volume handled by each port worker.

Taking natural logarithms on both sides of (2.3), we obtain

$$\ln\left(\frac{Y_i(t)}{L_i(t)}\right) = b_0 + b_1 \ln\left(\frac{K_i(t)}{L_i(t)}\right) + b_2 \ln\left(\frac{H_i(t)}{L_i(t)}\right) + b_3 \ln X_i(t) + \varepsilon_1 \qquad \forall i = 1,2,3 \quad (2.4)$$

[12] Equation (2.3) advocates that throughput per worker (also interpreted as the productivity of labor) is positively related to the amount of capital per worker, average education level ($H_i / L_i = L_i G_i / L_i$) and conducive economic environment. By normalizing throughput by the number of workers in a port, we allow for more meaningful comparisons across ports of different sizes. Ideally, the total number of worker hours should be used in place of number of workers if the necessary data is available. Alternatively, we could have normalized the throughput using amount of physical facilities since size of labor force and amount of physical facilities are both indicators for a port's capacity. We have chosen to normalize throughput with amount of labor because doing so will enable us to estimate the returns on labor quality improvement and capital investment more directly later in the study.

The use of a translog function in (2.4) allows for modeling of nonlinear relationships between input factors and estimations of parameters by means of multiple linear regressions.

Other special variations of the model are presented by Tongzon (1995) and Cullinane and Song (2006) who assumed a port's cargo traffic function[13] as:

$$Y_i(t) = e^{\alpha_0} K_i(t)^{\alpha_1} H_i(t)^{\alpha_2} X_i(t)^{\alpha_3} + \varepsilon \quad 0 < \alpha_i < 1 \qquad \forall i = 1,2,3 \quad (2.5)$$

A linearized model of (2.5) can be obtained by taking natural logarithms. This yields the following:

$$\ln Y_i(t) = \alpha_0 + \alpha_1 \ln K_i(t) + \alpha_2 \ln H_i(t) + \alpha_3 \ln X_i(t) + \varepsilon_2 \qquad (2.6)$$

The model presented in (2.6) has a potential limitation in that it allows for little or no correlation between the predictors. Correlations between predictors lead to the problem of multicollinearity, which in turn results in inflated variance and low parameters estimation precision. This poses a problem in the context of our study since *K* and *L* and (hence *H*) are some dimensions of port's capacity and hence expected to be correlated.

2.2 Empirical Analysis at the Aggregate Port Industry Level

2.2.1 Data Description and Sample

The required seaport, airport and economic data employed in this study are compiled from various issues of the Containerisation Yearbook, Airport Benchmarking Report, and World Competitiveness Yearbook. The data are reproduced in processed form in Appendix F. In order to avoid dominance of variables with larger measures over those

[13] In essence, this is a Cobb-Douglas function that is being widely used by economists including Romer (2001). Cobb-Douglas functions are power functions but the sum of exponents on the inputs is not necessarily restricted to 1. The use of such functions allows us to model the impact of changes in input variables on performance (i.e., cargo handled by port) without constraining ourselves to constant economies of scale restriction.

with smaller measures, raw data are normalized[14] before feeding them into the model. Normalization is done such that the best performing port in the category is given the highest score of 10 points. For example, the port with the largest amount of physical facilities will score 10. The score for other ports are computed using the formula: (Amount of physical facilities at port) ÷ (Maximum amount of physical facilities of port in sample) * 10. When dealing with economic data, a little more care is required to retain such scoring scheme. For dimensions like GDP or trade volume, it is straightforward that nations are scored relative to the nation with the highest GDP or trade volume. However, for dimensions like bureaucracy, corruption, political and economic risks, nations with the lowest level will be given the highest score of 10 and other nations are scored against the benchmark set by the best performing nation. In this way, we prevent the offsetting effect which will otherwise result (for example, high GDP versus high economic risk). Such scoring system, while retaining the original distribution of the data, also permits the modeling of relationship between cargo traffic and other performance indicators relative to the industry best practice.

According to Malchow and Kanafani (2004), ports can be selected based on two primary characteristics: (i) the volume of trade moved through the port and (ii) the proximity of the port to other significant ports. The authors emphasized that if two ports were geographically close, factors other than location may influence the shipper's choice between them. Therefore, the sample set includes 22 Asian ports that are major ports in their respective countries. These ports are Hong Kong, Singapore, South Korea (Pusan, Gwangyang and Incheon), China (Shanghai and Yantian,), Taiwan (Kaohsiung and Keelung) Malaysia (Port Klang and Tanjung

[14] In Sarkis (2000), normalizing is done by dividing each value of a respective airport for a given factor by the mean value of all airports for that respective input or output factor. Such mean normalization lessens the impact of large difference in data magnitude.

Pelepas), India (Jawaharlal Nehru and Chennai), Indonesia (Tanjung Priok and Tanjung Perak), Thailand (Laem Chabang and Bangkok), Philippines (Manila and Davao), and Japan (Yokohama, Tokyo and Kobe).

For airports, we have selected 14 international airports to be included in this study based on the availability of data. These are Hong Kong (Chek Lap Kok), Singapore (Changi), South Korea (Seoul Gimpo, Incheon), Japan (Narita and Kansai), China (Beijing Capital, Shanghai), Taiwan (Chiang Kai-Shek), Macau, Malaysia (Kuala Lumpur), Indonesia (Soekarno-Hatta), Thailand (Bangkok) and Philippines (Ninoy Aquino).

2.2.2 The Variables

The dependent variable is throughput *Y*, measured as the volume of cargo handled by the ports. More specifically, the physical measure of annual container throughput in twenty-foot equivalent unit[15] (TEUs) and metric tonnage are adopted as the basis for measuring the productive outputs of seaports and airports respectively. Independent variables consist of (i) capital, (ii) labor and (iii) an exogenous (or economic) factor.

(i) The Physical Capital K_i

The total capacity of physical infrastructure in a seaport, is represented using total length of container berths in the waterside operations and the total area of

[15] Ports handle a variety of cargo including liquid bulks, solid bulks, general cargo in containers and carried on container ships, general cargo in containers and transported in roll-on roll-off ships and general non-containerized cargo. Cullinane and Wang (2006) have advocated that container throughput is unquestionably the most important and widely accepted indicator of container port output and many past studies (i.e., Bernard 1991, Notteboom et al. 2000 and Cullinane and Song 2006) are precedents for this approach. Another reason for selecting container volume in preference over tonnage as the performance measure is because the production inputs required for movement of any single containers are about the same irrespective of a container's size and weight. This is facilitates the measurement of a seaport traffic which consist of both full containers and empty containers. Even within the category of container traffic, containers come in two sizes – twenty foot and forty foot equivalent units. The twenty-foot equivalent unit (TEUs) is adopted as the basis for measuring the productive output of container terminals in our study as TEU is also the standard size of container used for denoting the container carrying capacity for container ships.

terminals in the corresponding quayside operations. Among others, Tiwari et al. (2003) have found that the availability of sufficient berths is necessary to avoid port congestions and reduce ship-waiting time[16]. Meanwhile, adequate terminal area ensures available space for storage, towage and other peripheral port services such as ship repairs. Notwithstanding the fact that the productivities of berths and terminals are strongly affected by the provision of other handling and supporting facilities (such as cranes, straddles, tugs etc.), it suffices to estimate the relative proportion of physical capital in ports using total berth length and terminal area (Song and Yeo 2003).

Likewise, airports need to be equipped with adequate facilities for efficient airside and landside operations such as the provision of runway services, apron services, the loading and unloading of freight and processing of freight through the respective terminals and onto the aircraft especially at peak hours. We follow the standard convention and use the number of runways[17] and total terminals area[18] as indicators for airside capacity and landside capacity respectively.

As both types of operations (i.e., waterside and quayside operations for seaports; airside and landside operations for airports) are indispensible in the provision of port service, equal weights are attached to the specific physical

[16] Existing studies, such as Slack (1985) and Cullinane et al. (2004), confirmed that one of the main considerations of carriers in selecting a port is the port turnaround time.

[17] According to the ATRS, the number of runways indicates the airside capacity of an airport. Besides the absolute number, the length and crossing of runway are other important aspects that limit flight operations. Ohashi et al. (2005) stated a minimum length of 2800 is required to accommodate the Boeing 747 – 400. Hence, we check that all airports in our sample have at least one runway that is longer than 2800 meters and there is no intersecting runway in these airports.

[18] Yoshida and Fujimoto (2004) advocated that the size of the terminal determines the airport's ability to load passengers and cargo into aircrafts and hence plays an important role in airport operation activity. Considering that a significant percentage of the cargo volume is transported in combination flights that carry passengers and cargo, this study thus uses total terminal area as a proxy to the amount of physical capital used in an airport.

infrastructure in the computation of K_i. The required data on seaport infrastructure is gathered from the Containerisation Yearbook (1996 – 2008 issues) while those pertaining to airport infrastructure are obtained from Airport Benchmarking Reports (2002 – 2007 issues).

(ii) Labor L_i

While the number of employees working directly for a seaport operator is an ideal measure for the amount of human capital in a port, a reliable source of labor data[19] is not available (Wang and Cullinane 2006). Also given that the demand for port services is a derived demand from industries, Loo (2000) noted that the availability of labor in the economy in general is an important pull for industries and a boost for cargo traffic at ports through imports and exports. The presence of a large pool of labor, L_i, also exerts a downward pressure on wages that alleviate operating cost. L_i , whose data is obtained from the World Competitiveness Yearbook (1996–2008 issues), is supplemented with information on its quality $G_i(E)$. The quality of labor is important given that Culliane et al. (2004) has attributed the Hong Kong Port's international status as a major hub port in Asia to a number of factors, of which one of them is its highly educated workforce. Similarly, Wood (2004) discerned that the incompetitiveness of Tanzanian ports is partly due to the shortage of skilled labor and not just the amount of available labor alone.

In the context of airport, Quilty (2003) found that a highly skilled and knowledgeable workforce is required with advancing technology and user demands. By engaging sufficient and high quality labor in its operations, an airport can alleviate

[19] De Neufville and Tsunokawa (1981), Notteboom et al. (2000) and Cullinane and Wang (2006) had used a pre-determined relationship between labor and terminal facilities inputs. Wang and Cullinane (2006) highlighted the risk involved in assuming a pre-determined relationship between labor and terminal inputs because ports have different characteristics of production owing to scale and arrangements of equipment and labor employed.

its rush situation during busy hours by meeting peak demand more efficiently and ensuring seamless workflow that improve its competitiveness.

$G_i(E)$ is estimated by the average level of economic literacy in the economy on the assumption that an average worker's education at the country and port levels are the same. From equation (2.1), we multiply $L(t)$ and $G(E)$ to get $H(t)$.

(iii) The Exogenous Variable X_i

Finally, we can expect two ports with the same physical facilities and labor force but operating in different environments to achieve very different levels of traffic volume. This governing exogenous variable X_i, also termed as the Aggregate Economic Performance variable, is made up of five individual economic variables components $x_{i,j}$, namely, GDP, trade volumes, custom service efficiency and political and economic risk ratings as in equation (2.2). These economic-related data are obtained from the World Competitiveness Yearbook (1996 – 2008 issues). The X_i is then obtained

a. Gross Domestic Product $x_{i,1}$

Robinson (2002) and De and Ghosh (2003) remarked that seaports that are natural gateway to rich hinterlands could be at an advantage compared to ports in small island economies. Likewise, Hayuth (1991), Fleming and Baird (1999) and Loo and Hook (2002) advocated that the presence of a large local market enhances the attractiveness of a seaport.

In the airport industry, Edgar (1995) observed that air cargo growth is influenced by economic growth. Along the same line, Gillen and Lall (1997) articulated that efficiency of an airport will suffer when there is a slowdown in the economy regardless of airport management ability or effort. Alternatively, we can also see that wealthier nations enjoy higher human traffic volumes which trigger more flights to be scheduled to meet the demand. In turn, this increase in the number of flights will not only reduce connecting time for human traffic but also that of transshipment cargo due to the use of combination flights that carry both passengers and cargo. The shorter connecting time will enhance the attractiveness of a city as an air cargo logistics hub.

b. Trade Volume $x_{i,2}$

Other than pipelines, rail and road, airport and seaport are two major channels for exports and imports. Of which, sea transport is a preferred mode of transport for the less time sensitive and bulky products owing to its lower cost. Murphy at al. (1991) and Paik and Bagchi (2000) supported the view on water transport as the primary modal alternative in international distribution. Given that a large trade volume going through a port will stimulate more frequent ship calls and past studies (Slack 1985, Bird and Bland 1988, Tiwari et al. 2003) have found that shippers prefer to choose ports with higher frequency of ship calls, a virtuous cycle will continue as the greater frequency of ship calls stimulated by high volume of trade will, in turn, lead to more shippers selecting the port as transshipment points for their cargoes.

Meanwhile, Larson (1998) noted that the increasing prevalence of the use of JIT coupled with shortening of product life span has resulted more of the trade volume shipped using air transport in substitution for the slower mode of sea transport in recent decades. Hence, Zhang and Zhang (2002) observed that the air cargo volume throughput in the world is strongly linked to trade growth. The latter can be partially attributed to the increasing global sourcing of parts, global production, global marketing and global logistics alliances that replaced the traditional method of local sourcing of parts, local production, local marketing and independent transportation and services (Edgar 1995).

c. Control for Bureaucracy and Corruption $x_{i,3}$

Haynes et al. (1997) discussed how the advantages such as spacious water areas, developed hinterland and convenient land transport link enjoyed by Kaohsiung (Taiwan's largest port) had contributed to the port's early development. However, the authors noted that since its establishment, the port's growth in total cargo and containerized cargo has been lagging behind Hong Kong and Singapore. Haynes et al. reasoned that this phenomenon arose due to customers' dissatisfactions with service such as cumbersome custom clearances, costs and corrupt management. Other ports whose growths have been hampered by bureaucracy and corruption include Indian ports (De Monie 1995), East African ports (Hoyle 1999), Tanzanian ports (Wood 2004) and China ports (Song and Yeo 2004).

Likewise for airports, the trend towards more expensive aircrafts has added pressure to a terminal, making aircraft depreciations high, and aircraft utilizations and turnaround time critical. Cargo whether on a freighter or combination flight must be unloaded rapidly when a flight arrives, and outgoing traffic must be ready for quick loading. Associated with the turnaround time at airport is the paperwork that is required. O'Conner (1995) noted that one of the greatest delays in international air cargo is the awaiting of customs clearance. Kasarda and Green (2005) highlighted that 20 percent of the goods transit time and 25 percent of costs are spent in customs clearance. Hence, Ohashi et al. (2005) pointed out that delays in customs clearance procedure disrupt efficient logistics flows, and thus hinder the hub development in air cargo transport. Accordingly, the Hong Kong and Taiwan governments have taken significant steps to simplify the procedures in its import and export licensing (Zhang 2003 and Tsai and Su 2002).

d. Political and Economic Risk Rating $x_{i,4}$

The demand for port services occurs as a result of the interaction between individuals or sectors within an economy or across countries for the exchange of goods that are produced and consumed at different locations (Tongzon, 1995). Good credit rating of an economy instills confidences in local and overseas investors, increasing employment, promoting exports and consumption of goods (including imported goods). A study by Teng et al (2004) found that economic stability is important in achieving seaport competitiveness in Asia. For airports, Tsai and Su (2002) remarked that the success in air hub developments is closely related to government performances, and political or economic risk is important in determining the success of such developments.

Among these individual economic variables, GDP and trade volume are measured in current US dollars while custom efficiency and risk ratings are given as perceived ratings by businesses in the extensive survey results. For simplicity, GDP per capita is used despite the fact that the effective demand for cargo services in the domestic market is also influenced by the income distribution in the nation and port traffic is often affected by GDP of more than one country. The latter is partially circumvented through the incorporation of trade volume that reflects the economic conditions of international trading partners.

2.2.3 The Results

This sub-section presents the cross-sectional multiple-regressions models with ln $\left(\frac{Y_i}{L_i}\right)$ being the dependent variable and $\ln\left(\frac{K_i}{L_i}\right)$, $\ln\left(\frac{H_i}{L_i}\right)$ and ln X_i being the independent variables[20] as expressed in equation (2.4). The results obtained from ordinary least square (OLS) estimates are given in Tables 2-1 and 2-2 for the seaport and airport industries. We check that errors are normally distributed with constant variances in the residual plots and there is no apparent outlier in the sample of ports.

For seaports, apart from the constants, the coefficient estimates that are statistically significant at 95 percent significance level are capital intensity (i.e., $\ln(K_i / L_i)$) in year 1994 through 2006 and labor productive services (i.e., $\ln(H_i / L_i)$) in year 2000. The exogenous factor, $\ln X_i$, is on the verge of attaining statistical significance in 2006. With the exception of 1994 and 2000, the regression models in Table 2-1 report adjusted R-square values above 87 percent[21].

[20] We have attempted to fit the parameter values in Equation (2.6). However, this results in a model with an adjusted R-square as low as 6 percent and wrong signs. The latter would probably be due to the nature of our data that entails correlation between the predictors. For example, a large $K_i(t)$ is usually associated with large $L_i(t)$ and hence $H_i(t)$. Cullinane and Wang (2006) and Yoshida (2004) observed that labor and capital are complements in the seaport and airport industry.

[21] Although regression models generated using cross-sectional data are usually known to give low R-square values, the relatively lower R square values in 1994 and 2000 may entail 2 possible implications. First, some special and important factors (other than production and economic factors) affect the cargo traffic in the particular two years. Second, disturbances occur in the aggregate industry as ports adjust their physical and human capacities to their intended states.

Table 2-1 Regression Results for Seaport Performances, 1994 – 2006

	Model 1 (1994)	**Model 2 (1997)**	**Model 3 (2000)**	**Model 4 (2003)**	**Model 5 (2006)**
b_0	13.1636 (<0.001)	13.2001 (<0.001)	15.1459 (<0.001)	13.4557 (<0.001)	13.7474 (<0.001)
b_1	1.5588 (0.0038)	0.9743 (0.0005)	1.2116 (0.0000)	1.0349 (0.0001)	1.0978 (0.0000)
b_2	-0.7467 (0.4507)	0.3467 (0.4486)	-2.1722 (0.0002)	-0.0169 (0.9708)	-0.3838 (0.4161)
b_3	0.2202 (0.8087)	0.0595 (0.8924)	0.1653 (0.6847)	0.0915 (0.7979)	0.6063 (0.0836)
R Square	0.8035	0.9367	0.6985	0.9040	0.8943
Adjusted R Square	0.7642	0.9248	0.6483	0.8880	0.8767
Standard Error	1.4422	0.6944	0.7830	0.7385	0.7717
Number of observations	19	20	22	22	22

* Figures in parenthesis give the p-values

On the other hand, Table 2-2 shows that the coefficient estimates that are statistically significant at a 95 percent significance level for airports are ln X_i in models 1, 2 and 4 and $\ln(K_i / L_i)$ in the models 3 and 4. Whereas at a 90 percent significance level, $\ln X_i$ is significant in all the four models, $\ln(K_i / L_i)$ is significant in models 2, 3 and 4 and $\ln(H_i / L_i)$ is significant only in model 2. It can be inferred that the physical capital intensity and nation's aggregate economic performances, but not labor quality, have a significant impact on labor productivity with physical capital intensity assuming higher importance in these more recent years. These regression models have high predictive accuracy between 83.44 to 92.26 percent.

Table 2-2 Regression Results for Airport Performances, 1999 – 2005

	Model 1 (1999)	**Model 2 (2001)**	**Model 3 (2003)**	**Model 4 (2005)**
b_0	10.7749 (<0.001)*	11.0766 (<0.001)	11.1651 (<0.001)	11.0505 (<0.001)
b_1	0.0714 (0.8596)	0.4398 (0.0948)	0.7406 (0.0016)	0.8299 (0.0251)
b_2	0.8039 (0.1228)	0.5609 (0.0918)	0.4295 (0.1866)	0.0872 (0.9074)
b_3	1.0673 (0.0284)	0.8605 (0.0090)	0.5449 (0.0946)	0.8574 (0.0192)
Standard Error	0.3040	0.3430	0.4393	0.4341
R-Square	95.160%	93.182%	89.452%	91.453%
Adjusted R-Square	92.256%	90.909%	86.287%	88.605%
Number of observations†	9	13	14	13

*Figures in parenthesis give the p-values
† Shanghai Hongqiao and Seoul Gimpo airports are taken out of the sample after 2001 and 2003 respectively, after the bulks of their traffic are channeled to Shanghai Pudong and Incheon.

Before proceeding further, it is also imperative to check if there is any presence of multicollinearity[22] which may lead to misleading model results. In all the three models, we examine the signs of parameters and found that they turned out to be as expected. t tests confirm that the coefficients of at least one parameter other than the intercept are statistically significant at 95 percent confidence level and *F* test on the overall model adequacy is also significant. Noting that many data sets with significant multicollinearity may not exhibit the patterns of wrong signs and insignificant t-tests, we compute the Tolerance and Variance Inflation Factor (VIF). The tolerances for all variables are above 0.10, which corresponds to VIF values below 10. Additional diagnostic measures of multicollinearity are Condition Index and Variance Proportions. No multicollinearity problem is indicated since all condition indexes are less than 30 (please see Tables C-1 and C-2 in Appendix C).

[22] While we seek to model port production in a way that multicollinearity is at a minimum, we admit that it still probable that for capital investment in publicly owned ports to be related to the country's GDP, level of corruption and political and economic risk. Also for private ports, it is clear that political and economic risk, the capacity of attracting FDI and the level of bureaucracy and corruption might have a relevant role in the determination of the capital investments in port infrastructure as high levels of corruption or unstable political situations hamper the realization of long-term investments.

As an overall check for multicollinearity, we remove the non-significant parameters and see how the model fit would be affected. The absence of multicollinearity in the seaports and airports models is demonstrated from all the adjusted R-square values that remain very stable in the reduced models as shown in Tables 2-3 and 2-4.

Table 2-3 Results for Reduced Seaport Regression Models, 1994 – 2006

	Model 1 (1994)	**Model 2 (1997)**	**Model 3 (2000)**	**Model 4 (2003)**	**Model 5 (2006)**
b_0	12.2920 (<0.001)*	13.3486 (<0.001)	15.2931 (<0.001)	13.7273 (<0.001)	14.1472 (<0.001)
b_1	1.2852 (<0.001)	1.1003 (<0.001)	1.2458 (<0.001)	1.0439 (<0.001)	1.0355 (<0.001)
b_2	N.A	N.A	-2.1817 (0.0010)	N.A	N.A
b_3	N.A	N.A	N.A	N.A	N.A
R-Square	0.7636	0.9339	0.6957	0.9037	0.8709
Adjusted R-Square	0.7496	0.9302	0.6637	0.8988	0.8644
Standard Error	1.5917	0.6688	0.7657	0.7020	0.8094
Number of observations	19	20	22	22	22

*Figures in parenthesis give the p-values

Table 2-4 Results for Reduced Airport Regression Models, 1999 – 2005

	Model 1 (1999)	**Model 2 (2001)**	**Model 3 (2003)**	**Model 4 (2005)**
b_0	10.0355 (<0.001)*	11.3152 (<0.001)	10.9333 (<0.001)	11.0581 (<0.001)
b_1	N.A	N.A	0.9058 (<0.001)	0.8844 (0.0003)
b_2	N.A	0.9904 (0.0008)	N.A	N.A
b_3	1.6680 (<0.001)	0.9354 (0.0085)	0.8174 (0.0050)	0.8475 (0.0116)
Standard Error	0.3629	0.3833	0.4591	0.4121
R-Square	90.339%	90.542%	87.331%	91.440%
Adjusted R-Square	88.959%	88.650%	85.028%	89.728%
Number of observations	9	13	14	13

*Figures in parenthesis give the p-values

2.2.4 Implications of Findings

We see that all the three regression models take the form:

$$\ln\left(\frac{Y_i}{L_i}\right) = b_0 + b_1 \ln\left(\frac{K_i}{L_i}\right) + b_2 \ln\left(\frac{H_i}{L_i}\right) + b_3 \ln X_i + \varepsilon$$

In order to gain better insights from the model, we rewrite the above as

$$\ln Y_i - \ln L_i = b_0 + b_1 (\ln K_i - \ln L_i) + b_2 (\ln H_i - \ln L_i) + b_3 \ln X_i + \varepsilon$$

Rearranging, we get

$$\ln Y_i = b_0 + b_1 \ln K_i + (1 - b_1 - b_2) \ln L_i + b_2 \ln H_i + b_3 \ln X_i + \varepsilon$$

Recalling that $H_i = L_i G_i$,

$$\ln Y_i = b_0 + b_1 \ln K_i + (1 - b_1) \ln L_i + b_2 \ln G_i + b_3 \ln X_i + \varepsilon$$

The coefficient estimates in the log-linear regression function above measure the percentage change in Y_i associated with one percentage change in the respective parameters, holding the other parameters constant. Specifically, b_1, $1-b_1$, b_2 and b_3 gives the percentage change in throughput for a one-percent change in K_i, L_i, G_i or X_i respectively. By observing how the values of these parameters change over time, we will be able to understand the *trend* underpinning the relative influences of the various competitive aspects on port's growth and hence direct port improvement efforts appropriately. Tables 2-5 and 2-6 below provide a summary for the influence of capital, labor and economic performance on seaport and airport throughputs over the years.

Table 2-5 The Influences of Capital, Labor and Economic Performance on Sea Cargo Traffic, 1994 - 2006

Parameter	Meaning	1994	1997	2000	2003	2006
b_0	The ln(Vol) handled by ports with one unit of K_i, L_i & G_i	13.1637	13.2001	15.1459	13.4557	13.7474
b_1	The % change in throughput, Y_i, associated with 1% change in physical capital K_i	1.5588	0.9743	1.2116	1.0349	1.0978
$(1-b_1)$	The % change in throughput, Y_i, associated with 1% change in labor size score L_i	-0.5588	0.0257	-0.2116	-0.0349	-0.0978
b_2	The % change in throughput, Y_i, associated with 1% change in labor quality score G_i	-0.7467	0.3467	-2.1722	-0.0169	-0.3838
b_3	The % change in throughput, Y_i, associated with 1% change in aggregate economic performance score X_i	-0.2203	0.0595	0.1653	0.0915	0.6063
$1+b_2$	Economies of Scale from physical and total human capital investment	0.2531	1.3467	-1.1722	0.9831	0.6162

Table 2-5 above shows that the constant term increases from 13.1637 to 13.7474 over the years. In other words, for a port with one unit of physical capital, labor and economic rating[23], the volume of cargo handled increases from 521,101 TEUs in 1994 to 934,152 TEUs in 2006. The Asia port industry witnesses an exceptionally high contribution of physical infrastructure corresponding with a low contribution of labor productive services, to cargo traffic in 1994 and 2000. Discounting such abnormal observations, the returns from physical capital shows a general upward trend from 0.9743 percent increase in Y_i for a 1 percent increase in K_i in 1997 to 1.0349 and 1.0978 percent in 2003 and 2006 respectively. On the contrary,

[23] While having the same score of 1, we caution that the amount of capital facilities in ports, size of labor force in economies have increased and the performance of a nation have improved over the years. However, this is not reflected explicitly since the scores are computed based on relative terms.

human capital (i.e., size and skills of workforce), with initial marginal positive returns in 1997, gives negative returns in 2003 and 2006. The aggregate economic performance of a nation begins to have some impact on the performances of its port in the recent years.

Correspondingly, for an airport with one unit of physical capital, labor and economic rating, the volume of airfreight handled increases from 47806 and 62975 metric tons (as exhibited by the increase in the constant term from 10.7749 to 11.0505 over the six years in Table 2-6). The contribution of physical infrastructure to cargo traffic also increases dramatically from 0.0714% increase in Y_i for a 1% increase in K_i in 1999 to 0.8299% in 2005. Human capital gives decreasing returns throughout the study horizon. The aggregate economic performance of a nation impacts the performances of its airport most significantly, averaging 0.8325 for the six years.

Table 2-6 The Influences of Capital, Labor and Economic Performance on Airfreight Traffic, 1999 - 2005

Parameter	**Meaning**	**1999**	**2001**	**2003**	**2005**
b_0	The ln(Vol) handled by airports with one unit of K_i, L_i & G_i	10.7749	11.0766	11.1651	11.0505
b_1	The % change in throughput, Y_i, associated with 1% change in physical capital K_i	0.0714	0.4398	0.7406	0.8299
$(1-b_1)$	The % change in throughput, Y_i, associated with 1% change in labor size score L_i	0.9286	0.5602	0.2594	0.1701
b_2	The % change in throughput, Y_i, associated with 1% change in labor quality score G_i	0.8039	0.5609	0.4295	0.0872
b_3	The % change in throughput, Y_i, associated with 1% change in aggregate economic performance score X_i	1.0673	0.8605	0.5449	0.8574
$1+b_2$	Economies of Scale from physical and total human capital investment	1.8039	1.5609	1.4295	1.0872

The scale returns for the total port development effort is derived from a summation of the rates of returns for physical facilities investment, labor force expansion and labor quality improvement. Overall, both the seaport and airport industries face declining returns to scale.

While the analysis seeks to model port production in a way that multi-collinearity is at a minimum, it still probable that for capital investment in publicly-owned ports to be related to the country's GDP and trade volume. Also for private ports, it is clear that political and economic risks might have the capacity of attracting FDI and a relevant role in the determination of the capital investments in port infrastructure as unstable political and economic situations will hamper the realization of long-term investments. The relationship among cargo traffic, capital investment and economic condition in an economy possibly explains the differences in the significance of the aggregate economic variable between seaport and airport industries. Section 2.3 examines these perplexing relationships in greater details.

2.3 Cluster Analysis at the Disaggregate Individual Port Level

For each year, we plot the graphs for capital productivity[24] against volume and volume against nation's economic performances. From the figures given in Appendix D, we observe that capital productivity is higher for ports with higher volume. Similarly, we also see that traffic volume is positively correlated with economic performance. In each of the figures relating to capital productivity and volume, we fit

[24] Capital productivity in seaports is obtained by dividing volume of cargo with the total berth length. For airports, two types of capital – number of runways and total terminal area are considered. High capital productivity, though signifying good asset utilization and low per unit cost, may also imply possible congestions. On the other hand, low capital productivity may also be attributed to deliberate over-investment in capital and indicate aggressiveness of port authorities in developing their ports. Huge capital investment avoids congestions, leading to shorter turnaround time for ships or aircrafts. This may, in turn, increase the attractiveness of the ports result in better port performances.

a line, using least squares estimates, which provides the predicted (standard) capital productivity for a port of a given volume. Likewise, in each of the figures relating to volume and nation's economic performances, the fitted trend line gives the "economic volume" that a port is expected to achieve for her nation's economic performances, everything else remaining equal.

To obtain more meaningful interpretation of results presented in Appendix D, we construct a grid with the vertical and horizontal axes being traffic volume deviations and capital productivity deviations respectively. To be more specific, the vertical axis measures the deviations between the achieved throughput and economic volume that is computed as a function of nation's performances (which comprise of the GDP, trade volume, bureaucracy and corruption as well as political and economic risk ratings). The horizontal axis gives the deviations of the achieved capital productivity from the standard capital productivity of ports of the given size. Simply put, the deviations measure the vertical differences between the observed points and the fitted line in figures presented in Appendix D. With this grid, we see that ports of particular interest to us will be those ports falling into one of the four categories below:

Quadrant 1 - Aggressor

Aggressor ports invest significantly in their physical infrastructure and facilities. To some extent, these investments may have helped the ports to achieve volume above what they could otherwise achieve given the economic conditions in their operating environments. The low physical capital productivity is a deliberate result from the aggressiveness of these ports to fight for more traffic volume in the near future. Other reasons for their extraordinary achievements can be accredited to their superior geographical locations, natural port attributes, good management practices etc.

Quadrant 2 - Defender

Defender ports are equipped with physical facilities above the required level for their existing volumes. While one possible rationale for keeping excess facilities is to protect their market share, it is also apparent that such investments have little success in attracting greater volume. Relative to the competition, ports in this category may be perceived to be less attractive by users for other reasons (such as inferior geographical location, lack of supporting infrastructure, restrictive open waters/ sky policies, unfavorable service-cost ratio and so forth). As a result, defender ports experience concurrent low capital productivity and cargo volume.

Quadrant 3 - Challenger

Challenger ports are promising ports that have shown exceptionally good performances. At the same time, the high physical capital productivity of these ports implies good asset utilizations and return on investment. However, excessively high capital productivity may result in congestions[25] that hinder ports to achieve even higher volume.

Quadrant 4 - Passive Survivor

An inadequate provision of physical facilities for the existing traffic volume could be one of the causes for the high capital productivity experienced by passive survivor ports. The resulting congestions reduce the attractiveness of these ports, leading to their actual performances to fall below national economic volumes. These ports may perform better by pursuing a proactive investment strategy in the capacity of port facilities.

[25] Talley (2006) suggests that one way to determine the presence of port congestion is to compare the average arrival time of vessels and the average service time of vessel, which gives the average waiting time per vessel.

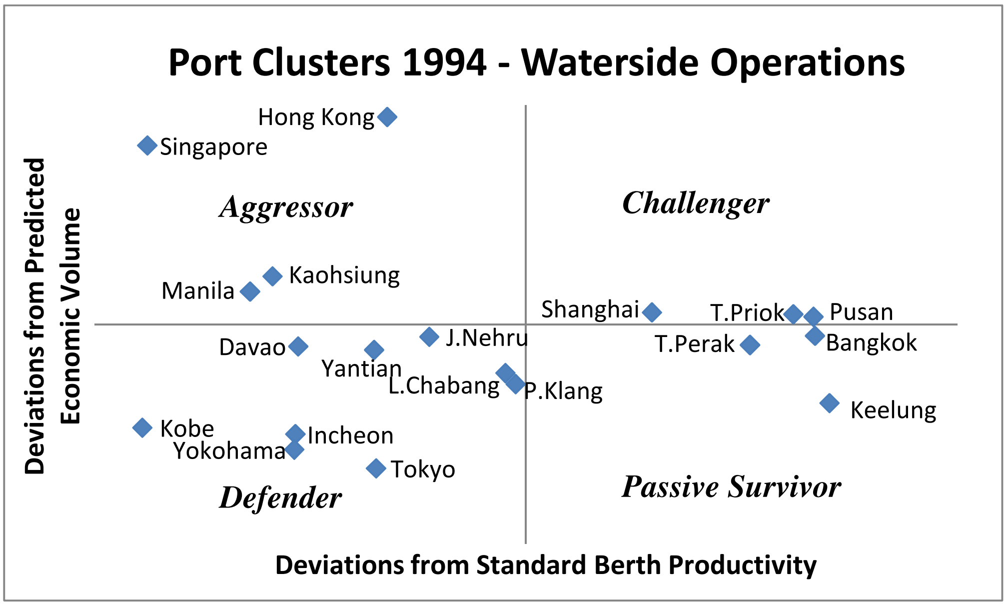
In this sub-section, we analyze the clusters on waterside/ airside operations first followed by clusters on quayside/ landside operations in seaports/airports.

2.3.1 Seaport Cluster Analysis

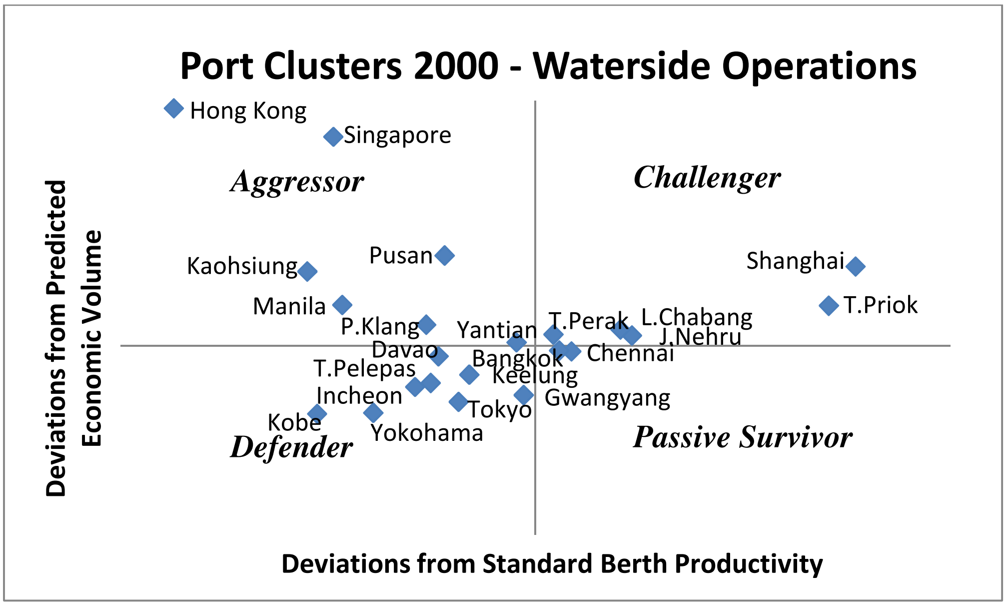
Waterside Operations

Figure 2-1(a)-(c) below shows port clusters for waterside operations between 1994 and 2006 in the Asia seaport industry.

(a)



(b)



(c)

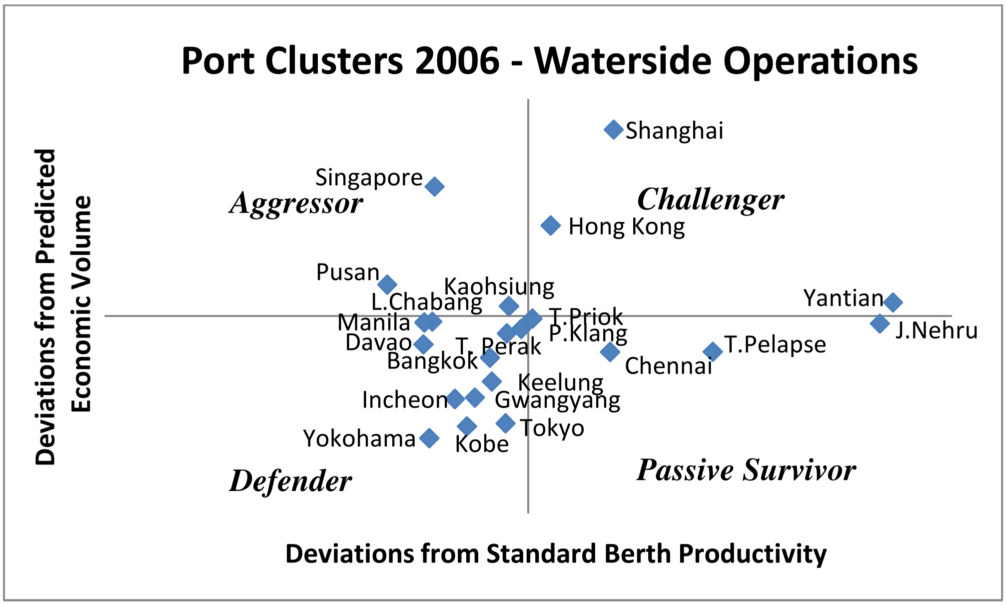


Figure 2-1 (a) Port Clusters – Waterside Operations in 1994; (b) Port Clusters – Waterside Operations in 2000; (c) Port Clusters – Waterside Operations in 2006

(i) Northeast Asia:

Throughout the study horizon, Kobe, Yokohama and Tokyo ports have experienced concurrent low berth productivity and cargo volume. These Japanese ports have not achieved cargo volume comparable to their economic volume despite the provision of adequate physical facilities. A likely cause for such phenomenon may be due to the higher cost in Japanese ports. Recent moves to reduce berth capacity in Kobe and Yokohama have shifted the ports nearer to the standard berth productivity (i.e., the vertical axes), though the ports continue remain as defenders.

Relative to Japan, ports in South Korea are estimated to be 30 % to 40% cheaper. Initial aggressive investment in berthing facilities in Pusan, a major port of South Korea and a challenger to other ports in the region, has brought significant improvements in cargo traffic above economic volume. However, subsequent expansions are not met with equal success. Until today, much of the South Korean traffic is still concentrated in Pusan port which is an aggressor. As traffic in Incheon and Gwangyang are considerably lower than Pusan, Incheon and Gwangyang are defenders. Of the two ports, berth capacity utilization is lower in Incheon.

Following the rapid rise in the Chinese economy, Shanghai and Yantian ports have shown concurrent improving capital productivity and volume. Both ports are classified as challengers by 2006. As berth utilizations approach their limits, subsequent increase in berth capacity is expected. In the Special Adminstrative Region (SAR), the port of Hong Kong has continued to invest heavily into its port facilities. Even though the Hong Kong port has lost some traffic to the upcoming ports in China, the port continues to achieve impressive cargo traffic.

In Taiwan, the port of Kaohsiung is an aggressor characterized by low berth productivity and high cargo traffic. However, there are indications that Kaohsiung port is losing its attractiveness as the amount of cargo that the port achieved above economic volume dwindles significantly after 2000. By 2006, Kaohsiung port is positioned close to intersection of the axes that implies industry-standard berth utilization and cargo volume. The second largest Taiwanese container port is Keelung port, a passive survivor in 1994. Although cargo volume continues to grow, the port becomes a defender after its berth capacity is expanded by more than double.

(ii) Southeast Asia

The Singapore port, as a major transshipment port in Southeast Asia, has consistently attained traffic above its economic volume. The port is an aggressor which equipped with the huge berth capacity. However, the setting up of Tanjung Pelepas port (among other ports in Malaysia) just 9.1 km away, has captured some traffic from the Singapore port. Since the beginning of its operations, Tanjung Pelepas port has enjoyed increasing berth utilization from increasing cargo traffic even though its volume still falls short of its economic volume. The low cargo volume handled may be resulted from the inadequacy of berth capacity, following Tanjung Pelepas port's transition from a defender to a passive survivor. At the same time, traffic at Port Klang (the most established and largest port in Malaysia) is growing at a faster pace than capacity expansion. Port Klang is at the verge of joining cluster of passive survivors with Tanjung Pelepas in 2006.

Bangkok and Laem Chabang are the two largest ports in Thailand. Moving from a passive survivor to a defender, Bangkok port faces decreasing berth utilization as berth capacity increases and cargo volume drops below economic volume. On the contrary, Laem Chabang port experiences significant growth (in traffic and size) between 1994 and 2000 as the port progresses from a defender to a challenger. Further increase in volume is expected to bring the port into the cluster of aggressors.

In Philippines, Manila port is an aggressor in 1994 and 2000. The port joins Davao in the cluster of defenders in 2006 when the cargo traffic growth in Manila port falls short the economic growth. Meanwhile, increasing berthing capacity in Tanjung Priok and Tanjung Perak put the ports in the right capacity and both

Indonesia ports attain cargo traffic on par with their economic volume (i.e., Tanjung Priok and Tanjung Perak ports are positioned at the intersection of axes in 2006).

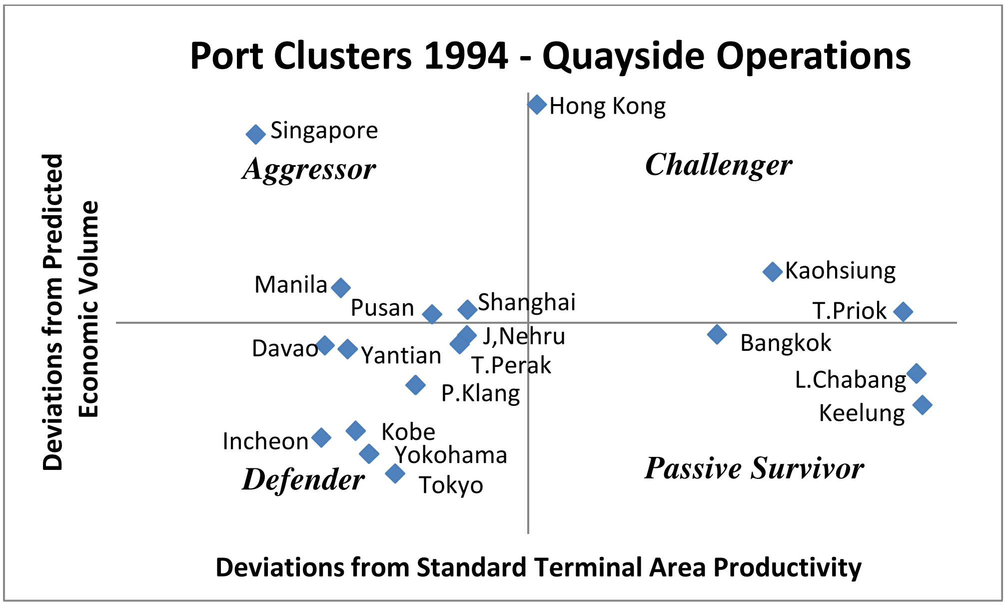
(iii) South Asia

India, being a vast country in South Asia, enters a stage of rapid economic growth in the recent decades. Congestions in Jawaharlal Nehru port become increasingly severe as increase in port berthing capacity cannot keep pace with the growth in cargo traffic that comes along with economic progression. Even with the setting up of Chennai container port, the Jawaharlal Nehru port continues to move rightwards. As passive survivors, both Indian ports will benefit from berth capacity additions that allow handling of more cargo traffic.

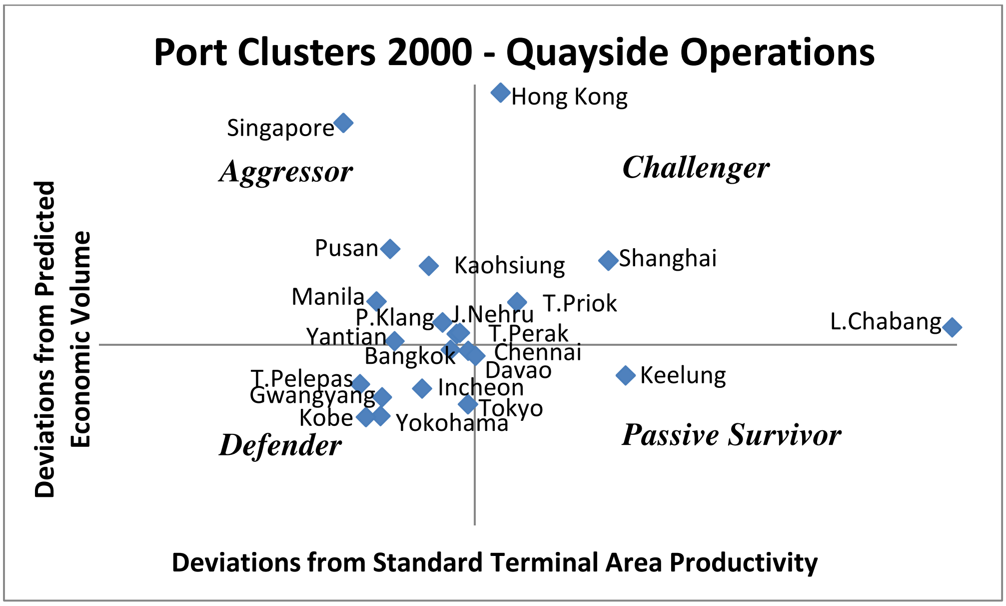
Quayside Operations

Figure 2-2(a)-(c) below shows port clusters for quayside operations between 1994 and 2006 in the Asia port industry.

(a)



(b)



(c)

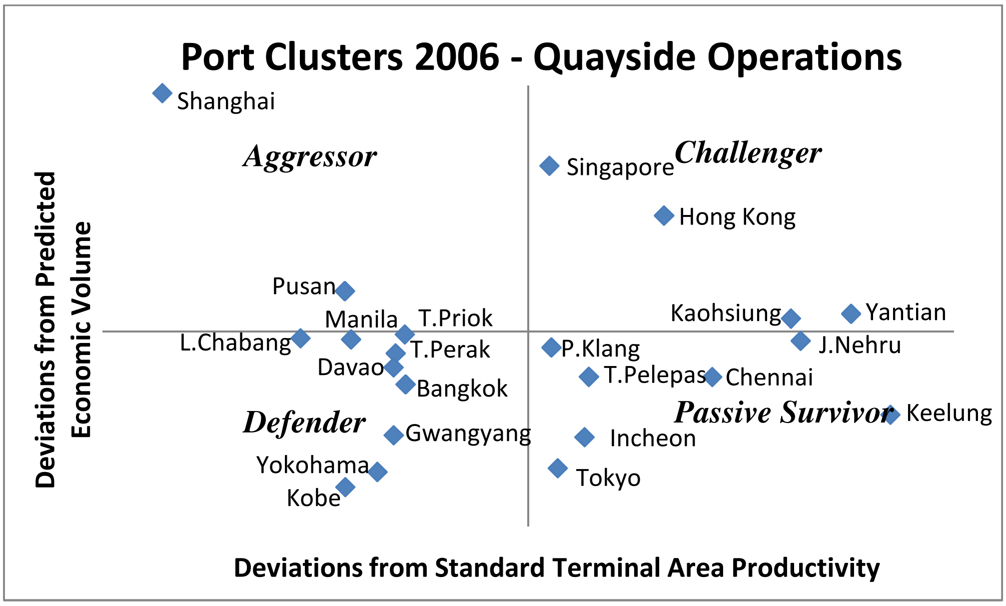


Figure 2-2 (a) Port Clusters – Quayside Operations in 1994; (b) Port Clusters – Quayside Operations in 2000; (c) Port Clusters – Quayside Operations in 2006

(i) Northeast Asia

All the three Japanese ports (i.e., Kobe, Yokohama and Tokyo) register cargo traffic below its economic volume. As Tokyo port overly trims down its terminal size, the port departs from its defender sister ports (Kobe port and Yokohama port) to join the group of passive survivors.

In South Korea, aggressor Pusan port consistently attains cargo traffic above its economic volume with huge investment in port capacity. Traffic and capacities in the Gwangyang and Incheon ports have also grown substantially, even though these newer Korean ports have yet to achieve traffic that is at least on par with their economic volume.

Hong Kong port is a challenger that has shown exceptional cargo traffic with high utilization of its terminal area. Until the early 2000s, Hong Kong has registered the most extraordinary traffic performance above economic volume. Though traffic at Hong Kong port continues to be impressive, its title as "most extraordinary performer" is overtaken by the Shanghai port in 2006. Some reasons are the soaring economic growth in the eastern regions of China, lower operating cost in China and the aggressive port development strategy undertaken by the Shanghai port. The economic growth in China as a country has also brought increasing traffic to other Chinese ports. Over the years, Yantian port is seen to progress from defender to aggressor to challenger.

Kaohsiung port moves between the clusters of aggressors and challengers with cargo traffic staying above economic volume as port operators adjust the terminal area of the port. While Keelung port experiences increase in absolute cargo volume, standstill capacity may be a cause for the lagging of traffic growth behind economic growth and the port remains as a passive survivor throughout the study horizon.

(ii) Southeast Asia:

The Singapore port has enlarged its terminal size considerably to cope with the cargo traffic that has increased over the last decade. In spite of the keen competitions from the Malaysian ports that have taken away some market shares from the Singapore port in the expanding pie, the trend towards higher utilization of terminal area persists in the Singapore port. As a result, the Singapore port transforms from an aggressor to a challenger.

As the Malaysian government embarks on a national agenda to develop the country's logistics industry, Port Klang benefits from huge increases in cargo traffic that promote its status from a defender to an aggressor in 2000. Port Klang subsequently becomes a passive survivor as increase in terminal area cannot keep pace with the traffic growth. Meanwhile, the new Tanjung Pelepas port also advances directly from a defender to a passive survivor with rapid traffic increase.

In Thailand, Bangkok and Laem Chabang ports are both passive survivors in the early 1990s. Beginning 2000s, the severe congestions in Laem Chabang port have prompted the Thai port authority to pour in substantial funds to expand the physical size of port so much so that Laem Chabang is four times the size of Bangkok by mid of the 21^{st} century. Some terminal expansions to Bangkok are undertaken after 2000. While such quayside capacity expansions stimulate some cargo traffic growth in Laem Chabang initially, further additions to terminal size have negligible stimulating effect on traffic and placed the Thailand ports into the cluster of defenders.

Owing to the declines in cargo traffic in the port of Manila, the Philippines port authorities reduce the terminal area of the port to cut down the unnecessary overheads. As the capacity adjustments is less than the reductions of cargo traffic, the status of Manila port degrades as an aggressor to defender. Davao port remains in the cluster of defenders throughout the study horizon.

The two Indonesian ports, Tanjung Priok and Tanjung Perak, are getting closer to each other. This observation is accounted by two main factors. One factor is large terminal area that is being added to the port of Tanjung Priok. The second is that the cargo volume at Tanjung Perak catches up with Tanjung Priok. Nonetheless, Tanjung Perak remains as a defender while Tanjung Priok upgrades from a challenger to an aggressor in the port industry.

(iii) South Asia

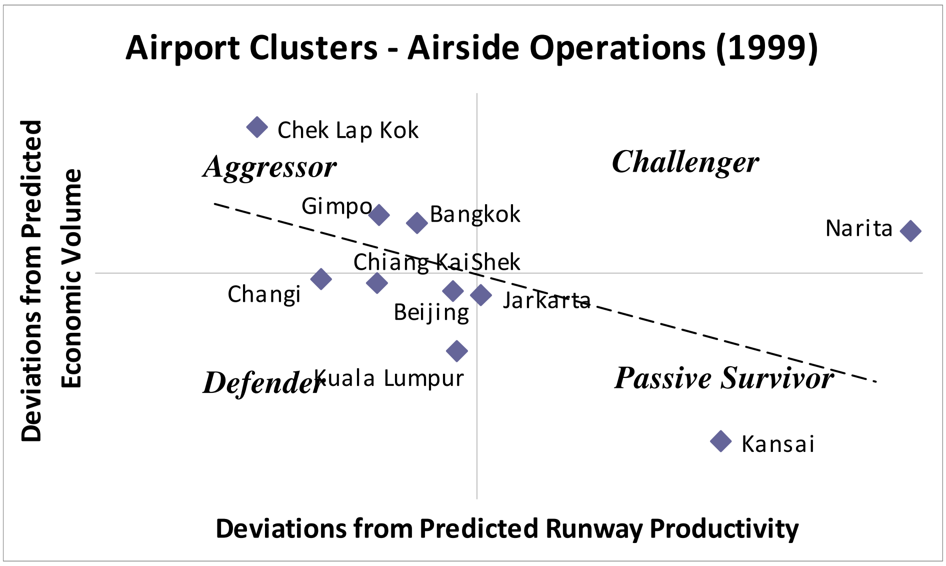
Jawaharlal Nehru port, as an aggressor, exhibits healthy growth in the 1990s to the early 2000s. Meanwhile, Chennai port is equipped with a quayside capacity level that is well-suited to the traffic volume being handled at the time of establishment. Nonetheless, rapid developments of the India economy have brought along huge traffic increases that put pressure on the capacities of Indian ports. Both Jawaharlal Nehru and Chennai ports are in the cluster of passive survivors in 2006.

2.3.2 Airport Cluster Analysis

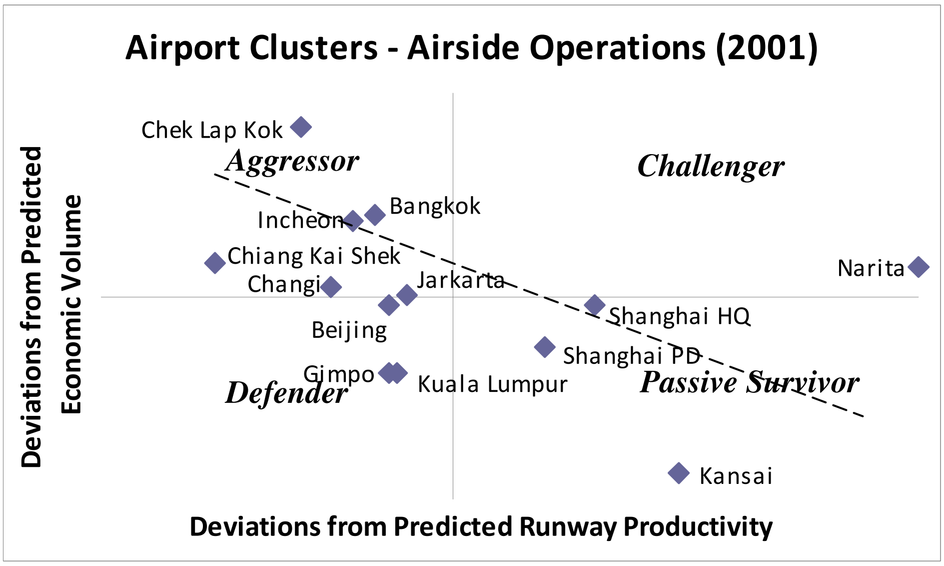
Airside Operations

Figures 2-3(a)–(d) depicted the strategic inclination of airports for their airside operations. The balancing partition, represented by the dashed line, suggests that low runway utilizations may be associated with high traffic above economic volume in the earlier years (i.e., 1999 and 2001). But, more recently, most airports lie close to the vertical axis. These airports achieve almost standard runway productivity for their size but their associated deviations (in some cases, large deviations) from their respective economic volumes point to the fact that there are other deciding factors for an airport’s cargo traffic.

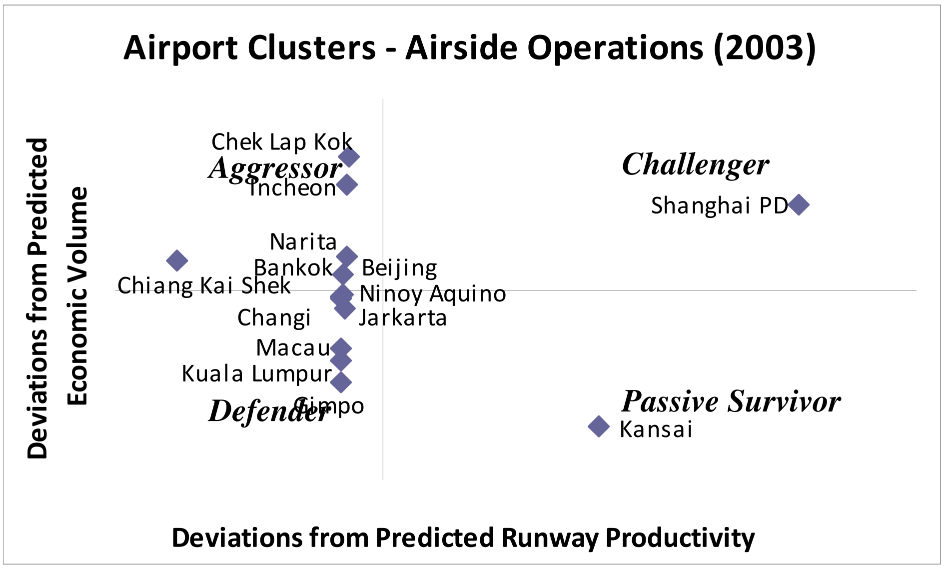
(a)


Airport Clusters - Airside Operations (1999)
Chek Lap Kok
Aggressor
Challenger
Gimpo
Bangkok
Narita
Chiang KaiShek
Changi
Beijing
Jarkarta
Defender
Kuala Lumpur
Passive Survivor
Kansai
Deviations from Predicted Economic Volume
Deviations from Predicted Runway Productivity

(b)


Airport Clusters - Airside Operations (2001)
Chek Lap Kok
Aggressor
Challenger
Bangkok
Incheon
Chiang Kai Shek
Narita
Changi
Jarkarta
Shanghai HQ
Beijing
Shanghai PD
Gimpo
Defender
Kuala Lumpur
Passive Survivor
Kansai
Deviations from Predicted Economic Volume
Deviations from Predicted Runway Productivity

(c)



(d)

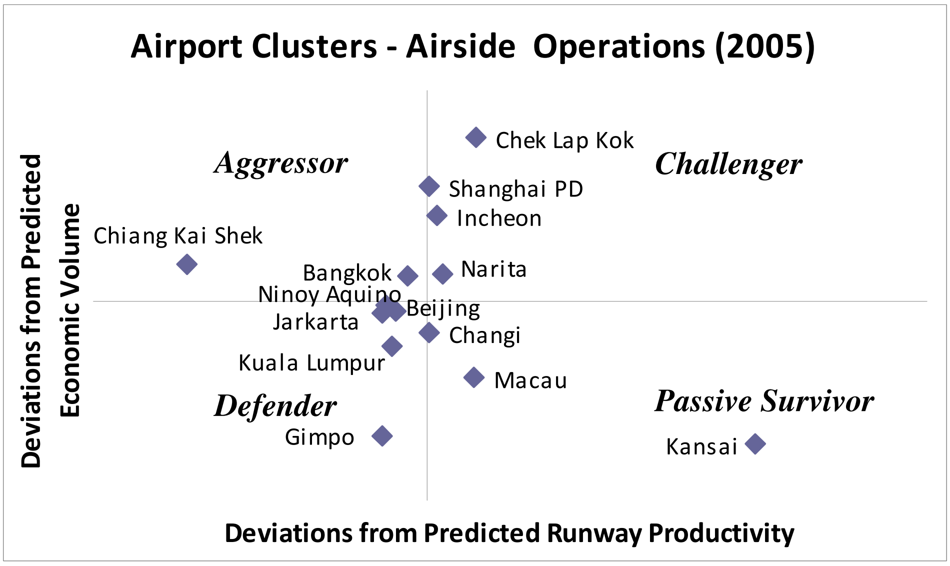


Figure 2-3 (a) Airport Clusters – Airside Operations in 1999; (b) Airport Clusters – Airside Operations in 2001; (c) Airport Clusters – Airside Operations in 2003; (d) Airport Clusters – Airside Operations in 2005

(i) North East Asia:

Being the major airport for the capital city of *Japan*, Narita airport is a challenger to other Asian airports in 1999 and 2001. The additional of a new runway after 2001 moves the airport into the cluster of aggressors in 2003. Perhaps, owing to lag effect of capacity investment on airlines demands, the airport returns to the status of a challenger with slight increases in traffic in 2005. The second largest Japanese airport, Kansai, is a passive survivor throughout the study horizon. With a higher runway productivity and lower cargo volume than the industry norm, this could be a sign that airside congestion is hindering further development of the airport.

Incheon airport has its beginnings as an aggressor owing to the *South Korea*'s government plan to develop the country into a regional air hub. Despite the enormous investments into capacity, the spectacular traffic growth of the airport exceeds capacity and Incheon airport becomes a challenger exhibiting runway productivity in 2005. Meanwhile, Seoul Gimpo airport transforms from an aggressor to a defender as more of its traffic is being channeled to the new Incheon airport. Subsequent reduction in the capacity of Gimpo is expected to bring the airport into the cluster of passive survivors.

Situated in the capital city of *China* in northern china, it is unsurprising that Beijing Capital airport maintains large capacity even though this may not lead to significant cargo traffic improvements. As such, the cluster analysis results show negligible movement in position of Beijing Capital airport as a defender. In recent years, eastern China experiences a soaring escalation of the manufacturing investments. Shanghai Pudong airport, in the northeast part of China, has achieved remarkable growth especially between 2001 and 2003 when the airport officially takes over most of the international traffic from under-capacitated Shanghai Hongqiao airport. Shanghai Pudong airport will take on the status of an aggressive player as more investment is pumped into the airport.

At the Southern part of China, Chek Lap Kok airport in *Hong Kong* is an aggressor in the early 2000s. By 2005, this airport has achieved such impressive traffic that gives it a runway productivity significantly above the standard productivity and hence a challenger airport status. On the other hand, defender *Macau* airport becomes a passive survivor due to the slower development of its air logistics industry relative to other parts of East Asia that places less emphasis on the airport's role as an air cargo hub. In *Taiwan*, Chiang Kai Shek airport has added a new runway after 1999. The provision of an additional runway, among other government initiatives and incentives, stimulates an obvious increase in traffic in Chiang Kai Shek airport. The airport progresses to an aggressor status rather than a mere defender in the subsequent years.

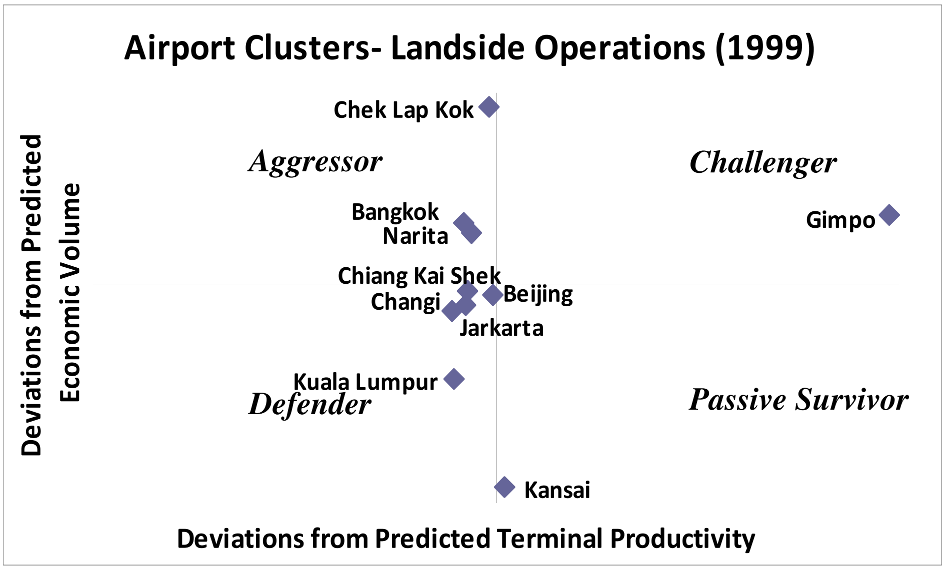
(ii) Southeast Asia:

Throughout 1999 to 2005, Changi and Kuala Lumpur airports are defenders and Bangkok airport is an aggressor. Ninoy Aquino and Jarkarta Soekarno Hatta airports are on the boundary between aggressor and defender, implying low runway productivity and traffic quite on par with economic conditions. These findings are congruent with expectation, considering that they are major airports for their respective country and the provision of adequate capacity is indispensable regardless of traffic or capacity utilization levels.

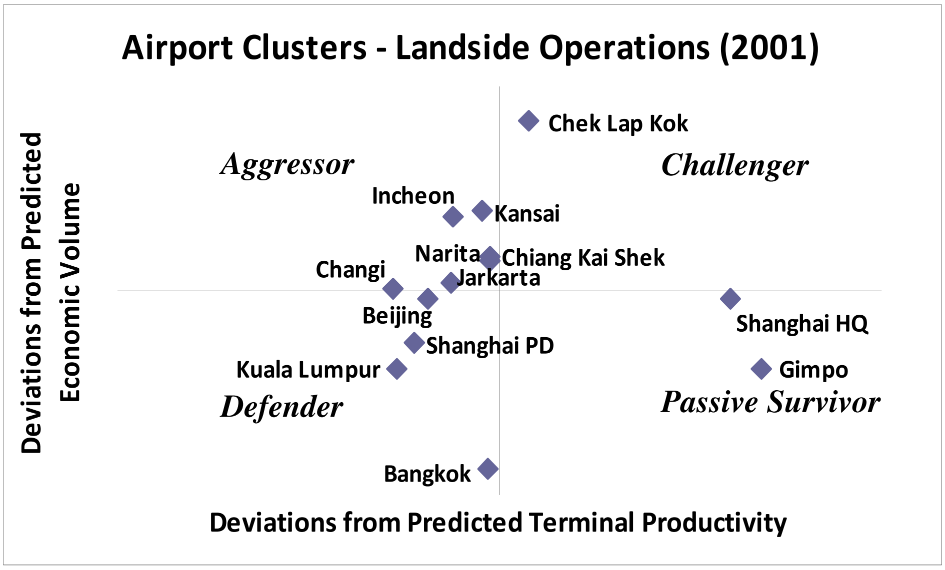
Landside Operations

Figures 2-4(a)-(d) show that almost all airports lie near the vertical axis in 1999. However, the alignment is broken in the latter years. Particularly, the airports form a fuzzy negative slope in the balancing partition of the productivity-traffic grid in 2003 but transform into a positive slope in 2005. This leads to a possible inference that cost is gaining importance in the recent years.

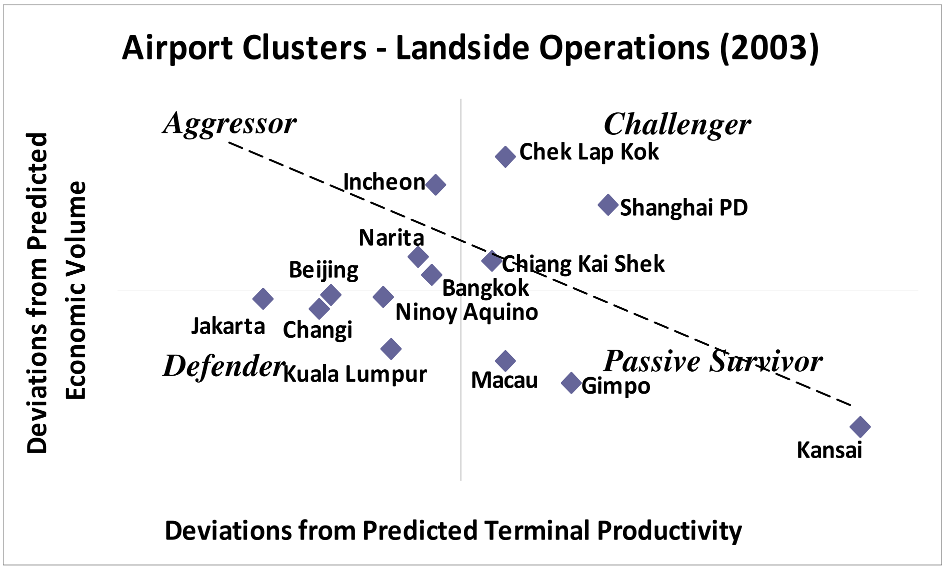
(a)


Airport Clusters- Landside Operations (1999)
Chek Lap Kok
Aggressor
Challenger
Bangkok
Narita
Gimpo
Chiang Kai Shek
Changi
Beijing
Jarkarta
Kuala Lumpur
Defender
Passive Survivor
Kansai
Deviations from Predicted Economic Volume
Deviations from Predicted Terminal Productivity

(b)


Airport Clusters - Landside Operations (2001)
Chek Lap Kok
Aggressor
Challenger
Incheon
Kansai
Narita
Chiang Kai Shek
Changi
Jarkarta
Beijing
Shanghai HQ
Shanghai PD
Kuala Lumpur
Gimpo
Defender
Passive Survivor
Bangkok
Deviations from Predicted Economic Volume
Deviations from Predicted Terminal Productivity

(c)



(d)

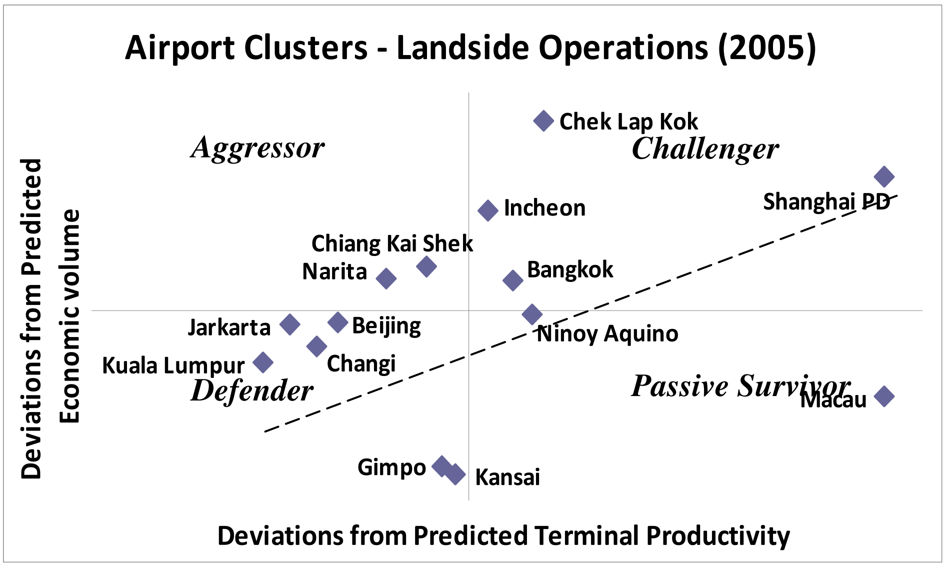


Figure 2-4 (a) Airport Clusters – Landside Operations in 1999; (b) Airport Clusters – Landside Operations in 2001; (c) Airport Clusters – Landside Operations in 2003; (d) Airport Clusters – Landside Operations in 2005

(i) Northeast Asia:

Narita airport is an unwavering aggressor that consistently performs above its economic volume. The airport provides cargo service with little landside congestion as reflected by its relatively low terminal area utilization. On the other hand, the positions of Kansai airport have been volatile over the six years. Between 1999 and 2001, the passive survivor airport joins the cluster of aggressors following a fall in terminal productivity that is accompanied by a more than proportionate increase in traffic. The perception that the potential growth of Kansai's is limited by its terminal area is further reinforced when sharp increase in terminal productivity in 2003 is met with traffic reductions to a level that is below its economic volume; and the airport returns to a passive survivor status. However, this perception is later proved to be incorrect when subsequent increase in terminal area turns the airport into defender with no apparent increase in traffic. Such observation may suggest that the potential growth of Kansai airport is not hindered by landside congestion but rather by other factors. Of which, cost may be one of them.

Following the plan to convert Seoul Gimpo into a domestic airport, international traffic is being diverted to Incheon airport. As a result, Seoul Gimpo airport experiences gradual and consistent terminal productivity declines that replace the airport's initial standing as a challenger with that of a passive survivor in 2003. Meanwhile, Incheon airport progresses from an aggressor in 2001 and 2003 to a challenger in 2005 as the higher traffic utilized the airport's capacity as planned by the authorities.

Beijing Capital and Shanghai Hongqiao airports in the mainland China exhibit some signs of landside congestions. For Beijing Capital airport, a reduction of terminal area productivity in 2003 has enabled the defender airport to achieve its economic volume but an increase in terminal area productivity in 2005 gives an opposite effect. Likewise, Shanghai Hongqiao airport exhibits high terminal productivity but low traffic as a passive survivor in 2001. After the diversion of international traffic from Shanghai Hongqiao airport to the larger Shanghai Pudong airport in 2001, concurrent increases in volume and terminal productivity move the defender Shanghai Pudong airport swiftly to the cluster of challengers in 2003. Growth in traffic and terminal area productivity perpetuate into 2005 and Shanghai Pudong airport continues to grow as a challenger.

Chek Lap Kok airport is an extraordinary performer. Being an aggressor in the late 1990s, the airport is seen as challenger since the turn of the decade with impressive performances in traffic and capital utilization. Chiang Kai Shek progresses from a defender to an aggressor to a challenger as traffic volume gradually improves over the years. The airport returns to aggressor as additions to terminal area after 2003 ease congestion and bring along higher traffic. Macau airport also exhibits some signs of landside congestions as a passive survivor. Increase terminal area productivity between 2003 and 2005 has brought along some reductions in traffic volume.

(ii) Southeast Asia

Changi airport's terminal area productivity falls gradually from 1999 to 2005 while its traffic volume fluctuates around the economic volume. In Thailand, Bangkok airport experiences dramatic fluctuations among the clusters that also show no apparent relationship to terminal area productivity. Similarly, landside congestion is not a cause of underperformance for defender airports like Kuala Lumpur and Jarkarta Soekarno Hatta airports, which experience concurrent low terminal area productivity and traffic volume.

2.4 Discussions

The volume of cargo handled by an average Asian port has increased over the years that the analyses have undertaken. Alongside, the rising significance of physical facilities on port cargo traffic is compatible with the ever-increasing expectations of liner shipping companies/ airlines for efficient services in that an adequate provision of physical facilities relative to the cargo volume enables quick vessel/ aircrafts turnaround and timely processing of cargo. The capacity constraints at Asian ports are well documented in the literature. For examples, De Monie (1995) and Cullinane et al. (2004) observed that the insufficient provisions of physical infrastructure such as berths entail long waiting time of ships to load and unload their cargo in Indian and China ports. Meanwhile, Hufbauer et al. (1995) witnessed the acute competitions between US and Asian carriers for slots at Narita airport due to congestions. The adverse impact of congestion on quality of service to carriers becomes more acute in the late 1990s when the increase in physical infrastructure cannot keep pace with the rapidly increasing cargo traffic.

According to Heaver (1995), contemporary port selections by shippers and carriers are influenced by the most efficient terminal facilities and services among the competition. The push for more efficient port services, together with increasing labor cost, has also prompted ports to mechanize. At the same time, technological advancement has enabled ports to engage in extensive automations[26] in different areas of port operations. Another possibility is that ports have increased their level of outsourcing during their development in the 1990s, which result in a declining number of workers directly hired by the ports (Chapter 5 of the dissertation examines

[26] Prior to the shift towards automation, airports like Narita and Changi that are operating under cost escalations have attempted to control their cost by hiring cheaper labor from Thailand, Philippines and India. As operating cost continues to increase, these airports resort to more extensive automations made possible through technological advancements and airport users' acceptances.

this issue in greater depth). These lead to a reduction in the need for labor, which explains the declining returns of labor in ports. Comparatively, the returns of economic literacy of labor exhibited more significant reductions. In general, the education level of the present labor force is higher compared to the past. Microeconomics theory postulates that the percentage increase in gains from an additional year of schooling falls as the amount of schooling rises. Considering that more educated workers command higher wages, the net benefit to a port inevitably diminishes. While the returns from labor and its productivity show declining trends that reflect the reduced port reliance on manual labor, the negative rate of return in the seaport industry further implies that the substitution of labor for automation is detrimental to the performance of a seaport. Particularly, the negativity in the returns for labor upgrading is magnified as cost control and efficiency in port operations gain growing importance under the intensified competition.

Summing up the returns from physical and human capital investment, diminishing scale returns for the general effort towards rapid and reliable port services may also indicate the increasing ease of newly developed and smaller ports to catch up with the more established and bigger ones as size of operations (leading to cost efficiency and throughput volume generation) is less of a hurdle to overcome now.

More interestingly, the exogenous factor exhibits different degree of influences on the cargo traffic in the Asia seaport and airport industries. Specifically, the aggregate economic performances of a nation are shown to exert significant influences on air cargo traffic but not sea cargo traffic. One possible reason for the insignificance of the economic factor to port container traffic is that containers contain low value, bulky, less time-sensitive and usually staple products or necessities such as rice, oil, textile and intermediate inputs to production of final goods which are relatively insensitive to income level and other aspects of the exogenous variable. Whereas, air cargo generally comprises of high value and/or time sensitive products, higher income increases demand for high value products and quick custom clearance is critical for time sensitive products. Other contributing factors include shortening product lifespan, increasing JIT adoption and lowering airfreight rates that prompted shippers to move from the use of sea transport to air transport on condition that there will be greater demand for higher value and more rapidly launched new products. Nonetheless, economic conditions begin to have some impact on the cargo traffic of seaport in the more recent years. Technological breakthroughs in the maritime sector such as faster vessels and refrigeration etc., that allow liner shipping companies to carry more time-sensitive cargo and perishables, may provide an explanation for the increasing significance of economic conditions.

From another angle, the insignificant economic influences on sea cargo traffic can be explained by the fact that improvements in economic conditions in advanced and developing nations affect sea cargo traffic differently and thereby producing an offsetting effect. This observation can be more clearly seen through the cluster analysis that reveals the dynamics within the Asia port industry as major ports adjust their strategic postures. Such adjustments result in some disturbances in 1994 and 2000 before settling at the steady state in 2006. Based on their exhibited strategic postures, ports are classified as aggressor, defender, challenger and passive survivor. The dynamics of Asia port industry depict the “flying geese paradigm” as cargo traffic at ports subsequently follow the relocation process of manufacturing industries from advanced to developing countries during the latter's catching-up process. Port traffic in North East Asia is initially diverted from the Japanese ports to Pusan, where cost is significantly lower in neighboring South Korea. Over the years, this cost advantage enjoyed by Pusan is gradually being eroded by upcoming Chinese ports. Meanwhile, Hong Kong also loses its cost competitiveness to Chinese ports. In South East Asia, Malaysian ports have gained a significant share of the expanding market from Singapore. Competitive prices and improving efficiency in less developed countries, apart from the provision of dedicated terminals, are some of the major reasons. Similarly, the rapid developments of the Indian economy in South Asia boost the cargo traffic at major Indian ports. Such observations are reasonable considering that demand for port services are a derived demand from manufacturing industries.

The cluster analysis that is carried out within the Asia airport industry also helps to further distinguish between the influences of airside and landside facilities, noting the potent effects of the physical architecture of an airport on air cargo traffic. After adjusting for differences in airport size and economic conditions, it is found that high (low) runway productivity is associated with low (high) cargo traffic in 1999 and 2001. This implies that airside congestion may be hindering potential demand for air cargo service. In response, Chiang Kai Shek and Narita airports have added new runways while China and South Korea re-divert their traffic from Shanghai Hongqiao and Seoul Gimpo airports to Shanghai Pudong and Incheon airports respectively. Despite the fact that almost all airports achieved “industry standard” for runway productivity in 2003 and 2005, traffic still differ significantly. Therefore, it is reasonable to believe that other factors beyond adequate runway provision and aggregate economic circumstances play a greater role in driving demand of air cargo service. In comparison, airport landside operations exhibited an interesting relationship between the provision of facilities and cargo traffic in years 2001 through 2005. In 2001 and 2003, airports that plan for extra capacity attract more traffic. Adequate provisions of facilities, though lowering the utilization of such facilities, ensure that cargo will be able to flow smoothly and in a more-timely manner without incurring unnecessary waiting time for loading and unloading. However, the reverse is observed in 2005. High utilization of physical landside capacity is associated with high air cargo traffic. Since high productivity (or utilization) is achieved when a large cargo volume is spread over the given capacity, it may be inferred that cost savings has become more critical under the intensifying competitive pressure and the narrowing profit margins in the downstream cargo service industry of the airlines.

2.5 Conclusions

Lirn et al. (2004a) noted that the increasing concentration within the liner shipping industry has increased the potential impact of a move by a major port user (for example, a global container carrier) on the individual port's overall traffic. In the airport industry, Taneja (2002) observed that the top ten air cargo hubs account for around two-thirds of air cargo movements; whereas the top ten passenger hubs account for only one-third of passengers. Holloway (2003) advocated that the growth of focused cargo alliances among is likely to add further momentum to this pattern of concentration, which fuels greater competition among airports for cargo traffic. At the same time, increasing freedom for carriers to choose where they will base their hubs and which ports they will use to route their connecting traffic has translated into heighten demands for efficient port services and competition among ports in Asia intensifies as each port tries to retain their existing user base and attract more users.

Given the competitive pressures, it is of paramount importance for a port to be able to provide the best services in the most efficient manner possible in order to survive the competition. This chapter explores into production and economic factors accounting for the differing success among ports in East Asia. There are three implicit assumptions underpinning the analysis. First, the primary objective of the port is traffic maximization and the port is assumed to be a price taker in its input market. The corollary of this assumption is that input prices may be treated as exogenous to the model. Second, the production function that is estimated in operationalizing the model relates to a single form of output. This is justified on the basis that the main operational function of cargo terminals and the main issue of policy interest is container and airfreight handling (Cullinane and Song 2006). Third, the log-linear Cobb-Douglas function is assumed to be an appropriate structure for the model. We decompose the contributions to a port's output into four sources, namely, labor (quantity and quality), capital, and an aggregate economic performance measure. The good fit [27] of real empirical data to the proposed analytical translog model demonstrates the applicability of the model in explaining the traffic handled by the ports. By analyzing data across different years, the chapter examines how the contributions of these factors to cargo traffic in the aggregate East Asia port industry have changed over time. Through a cluster analysis, the study further investigates the dynamics within the industry.

In a nutshell, findings in this chapter have shown that common in the Asia seaport and airport industries an average port handles more traffic than before with the rates of return from physical capital investment on throughput rising consistently. This is reasonable with the increasing emphasis placed on speed, since facilities shortages have negative effects on port productivity and quality of services rendered to port users (i.e., liners, carriers and shippers) in terms of delays. At the same time, the returns from labor expansion and productivity improvement have fallen over the

[27] Regression models generated using cross-sectional data are usually known to give low R-square values. In this study, we have obtained amazing high adjusted R-square values. In addition, we have ascertained that our analytical model has allowed us to get around with the problem of multicollinearity effectively.

years owing to more extensive outsourcing, mechanization and automation of operations and custom clearances that have reduced the reliance on manual labor. The observation that labor quality improvement through education falling over the years is also congruent with microeconomic theory, which postulates that the percentage increase in gains from an additional year of schooling falls as the amount of schooling rises. Overall, the scale returns for operations of the cargo service in the East Asian port industry have fallen prominently. Two profound implications, especially for established ports, can be inferred from these results. First, smaller ports are more likely to be able achieve cost efficiency comparable to bigger counter parts. Second, ports will need to seek more creative ways to control cost as this study also envisages that cost savings has become more critical with increasing competitive pressure. One possible means for cost control is through outsourcing of peripheral services to specialized third parties.

Conversely, improvement in the economic standing of a nation is the most significant factor that stimulates cargo traffic at airports but yet has no significant effect on seaport performances. On one hand, we could be contended that the observed results could arise from the different nature of cargo handled by these two types of ports, such that cargoes in airports are often high-valued and time sensitive whereas cargoes in seaports are generally bulky and low value (per unit weight) items. On another hand, the cluster analysis that is subsequently carried out suggests that the effect of the improvements in economic conditions on sea cargo traffic differs between advanced and developing nations and thereby offsetting the statistical significance in regression analysis at the aggregate seaport industry level.

Through the cluster analysis, it is observed that the traffic diversion from higher-cost seaports to lower-cost seaports displays the “flying geese paradigm” as the latter catches up technically and economically. In the case of airports, an ample provision of physical facilities for landside operations is shown to be more important in driving an airport's cargo traffic performances compared to that for airside operations in recent years. Jorge and Rus (2004) reflected these findings when they opinioned that it is the terminal capacity that determines potential output and airside capacity matters little in comparison since cargo flights can operate during off-peak periods. Similar to Ohashi et al. (2005), our study also shows that time savings has become more critical than cost savings in the more recent and perhaps future years as utilization of landside facilities taken a step behind.

Admittedly, the analysis in this chapter is limited by the unavailability of data that precludes a more in-depth analysis. Firstly, surface access (or more generally inter-modal access) is not included in the study. Among many, Hayuth (1991) advocated that the quality of spatial connection of the seaport to its potential hinterland is a critical element for port competitiveness. Similarly Meredith (1995), Zhang (2003) and Lee and Yang (2003) pointed out that an airport attractiveness will be severely undermined if shippers will have to go through a lengthy and arduous process involving travel between airport and points of origin and destinations of their journey. Apart from increasing capacity for airways and airports, links to and from the airports (that is, accessibility and connections of surface transport modes) should be made to ensure rapid and efficient movement of goods. To this end, we have tried to include this important factor into our analysis using a binary dummy variable to represent the presence of seaports and railway links from the airport. This factor, however, turns out to be insignificant as distance from airport may be a better representation for the conveniences render by these surface transport modes.

Secondly, the effect of technology has not been considered in the study. According to Song and Yeo (2003), technological infrastructures in seaports such as supporting information systems provide value-added cargo tracking services and enhance the attractiveness of the ports among competing ports. Using EDI in customs application will also help to speed up the custom clearance process (Paik and Bagchi 2000). In the context of airports, Ohashi et al. (2005) commented that information technology systems, which simplify custom procedures by computerizing shipment information, enhance the efficiency of the airports by allowing pre-clearance of shipments. In this way technology increases the efficiency of capital and labor directly, resulting in an increased throughput with the same quantity of capital and labor. However, it is difficult to quantify technology in meaningful numerical terms.

Thirdly, we have used the national average education level of worker to control for human capital (labor quality). We recognize that in practice it is by no means a standard assumption that human capital only depends on years of education since many studies in labor economics would suggest work experience as another important factor. Nonetheless, without concrete worker turnover data, we deem that the average years of education present itself as a good surrogate because it represents the general level of quality of the workforce available for hired on a national basis. Unless there is a strong evidence to suggest that there is a bias in employing worker of higher/lower education qualification in the port industry, far short of conducting a detailed survey, using the current national average of education level is not unreasonable.

Fourthly, ports with the same amount of physical facilities differ in terms of the sophistication of these facilities. The importance of the availability of up-to-date efficient, reliable and flexible cargo handling equipments in determining port efficiency and competitiveness has been cited in many past studies (Burdg and Daley 1985; Murphy 1988, 1989, 1991 and 1992). Tongzon (2005) stressed that the quality of the hard (physical) infrastructure should not be neglected at the expenses of quantity. Ideally, quality of equipments can be measured the age of equipment because newer equipment tends to be more technologically sophisticated and productive. Another reasonable proxy is the level of capital investment in, or maintenance expenditure on, equipment over a given period of time. However, the task of collecting these data has proven to be insurmountable. Alike the study by Cullinane and Song (2006), we have implicitly assumed that there is a standard unit of equipment throughout this chapter.

Fifthly, port charges are omitted following the findings and reasoning in Tongzon (1995) that port charges are statistical insignificant since they constitute small proportion of total transport costs and their overall impacts on port choice decisions could have been offset by other more significant indirect costs of transport. Prior to this, Murphy et al. (1991) also discovered in their survey that low freight handling cost is not a dominant consideration in port selection and international shippers are willing to pay higher port cost in exchange for superior services. Similarly, air-cargo costs (generally include airport charges, terminal, ground-handling costs and other operating costs of the logistics facilities) are excluded in the analysis for reasons owing to the unavailability of consistent data and relative insignificancy of the charges. Zhang (2003) noted that accurate or meaningful cost comparisons with other air cargo centers are extremely elusive in that general cargo rates vary according to the time of year, and between inbound and outbound flights. Furthermore, Gillen and Lall (1997) and subsequently Ohashi et al. (2005) found that airport user charges account for just over 5 percent of airlines total costs on average for the world's airlines as a whole.

Last but not least, this empirical study has been deliberately kept simple and modeled at a macro-level for another reason being that the incorporation of operational factors into the regression model will give rise to over-fitting problems due to our small sample size. The issue of multicollinearity is also salient considering the possible correlations between operational factors and production inputs in promoting port's throughput. For example, we have tried including the frequency measure on flights (vessel) arrival and departures as an additional independent variable using the number of aircraft movements (port calls) as a proxy. Generally speaking, the higher the frequency, the shorter the time cargo will need to wait for connecting flight (vessel) to their ultimate destinations. However, the inclusion of this variable into our model has resulted in multicollinearity manifested in the form of high *p*-values and wrong coefficient signs of parameters. Higher frequency of flights (vessels) may be associated with more runways (longer berths) and perhaps larger terminal area as well. This is, in turn, associated with a larger labor force since more workers will be needed to serve at the check-in counters, gates and attending to the common floor area.

In the next chapter, we examine how internal port attributes such as port location, connectivity, operating hours, water depth, cost, availability of inter-modal transfer, relationship with other ports etc. will influence the attractiveness of a port and its attainment of a sustainable hub status.

CHAPTER 3

ASSESSMENT OF HUB STATUS AMONG ASIAN PORTS FROM A NETWORK PERSPECTIVE

3. Introduction

Following the pressure of intense competition in the maritime and port industry that squeezes profit margins, the container shipping industry has undergone some significant structural changes over the last two decades. In particular, major shipping conglomerates have attempted to globalize their service coverage through joint ventures, mergers and acquisitions within the liner industry, (Wang and Cullinane 2006; Parola and Musso 2007). At the same time, the deployments of increasingly large vessels, including post-panamax vessels, on mainline and feeder services help to further enhance cost efficiencies of these shipping conglomerates by reaping scale economies (Cullinane and Khanna 1999). As a result, carriers not only improve their service quality at lower prices to end users, they also strengthen their bargaining positions against ports. Whilst concentration within the liner shipping industry has increased the potent impact of a move by a major port user on the port's traffic, carriers are becoming increasingly footloose with more than one port to choose from, not just for transshipment traffic but also for gateway traffic in their hub-and-spoke networks. Such phenomenon is partly attributable to the advances in logistical systems that expand port hinterlands to some extent that the hinterland of one port overlaps with another. As the port industry is constantly at risks of losing important customers when carriers rationalize their shipping schedules, a port needs to constantly adapt itself to meet the frequently changing demands of its customers in a way that is superior to competing ports (Slack 1993; Notteboom and Winkelmans 2001).

On the other hand, the dominance of hub-and-spoke operating concept in the international shipping industry has aroused an increasing interest to justify the existence of cooperation opportunities among ports. According to Heaver (1995), port's service networks should complement each other in a meaningful inter-port cooperation. One example is ports that share a feeder-and-major port relationship. The carriers collect disparate volume from diverse feeder ports and transship the cargoes to the hub ports, which provide a location for consolidation and onward transport to further destinations in large volumes. The linkage formed between the two ports enables both ports to serve an increase volume of traffic from a wider range of origins and destinations. Under such a partnering relationship, the growth in one port helps another to grow. Despite the importance of justifying the existence of cooperation opportunities within port networks, Haralambides (2002) and Wang and Cullinane (2006) noted that only minimal consideration has been given in literature to the degree to which any individual container port is accessible to the wider maritime container transportation network.

In view of the perplexing relationships that exist among ports in the international maritime transport industry, this chapter contributes to the extant literature in its development of a novel network-based hub port assessment (NHPA) model customized to the international shipping industry. This model requires the use of a *connectivity* index and a *cooperation* index that are both founded upon the concept of network accessibilities and overlaps (Hansen 1959; Taylor et al. 2006; Takada 2004). The NHPA model is useful for port operators and policy makers as it (i) helps to identify important quality characteristics from which carriers base their port choices on (through the identification of important port attributes which provides port operators with key insights into how to improve their port infrastructures and operations), and; (ii) offers explicit measurements of the degree of port competition and cooperation relationships (the quantification of inter-port relationships would enable port authorities to clearly identify strong potential competitors and partners). A schematic describing the NHPA modeling process comprising two network-based indices, namely, connectivity and cooperation, is shown in Figure 3-1.

A direct measure of network connectivity is proposed in this chapter. The connectivity index for each port is based on counts of origin and destination (O-D) pairs served by individual ports in real carriers' networks. The explicit consideration of the network configuration allows a direct assessment of the connectivity of ports, which is an important measure in establishing the competitiveness of a port and its potential for achieving hub status (regional or global hub) for sea cargo since the main business of a container port is the transportation of cargo from the point of supply to the point of demand in a carrier's sailing network (Wang and Cullinane 2006). Any significant changes to the shipping routes served by a port can be explicitly accounted for through such a measure. Relationship between the network connectivity index and important observational qualities of port competitiveness can be modeled through factor analysis[1] which further offers a means of comparison of the performance of multiple ports using simple scoring methods. Such analysis could be viewed as an

[1] Lirn et al. (2004b) suggested that factor analysis would provide an alternative approach to narrow down the number of port attributes and improve the methodology of their chapter. Yeo et al. (2008) used factor analysis to evaluate the competitiveness of selected container ports in Korea and China.

extension to Tiwari et al. (2003), Nir et al. (2003) and Malchow and Kanifani (2004) in which the Multinomial Logit (MNL) model was applied without considering the network configuration explicitly.

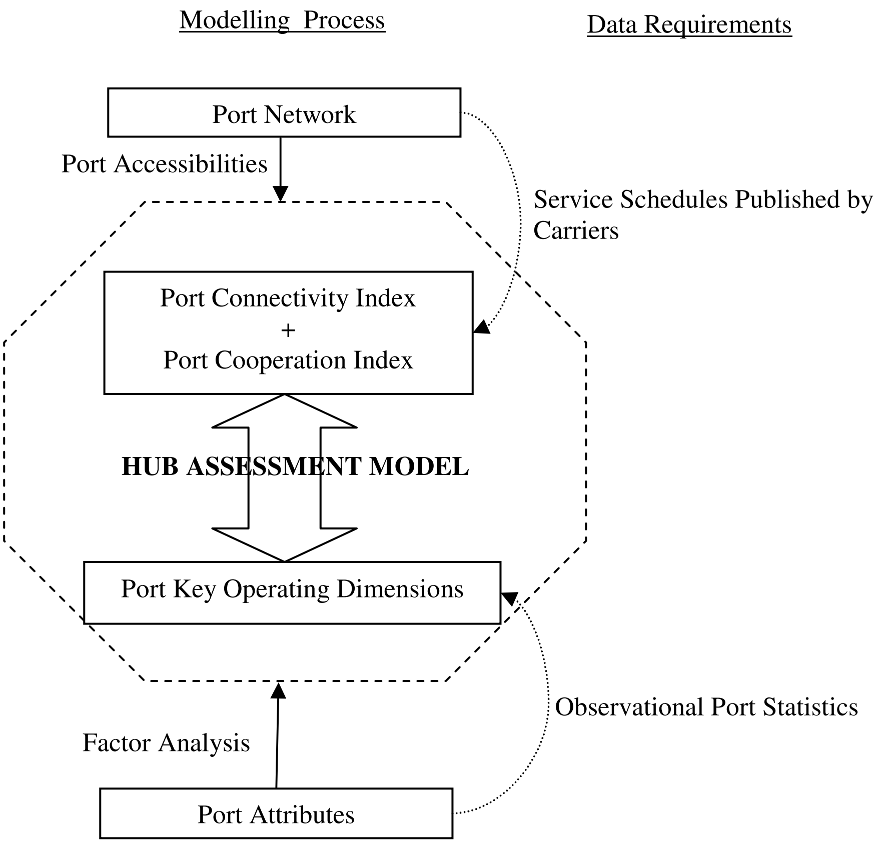


Figure 3-1 NHPA Modeling Process and Data Requirements.

To accurately appraise the performance of hubs and the dynamic evolution of hub status of ports, the network cooperation index is used in conjunction with the connectivity index. Given that the data are associated with individual carriers, the simultaneous consideration of these two indices allows the evaluation of hub performance and hub status evolution within the carrier networks. These two indices also offer a practical platform for assessing the stability of hub status from a network perspective. More specifically, the degree of connectivity gives an indication of whether the port is a hub port (regional or global hub) since good accessibility and comprehensive network coverage are both indispensable characteristics of a hub port (Tongzon and Heng 2005). The examination of the degree of cooperation among ports further allows the evaluation of the *sustainability* of existing network connectivity. Ports that engage in close cooperative relationships will complement each other within a carrier's network, thereby creating a win-win situation. By ensuring minimal overlap in the hinterlands served, these ports are also in better position to safeguard their connections. In contrast, ports that exhibit low cooperative relationships with other ports are more vulnerable to the loss of transshipment traffic to the competition because they are likely to lose their connections when a major carrier streamlines its sailing schedules. As shown in Table 3-1 below, ports that display high connectivity indices are classified as global hub ports whose sustainability depends on their cooperation indices. Conversely, ports with low connectivity indices but high cooperation indices are classified as regional hub ports with potential to be developed into global ports.

Table 3-1 NHPA Framework on Hub Status Assessment

		Connectivity Index	
		Low	High
Cooperation Index	High	Sustainable Regional Hub Port; Potential for Global Hub Status	Sustainable Global Hub Status
	Low	Unstable Regional Hub Port	Unstable Global Hub Status

The rest of this chapter is organized in the following manner. Section 3.1 reviews the extant literature on inter-port relationship and motivates the need for a joint consideration of both the competitive and cooperative indices based on underlying network connectivity considerations. Section 3.2 builds the components required for the NHPA model from a network perspective. Section 3.3 presents three empirical case studies that apply the proposed methodology to the service schedules offered by three of the largest carriers in the global maritime shipping industry.

Through the shipping networks of these three carriers, a sample of 11 major Asia-Pacific ports is classified into regional and global hub ports, and some insights into the dynamics of the evolution of the Asia-Pacific port industry within these networks can be derived. Section 3.4 describes some analytical insights on the Asia-Pacific derived from this analysis. It further relates the empirical findings to specifics of the ports' operating environment, discusses the robustness of the results, identifies key competitive characteristics of ports and justifies the significance of port cooperation on port performance. Section 3.5 concludes the chapter.

3.1 Literature Review

A number of existing case studies investigated port competition and cooperation specific to particular region or country and identified key factors promoting or hindering port competitiveness. Hoyle and Charlier (1995) studied the East African port system and demonstrated that certain historical events have led to a series of problems in inter-port competition. In view of the port competition between the United States and Western Europe, Fleming and Baird (1999) proposed six sets of influences which can be combined to explain why certain ports inevitably develop an edge over their adversaries. In the Asian region, Slack and Wang (2002) focused on the local and regional competition faced by the ports of Hong Kong, Singapore and Shanghai from peripheral ports. The authors confirmed that the Hong Kong, Singapore and Shanghai ports are subjected to challenges from Shenzhen, Tanjung Pelapas and Ningbo respectively. However, Cullinane et al. (2004) concluded that the Hong Kong port will retain its role as a dominant regional hub despite Shenzhen's current competitive advantages. Within the mainland China, Cullinane et al. (2005) examined the port competition between Shanghai and Ningbo and evaluated the relative competitiveness of the ports on the basis of price and quality of service. Observing the active competition among ports in close proximity, Heaver (1995) questioned whether ports would be better off if they engaged in more cooperation. From a strategic perspective, Song (2002, 2003) examined the possibility of cooperation between adjacent container ports in Hong Kong and Shenzhen using Porter's five forces model.

Apart from the explicit consideration of port competition and cooperation, another branch of the literature attempted to study inter-port relationships through generic indicators such as changes in market shares. Fung (2001) attempted to provide a systematic treatment for the interaction between the ports of Singapore and Hong Kong, and to investigate how the rise of South China ports affects the demand for Hong Kong container handling services using a vector error correction model (VECM) with structural identification. Yap and Lam (2004) examined the relationship between ports in East Asia by means of an indifference analysis. (Please refer to Appendices B.1.3 and B.2.1 for technical descriptions of the VECM and indifference analysis). However, the tasks of port classifications and inter-port relationship quantifications (i.e., competitors and partners; global and regional hub ports) are basically unaddressed. Furthermore, despite the importance of network configurations, these have not been given adequate and explicit considerations in the existing port literature for hub port assessment, thus motivating the development of the NHPA model in this chapter which explicitly utilizes network configurations to assess port cooperation as a facet of hub status quality.

3.2 Model Components

3.2.1 Port Connectivity Index

Consider a hub-and-spoke network formed by two individual ports *i* and *j* as exemplified in Figure 3-2. Define two sets of origin-destination (O-D) pairs[2] – set A_i and set A_j such that A_i represents the set of O-D pairs that is served by port *i* either in competition or cooperation with port *j* and A_j represents the set of O-D pairs that port *j* serves either in competition or cooperation with port *i*. It follows that the intersection of the two sets, $A_i \cap A_j$, represents the set of O-D pairs that both ports *i* and *j* will serve and the union, $A_i \cup A_j$, represents the set of O-D pairs that is served by either port *i* or port *j*.

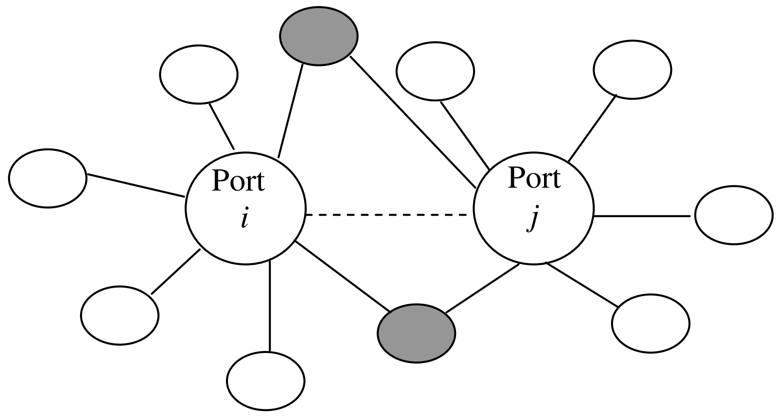


Figure 3-2 Hub-and-Spoke Network Configuration of Port *i* and Port *j*.

Ports do not operate in isolation from each other in today's inter-dependent global market. Min and Guo (2004), in the analysis of hub seaport location problem, stated that the container movements from an origin port to a destination port occur within the liner's hub-and-spoke network that link container ports around the globe. In Figure 3-2 above, the linkage between port *i* and port *j* as represented by the dotted

[2] Much of the existing port literature has documented that immense competitive pressure arises as each port seeks to attract transshipment traffic. Our model defines the set in terms origin-destination pairs served by a port so as to represent transshipment routes going through the port. On the other hand, if the sets are simply defined as nodes served by a port, only the case of direct shipping (starting or ending at the port) can be considered

arc between the two ports, suggests that each port will leverage on the network of the other port to expand its hinterland and serve a wider user base.

In order to compute the size of the sets defined above, let n_i and n_j be the number of exclusive nodes (including the port itself[3]) that can only be reached by port *i* and port *j*. There is also a number of common nodes, denoted as n_{ij}, that can be reached by using either port *i* or port *j* (represented by the shaded nodes in Figure 3-2). Given the definition of sets A_i and A_j, $n(A_i) = n(A_j) = n_i n_j + n_{ij}(n_i + n_j + 2n_{ij})$. The first term, $n_i n_j$, represents the number of O-D pairs that begins from an exclusive node of port *i* and ends with an exclusive node of port *j* (or vice versa). The second term computes the number of O-D pairs that involve a common node. More importantly, the expression in the second term implies that we do not preclude the possibility of having an O-D pair between two identical common nodes via port *i* or port *j*, as opposed to $n(A_i \cap A_j) = 2n_{ij}(n_{ij} - 1)$. Such inclusion of O-D pairs where the vessels begin and end at the same node is necessary to represent loop services between common nodes.

The total number of O-D pairs that can be achieved with each port functioning independently is computed as $n(A_i \oplus A_j) = 2n_{ij}(n_i + n_j + n_{ij})$. Routes that require cooperation (i.e., connection) between port *i* and port *j* are those that start from an origin which has a single direct connection from port *i* to a destination that also has a single direct connection from port *j* only or vice versa. Using $\{A_i \otimes A_j\}$ to represent the complementary set of O-D pairs that are jointly served by ports *i* and *j*, we obtain $n(A_i \otimes A_j) = 2n_i n_j$. As the sets $\{A_i \oplus A_j\}$ and $\{A_i \otimes A_j\}$ are mutually independent, the

[3] This extra node is needed to account for the possibility of a direct shipping route starting from a common node and ending at the port itself (or vice versa) without going further to other exclusive nodes from port.

total number of O-D pairs that can be served when both ports engage in cooperation is given by $n((A_i \oplus A_j) \cup (A_i \otimes A_j)) = 2(n_i + n_{ij})(n_j + n_{ij})$.

According to Wang and Cullinane (2006), ports constitute the nodes of a liner-shipping network and liner-shipping services provide the links that give the accessibility of a port relating to the potential for movement of cargoes between ports. The accessibility of the port *i* is given by $\sum_j 2(n_i + n_{ij})(n_j + n_{ij})$, which can be viewed upon as a variation of the Hansen integral accessibility index described in Taylor et al. (2006). The authors also pointed out that such accessibility index is often used in normalized form. Hence we express the accessibility or connectivity index of port *i*, S_i, as a fraction of the total number of O-D pairs in the sample that is served by port *i*. That is, $S_i = \frac{\sum_j 2(n_i + n_{ij})(n_j + n_{ij})}{\sum_j \sum_i 2(n_i + n_{ij})(n_j + n_{ij})}$. As a normalized index, S_i is bounded between 0 and 1. A S_i value of 0 occurs when the port is not called upon by any liner (i.e., the port is not connected to any other port via liner's voyages). At the other extreme, S_i is equal to 1 if port *i* is connected to all origins and destinations served by other ports in the sample. That is, port *i* will offer a network coverage equivalent to the aggregate network coverage of all ports in the sample.

S_i attempts to measure the comprehensiveness of a port network and the accessibility of the hub port, which determines potential for a port to achieve global hub status to a great extent. Such an index can be easily applied to quantify the connectivity of any hub ports within the entire global shipping network through pair-wise computations. Since counts of O-D pairs are used, this index can also consider frequency of sailings between O-D pairs. Here, the frequency variable is omitted for two reasons, namely, (1) to simplify the formulation for connectivity index, and (2) to relate to the objective of our study that involves the modeling of carrier's port choice in a particular voyage given the existing port service frequencies and other important port attributes (described in section 3.4.1). In essence, we are primarily concerned with the presence/ absence of timely and convenient connections[4] between ports.

3.2.2 Port Cooperation Index

The intensity of competition between the two ports *i* and *j* can be expressed as a ratio of the number of O-D pairs which ports *i* and *j* can achieve independently without going through the arc *ij* to the total routes possible in the combined network (Takada 2004). Thus, the competitive index between port *i* and port *j* is $c_{ij} = \dfrac{n(A_i \oplus A_j)}{n((A_i \oplus A_j) \cup A_i \otimes A_j)} = \dfrac{n_{ij}(n_i + n_j + n_{ij})}{(n_i + n_{ij})(n_j + n_{ij})}$. The intensity of direct competition between port *i* and port *j* depends on the number of common nodes in the networks of the two ports. We illustrate two extreme cases of perfect complementary and competitive relationship. If $n_{ij} = 0$ (or equivalently, $n(A_i \cap A_j) = 0$), ports *i* and *j* are in perfect complementary positions (please see Figure 3-3 below). That is, $c_{ij} = 0$

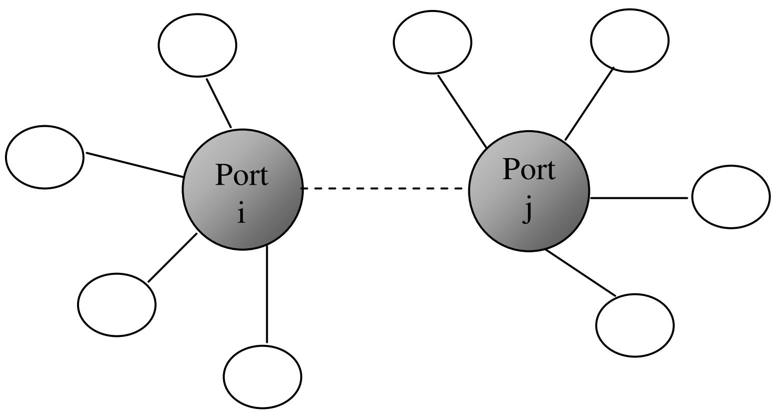


Figure 3-3 Example on Network of Perfect Complementary Relationship

[4] Apart from extensive network coverage, port services are differentiated in terms of the connecting time. Hence, a competitive and accessible port is one that serves many O-D pairs in a timely manner.

On the other hand, if the set of O-D pairs served by one port is a proper subset of another port (i.e., $A_i \subset A_j$ or $A_j \supset A_i$), the two ports are in perfect competition with each other. In this case, every node in network of port *i* (port *j*) is a common node that is also served by port *j* (port *i*). Port *i* and port *j* are said to be in perfect competitive positions (see Figure 3-4). That is, $n_i = 0$ or $n_j = 0$ which give $c_{ij} = 1$.

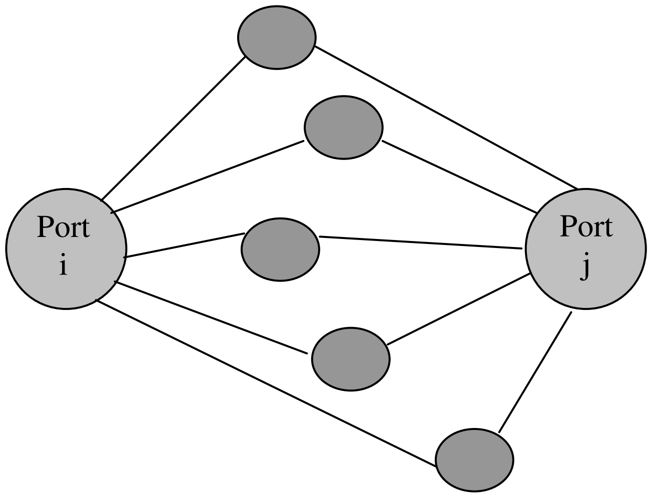


Figure 3-4. Example on Network of Perfect Competitive Relationship

Conversely, we can also compute the cooperation index between two ports as the ratio of the number of O-D pairs which ports *i* and *j* need to serve together (i.e., $n(A_i \otimes A_j)$) to the total number of O-D pairs in the combined network (i.e., $n((A_i \oplus A_j) \cup (A_i \otimes A_j))$). Denoting the cooperation index as $c_{ij}^{'}$, we have $c_{ij}^{'} = \frac{n_i n_j}{(n_i + n_{ij})(n_j + n_{ij})}$ where $c_{ij}^{'} = 1$ indicates perfect cooperative relationship between port *i* and port *j*. Noting that c_{ij} and $c_{ij}^{'}$ summed to 1, the cooperation index between two ports *i* and *j* is simply the complement of the competitive index between the two ports. In a sample of *k* ports, the cooperation matrix **C** is a $k \times k$ matrix such that its elements are given by $c_{ij}^{'}$ for $1 \le i, j \le k$.

The aggregate cooperative index for port i (denoted as ACI_i) is obtained by summing c'_{ij} across all other ports j. The ACI_i has a lower limit of 0, which occurs if port i does not engage in cooperation with any other ports in the sample. However, as there is no upper limit for ACI, the meaning of ACI of a specific port can only be interpreted relative other ports in the sample or across time. Generally, higher ACI implies higher level of cooperation.

3.3 The Case Studies

Industrial practitioners and academic researchers have observed that carriers today are nimble and getting increasingly footloose in their selected ports of call. This section compares the various ports' positioning in service networks of three of the largest players in the maritime industry. Due to concerns in data confidentiality, the identities of these carriers have been withheld. They are only described by their pseudonyms: Alpha, Gamma and Beta Shipping Lines. Alpha and Gamma Shipping Lines are independent carriers while Beta Shipping Lines is a member of a global strategic alliance. All three carriers registered almost equivalent market shares, with Alpha and Gamma being the largest and smallest among the three carriers.

The analysis centers on 11 major ports that include Singapore (SGP), Hong Kong (HKG), Kaohsiung (KSG), Shanghai (SHI), Pusan (PSN), Port Klang (PKG), Yokohama (YKH), Tokyo (TKO), Tanjung Priok (TPK), Laem Chabang (LCM) and Jawaharlal Nehru (JHN), following Wang (2005) who highlighted that the mainline hub-feeder structure has focused large international flows of containers and shipping capacity onto a small number of efficient ports that emerged as major ports for their countries or regions. Combined with the enhanced throughput capacity of these ports, these ports will attain significance at both the global and regional scale.

3.3.1 Alpha Shipping Lines

The connectivity indices, displayed in Table 3-2, show the accessibility of 11 major ports as derived from the published service schedules of Alpha Shipping Lines in June 2007 and June 2008. Other than being an indication of its effectiveness as a hub port, the connectivity index also functions as a leading indicator for any changes in the relative competitiveness of competing ports. For example, between 2007 and 2008, ports that have improved upon their connectivity are Pusan, Yokohama, Kaohsiung, Shanghai and Jawaharlal Nehru. In contrast, the Singapore, Hong Kong, Tokyo, Tanjung Priok, Laem Chabang and Port Klang have experienced slight deteriorations.

In descending order of port traffic volume, the cooperation indices between port i and port j (c'_{ij}) are expressed as a symmetrical matrix $\boldsymbol{C}$ in Table 3-3. The fall in ACI in all ports illustrates that competitions among ports have intensified over the past one year. Of these, the ports of Yokohama and Kaohsiung are the most aggressive while competitive pressures are almost equally strong among the established and smaller ports. Notable exceptions are the increased inter-port cooperation between Tokyo and Shanghai, Tokyo and Pusan, Jawaharlal Nehru and Laem Chabang ports, as well as some slight improvements in cooperative relationships between Port of Singapore and other bigger ports like Kaohsiung, Pusan and Shanghai.

Table 3-2* Number of O-D pairs served by ports and their connectivity indices S_i, utilizing data from Alpha Shipping Lines (2007 – 2008)

PORT	SGP	HKG	PSN	YKH	TKO	KSG	TPK	LCM	SHI	PKG	JHN
SGP	--										
HKG	104 190	--									
PSN	112 170	40 60	--								
YKH	112 216	40 84	32 84	--							
TKO	84 72	30 12	24 20	24 24	--						
KSG	84 112	16 56	24 56	24 48	18 32	--					
TPK	56 64	20 20	24 28	24 24	18 16	18 16	--				
LCM	56 64	30 20	16 28	16 32	12 16	12 24	18 8	--			
SHI	56 102	20 12	16 56	16 42	12 30	12 42	12 18	8 18	--		
PKG	28 34	20 8	16 12	16 14	12 6	12 10	12 2	12 2	8 4	--	
JHN	28 128	20 56	8 72	8 80	6 48	6 64	12 32	12 32	4 40	8 32	--
Total O-D	720 1152	340 518	312 586	312 648	240 276	226 460	214 228	192 244	164 364	144 124	112 584
S_i	0.242 0.222	0.114 0.100	0.105 0.113	0.105 0.125	0.081 0.053	0.076 0.089	0.072 0.044	0.065 0.047	0.055 0.070	0.048 0.024	0.038 0.113

* The upper and lower figures refer to the cooperation index in 2007 and 2008 respectively

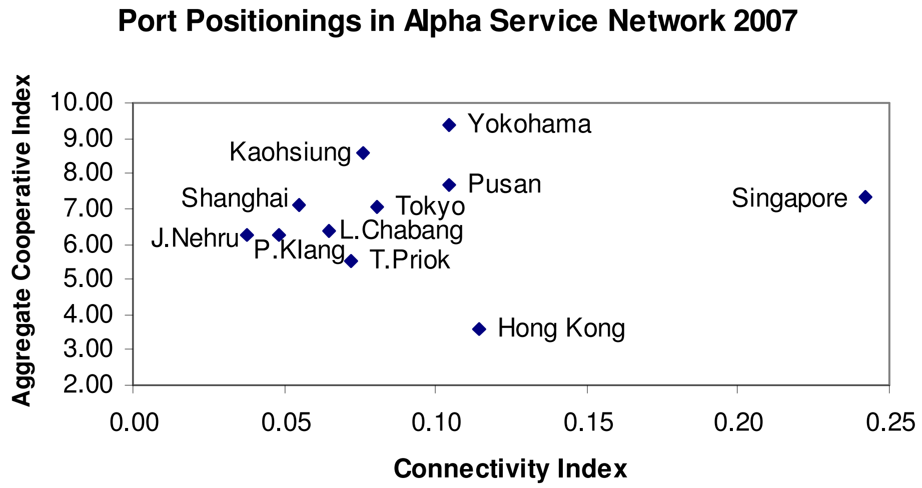
Using the S_i and ACI_i computed as shown in Tables 3-2 and 3-3, we position the respective ports within the NHPA framework for the assessment of the potential and sustainability of hub status in the network of Alpha Shipping Lines as shown in Figure 3-5.

The port of Singapore has registered the highest port connectivity indices and is engaged in relatively stronger cooperative ties with other ports in the region, making it a global and sustainable hub port. Another port in Northern Asia, Pusan, has similar characteristics as the Singapore port. The Shanghai and Jawaharlal Nehru ports are progressing from regional hub ports towards global hub ports with increasing connectivity and cooperation vis-à-vis other ports while Kaohsiung port increased its connectivity but decreased its *ACI* in the process. However, the concurrent fall in connectivity index and *ACI* of the Hong Kong port may be an early indication of possible degradation of its status as a global hub. The sustainability of Yokohama port, as a global hub, and Tokyo port, as a regional hub, have also weakened over the past year. Other smaller ports like Port Klang and Tanjung Priok will have a longer way to go in achieving hub status.

Table 3-3* Cooperation among ports, c'_{ij} , and the aggregate cooperative index, ACI_i, utilizing data from Alpha Shipping Lines (2007 – 2008)

PORT	SGP	HKG	SHI	PSN	KSG	LCM	TPK	TKO	YKH	JHN	PKG
SGP	--										
HKG	0.692 0.632	--									
SHI	0.464 0.494	0.400 0.300	--								
PSN	0.429 0.519	0.600 0.286	0.375 0.286	--							
KSG	0.619 0.889	1.000 0.000	1.000 0.400	1.000 0.417	--						
LCM	1.000 0.232	0.533 0.429	1.000 0.429	1.000 0.333	1.000 0.188	--					
TPK	1.000 0.469	0.400 0.400	1.000 0.714	1.000 0.417	0.444 0.500	0.444 0.375	--				
TKO	0.619 0.469	0.533 0.400	0.333 0.714	0.500 0.750	1.000 0.500	1.000 0.667	1.000 0.250	--			
YKH	1.000 0.588	0.600 0.000	1.000 0.429	1.000 0.476	1.000 0.400	1.000 0.571	1.000 0.222	1.000 0.222	--		
JHN	1.000 0.941	0.400 0.429	1.000 0.833	1.000 0.857	1.000 0.667	0.333 0.800	0.333 0.000	1.000 0.000	1.000 0.000	--	
PKG	1.000 0.438	0.400 0.000	1.000 0.556	1.000 0.600	1.000 0.333	0.333 0.500	0.333 0.188	1.000 0.188	1.000 0.300	0.250 0.188	--
ACI_i	7.352 5.670	5.558 2.874	7.572 5.154	7.904 4.940	9.063 4.293	7.643 4.523	6.954 3.534	7.985 4.159	9.600 3.209	7.316 4.286	7.316 3.717

* The upper and lower figures refer to the connectivity index in 2007 and 2008 respectively



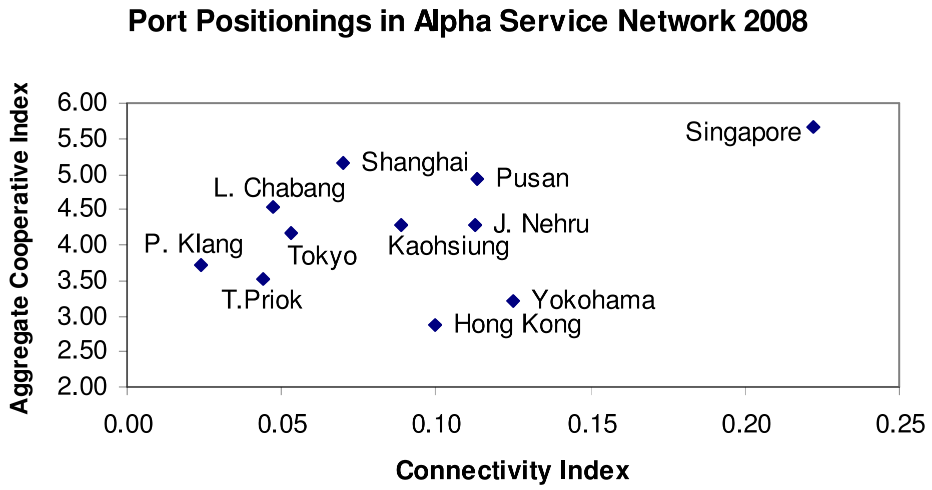


Figure 3-5 Port Classifications in the NHPA Framework, Alpha Shipping Lines (2007 – 2008)

3.3.2 Gamma Shipping Lines

Gamma Shipping Lines has streamlined its sailing network quite substantially over the period June 2007 to June 2008 that have resulted in a reduction in the number of O-D pairs served by many ports as shown in Table 3-4. Particularly, the connectivity of major ports like Singapore, Kaohsiung and Tokyo has dropped noticeably while those of Hong Kong, Pusan, Yokohama and Shanghai have increased. At the same time, the smaller ports, such as Laem Chabang and Jawaharlal Nehru, have also expanded their network coverage.

Table 3-4* Number of O-D pairs served by ports and their connectivity indices, S_i, utilizing data from Gamma Shipping Lines (2007 – 2008)

Port	SGP	KSG	TKO	PKG	HKG	PSN	LCM	YKH	SHI	TPK	JHN
SGP	--										
KSG	364 168	--									
TKO	988 140	338 112	--								
PKG	176 156	208 84	160 60	--							
HKG	312 140	234 154	112 110	224 120	--						
PSN	252 196	364 112	40 40	176 84	154 126	--					
LCM	132 120	132 56	120 56	110 96	144 112	132 88	--				
YKH	68 60	338 126	32 50	160 96	48 40	28 98	96 48	--			
SHI	160 168	80 112	50 84	144 84	130 154	60 182	90 126	50 128	--		
TPK	72 52	84 20	42 28	144 48	66 40	36 36	60 32	30 16	60 126	--	
JHN	60 84	60 36	24 30	32 30	56 66	36 48	32 30	16 30	28 60	20 18	--
Total O-D	2584 1284	2202 966	1906 700	1534 846	1480 1042	1278 996	1048 756	866 688	852 1224	614 412	364 432
S_i	0.175 0.139	0.150 0.105	0.129 0.076	0.104 0.092	0.100 0.113	0.087 0.108	0.071 0.082	0.059 0.075	0.058 0.133	0.042 0.045	0.025 0.047

* The upper and lower figures refer to the connectivity index in 2007 and 2008 respectively

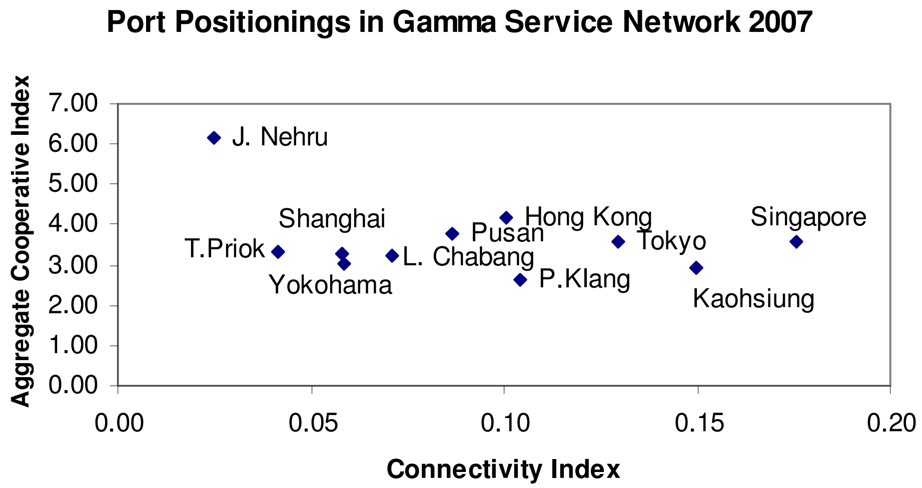
From Table 3-5, we can observe that Singapore, Yokohama and Pusan are the three bigger ports which have moved towards greater cooperation with other ports in the region. More specifically, both Singapore and Yokohama ports have forged closer cooperative relationships with Kaohsiung and other smaller ports like Laem Chabang, Port Klang, Tanjung Priok and Jawaharlal Nehru to serve the Thailand, Malaysia, Indonesia and India markets respectively. Besides, the Singapore port is also in partnership with Tokyo. Meanwhile, Pusan port engages in more cooperation with ports of Laem Chabang, Tanjung Priok, Shanghai and Kaohsiung. Nonetheless, we can infer from Table 3-5 there is an overall industry trend towards more competitive relationships rather than cooperative ones. This is especially true among the major ports that have taken a more competitive stand against one another.

Table 3-5* Cooperation among ports, c'_{ij}, and the aggregate cooperative index, ACI_i, utilizing data from Gamma Shipping Lines (2007 – 2008)

PORT	SGP	HKG	SHI	PSN	KSG	LCM	TPK	TKO	YKH	JHN	PKG
SGP	--										
HKG	0.256 0.133	--									
SHI	0.488 0.312	0.462 0.364	--								
PSN	0.516 0.396	0.312 0.286	0.267 0.396	--							
KSG	0.264 0.312	0.171 0.364	0.000 0.286	0.220 0.286	--						
LCM	0.152 0.589	0.375 0.714	0.444 0.286	0.455 0.636	0.273 0.357	--					
TPK	0.000 0.458	0.303 0.450	0.267 0.222	0.278 0.778	0.571 0.000	0.133 0.188	--				
TKO	0.334 0.462	0.589 0.436	0.240 0.190	0.200 0.150	0.130 0.268	0.400 0.429	0.571 0.714	--			
YKH	0.882 0.857	0.458 0.450	0.160 0.109	0.429 0.122	0.071 0.222	0.250 0.333	0.400 0.500	0.188 0.160	--		
JHN	0.467 0.564	0.857 0.545	0.714 0.700	0.778 0.500	0.867 0.278	0.750 0.400	0.600 0.222	0.667 0.400	0.000 0.400	--	
PKG	0.205 0.375	0.402 0.350	0.250 0.286	0.341 0.286	0.346 0.286	0.000 0.313	0.194 0.000	0.263 0.200	0.200 0.250	0.438 0.267	--
ACI_i	3.563 4.458	4.185 4.092	3.291 3.150	3.794 3.835	2.913 2.657	3.232 4.245	3.318 3.532	3.582 3.409	3.038 3.405	6.137 4.276	2.638 2.611

* The upper and lower figures refer to the cooperation index in 2007 and 2008 respectively

Figure 3-6 shows that Hong Kong, Singapore and Pusan ports have consolidated their status as global hub ports in the service network of Gamma Shipping Lines between the year 2007 and 2008. Shanghai port has upgraded to a global hub port but its low *ACI* indicates that its hub global hub status may not be stable (just like Kaohsiung port and Port Klang). Ports like Jawaharlal Nehru, Laem Chabang and Tanjung Priok operate primarily as regional ports for their respectively countries. On the other hand, the Japanese ports (especially Tokyo) have experienced deterioration in their connectivity and cooperation indices relative to other ports.



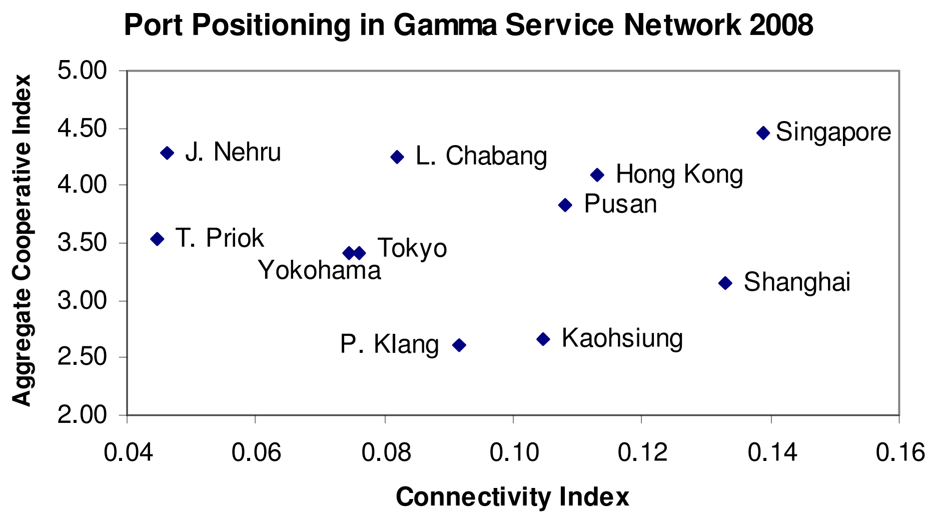


Figure 3-6 Port Classifications in the NHPA Framework, Gamma Shipping Lines (2007 – 2008)

3.3.3 Beta Shipping Lines

The final case study is based on Beta Shipping Lines which is a member of a strategic alliance. Between June 2007 and June 2008, apart from the subtle replacement of a handful voyage originating from the South East Asia region, the networks of the ports in the service schedules of Beta Shipping Lines have remained largely unchanged.

Table 3-6 Number of O-D pairs served by ports and their connectivity indices, S_i, utilizing data from Beta Shipping Lines (2007 – 2008)

PORT	SGP	KSG	PKG	PSN	HKG	TKO	YKH	SHI	TPK	LCM	JHN
SGP	--										
KSG	224	--									
PKG	154	126	--								
PSN	210	176	140	--							
HKG	144	96	98	98	--						
TKO	78	144	84	24	42	--					
YKH	96	96	70	56	48	18	--				
SHI	66	30	112	60	42	36	18	--			
TPK	48	32	98	36	24	20	24	30	--		
LCM	48	24	70	36	16	20	16	18	8	--	
JHN	22	18	12	16	14	8	10	8	6	6	--
Total O-D	1090	966	964	852	622	474	452	420	326	262	120
S_i	0.166	0.148	0.147	0.130	0.095	0.072	0.069	0.064	0.050	0.040	0.018

Similar to the two case studies presented earlier, the Port of Singapore stands out as the port with the highest connectivity as shown in Table 3-6. This is followed by Kaohsiung, Port Klang, Pusan and Hong Kong. Tokyo, Yokohama and Shanghai, which are relatively closer to one another, have offered moderate levels of connectivity. The connectivity of smaller ports like Tanjung Priok, Laem Chabang and Jawaharlal Nehru are comparatively lower. Meanwhile, the four ports that have exhibited exceptionally high *ACI* are Jawaharlal Nehru, Laem Chabang, Tanjung Priok and Tokyo. These ports function as major ports of India, Thailand, Indonesia and Japan and collaborate with other ports to link themselves to other parts of the world. Conversely, Port Klang, Pusan and Yokohama ports are the least cooperative among the eleven ports.

Table 3-7 Cooperation among ports, c'_{ij} , and the aggregate cooperative index, ACI_i, utilizing data from Beta Shipping Lines (2007 – 2008)

PORT	SGP	HKG	SHI	PSN	KSG	LCM	TPK	TKO	YKH	JHN	PKG
SGP	--										
HKG	0.375	--									
SHI	0.303	0.476	--								
PSN	0.476	0.245	0.700	--							
KSG	0.402	0.167	0.000	0.341	--						
LCM	0.458	0.000	0.222	0.778	0.000	--					
TPK	0.458	0.417	0.400	0.778	0.438	0.250	--				
TKO	0.564	0.476	0.500	0.000	0.194	0.600	0.600	--			
YKH	0.417	0.333	0.222	0.357	0.104	0.375	0.667	0.222	--		
JHN	0.000	0.857	0.750	0.875	0.889	0.667	0.667	0.750	0.800	--	
PKG	0.312	0.245	0.214	0.357	0.317	0.000	0.122	0.119	0.114	0.000	--
ACI_i	3.453	2.870	3.574	1.953	3.166	5.575	5.524	5.524	2.352	6.254	1.801

With the connectivity and aggregate cooperative indices in Tables 3-6 and 3-7, the ports are positioned in the NHPA framework shown in Figure 3-7. It can be observed that Singapore, Pusan, Hong Kong, Kaohsiung and Port Klang can be classified as global hub ports while Jawaharlal Nehru and Tanjung Priok are the regional hub ports in the Beta Shipping Lines service network.

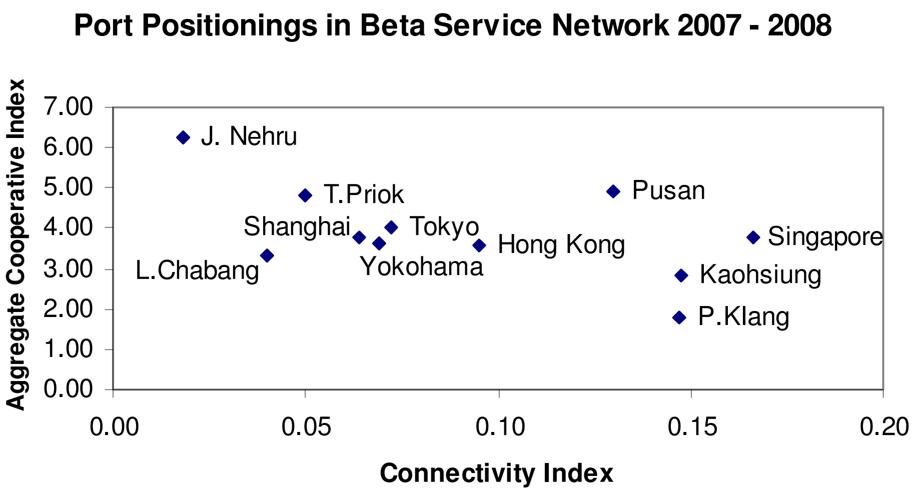


Figure 3-7 Port Classifications in the NHPA Framework, Beta Shipping Lines (2007-2008)

3.4 Discussions

Subsection 3.4.1 conducts a regional analysis of the empirical findings from the case studies presented in the preceding section for ports in Southeast Asia, South China, Northeast China and North Asia. Subsection 3.4.2 demonstrates the robustness of the empirical findings in a conservative analysis that eliminates links plied by only one or two carriers within the global network of the three shipping lines considered. Subsection 3.4.3 identifies the contributions of key internal port attributes to port connectivity. Subsection 3.4.4 examines how port cooperation will affect the volume of throughput at ports, given the presence of some environmental conditions.

3.4.1 Regional Analysis of Asian Ports

Southeast Asia: Singapore port is a global hub exhibiting relatively high connectivity and cooperation, especially in the service networks of the independent carriers. Its popularity as a stopover port in many of the liner sailings may be attributed primarily to its advantageous weather conditions and favorable geographical location which endow it with natural nautical accessibility. More specifically, Singapore lies at the nexus of major trading routes and is particularly well-positioned for the North-South trade with Australasia and the Intra-Asian trades. Other economic reasons that promote Singapore as a global hub port include conducive business environments and well-developed infrastructures that attract foreign investments and boost domestic exports and imports; quick turn-around time and presence of year-round deep harbor and supporting land-side facilities such as distribution parks and sophisticated logistics centers that draw transshipment volumes. In the recent decades, exceptional economic growths in giant Asian economies have also boosted the performances of smaller ports like Jawaharlal Nehru and Laem Chabang. These ports are quite representative of regional hubs in that they primarily function as main ports through which imports and exports are distributed to/ from other parts of their countries via small feeder ports.. In contrast, Port Klang has experienced drops in their connectivity and cooperation indices. This port may have faced stiffer competition from the sister Port of Tanjung Pelapas since 2005.

South China: The global hub status of the Hong Kong and Kaohsiung ports may be slightly unstable. While Hong Kong is still the leader in terms of value-added trade services such as consolidation, forwarding and financing, the cost advantage of its adjacent Shenzhen port (which is an agglomeration of several ports such as Yantian, Shekou, Chiwan and other smaller ports) in Southern China represents a constant threat. Furthermore, the differential advantage in terms of efficiency at the Hong Kong port is being gradually eroded as operations in the ports on mainland China improve. Consequently, the Hong Kong port has lost as much as 40 percent of its monopolized traffic from the region in the 1990's to ports in Southern China. The port of Hong Kong also acts as a bridge between Taiwan and China. With the improvements of political ties between Taiwan and China and increasing number of direct sailings between the port of Kaohsiung and Chinese ports like Xiamen and Fuzhou, the port of Kaohsiung is likely to be provided with even more room for securing transshipment cargoes between North America and China, in addition to those between North America and Southeast Asia. Such extensions of network coverage, however, could diminish its cooperative index with other ports (including Hong Kong).

Northeast China: The rise of China sees rapid and huge increases in the country's GDP and trade, giving the Chinese ports a huge domestic market to offer scale economies and attract direct shipping. Following the movement of manufacturing investments from South China and Hong Kong to China's eastern regions and the ongoing dredging efforts to increase the depth of its shallow waters, the Shanghai port (which currently functions as a regional hub port in the service networks of Alpha and Beta Shipping Lines) possesses significant potential to be further developed into a global hub.

North Asia: The prospect of achieving a sustainable global hub status within the networks of leading carriers' is very promising for the Pusan port. In spite of the stiff competition from ports in Northern China such as Qingdao, Tianjin and Dalian, Pusan port, which functions as a major port in the rapidly industrializing country of South Korea, has further enhanced its connectivity and cooperative relationships with other Asian ports. While the technologically advanced Pusan port benefits from a geographical centrality that allows the port to bridge cargo movements between ports in Russia, North China, North America, Europe and Southeast Asia, its physical location continues to impose a higher marginal cost (compared to Hong Kong and Shanghai ports) for vessels to call for some voyages (for examples,. voyages that sail between Singapore and Yokohama). The relative positions of the Japanese ports of Yokohama and Tokyo[5] as hub ports appear to have been weakened in recent years. This may be due to the presence of alternative ports in Korea and China coupled with their higher operation costs and port dues.

3.4.2 Robust Analysis

Based on the 2008 service networks of Alpha, Gamma and Beta Shipping Lines, we carry out a more conservative assessment of hub port status through an elimination of the inter-port links that are not concurrently present in the service networks of all the

[5] The Ports of Yokohama and Tokyo were once within the top 10 ports in the global rankings before 1999.

three carriers. The remaining links, depicted by the solid lines in Figure 3-8, represent stable links that will not be lost should any one or two of the carriers streamline their service networks.

We re-compute the set of port connectivity and the corresponding cooperative indices[6] using the reduced network. From resulting positions of the ports within the NHPA framework as illustrated in Figure 3-9, we may infer that the global hub ports are Singapore, Hong Kong, Shanghai, Pusan and Kaohsiung. Of these ports, Singapore and Hong Kong ports are the more stable ones. Jawaharlal Nehru, Laem Chabang and Tanjung Priok are the regional hub ports.

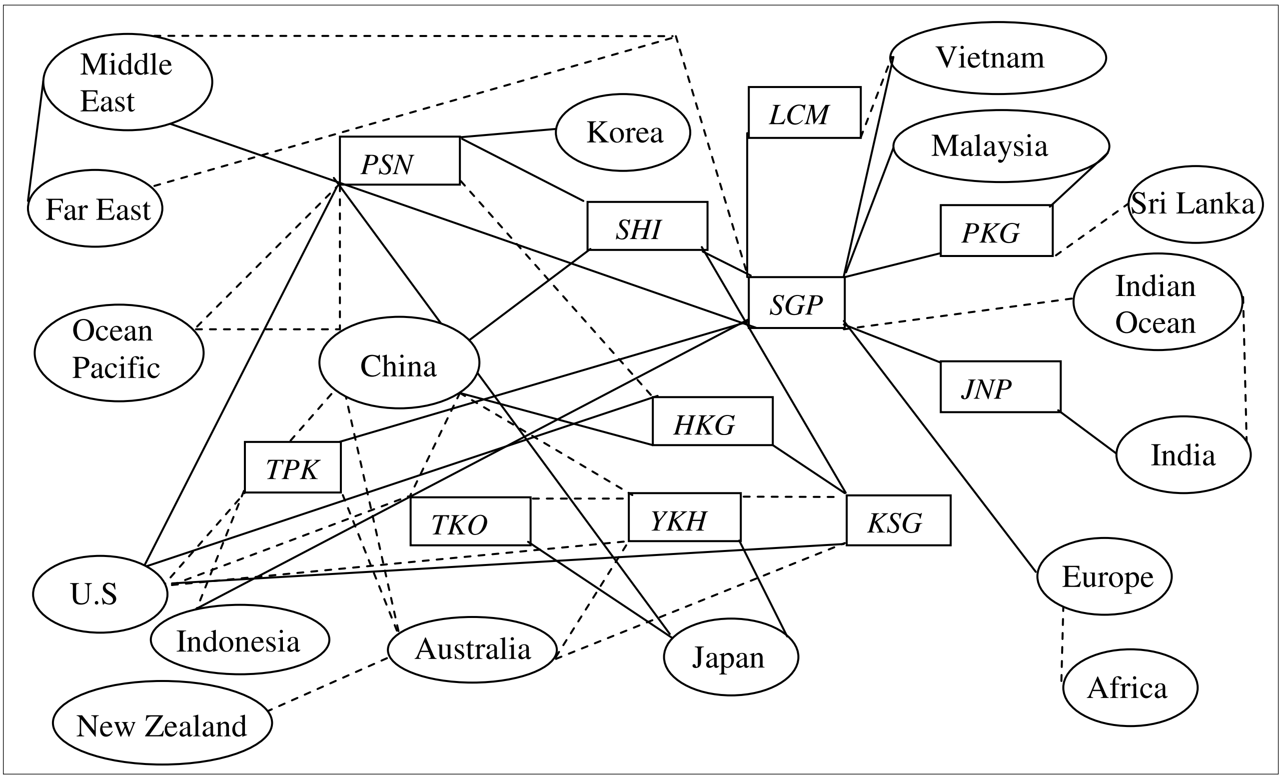


Figure 3-8 A Consolidated Partial Liner Services Network (Note: Italicized acronyms refer to ports)

[6] As an illustration, Singapore and Hong Kong ports are seen to serve 10 and 3 destinations respectively in the consolidated network (in Figure 8). Of these destinations, China is a common destination. That is, including the port itself, $n_{SIN} = 10$, $n_{HKG} = 3$ and $n_{SIN,HKG} = 1$. Applying the formulas in section 3.1, a total of 104 O-D pairs between Singapore and Hong Kong is obtained. Repeating this procedure for Singapore and the other 9 ports, Singapore port serves a total of 560 O-D pairs. A summation of all the 110 port combinations gives 2728 O-D pairs, from which a connectivity index of 0.2053 for the Singapore port is obtained. Similarly, the cooperation index of 7.39 is easily computed using the formula in section 3.2

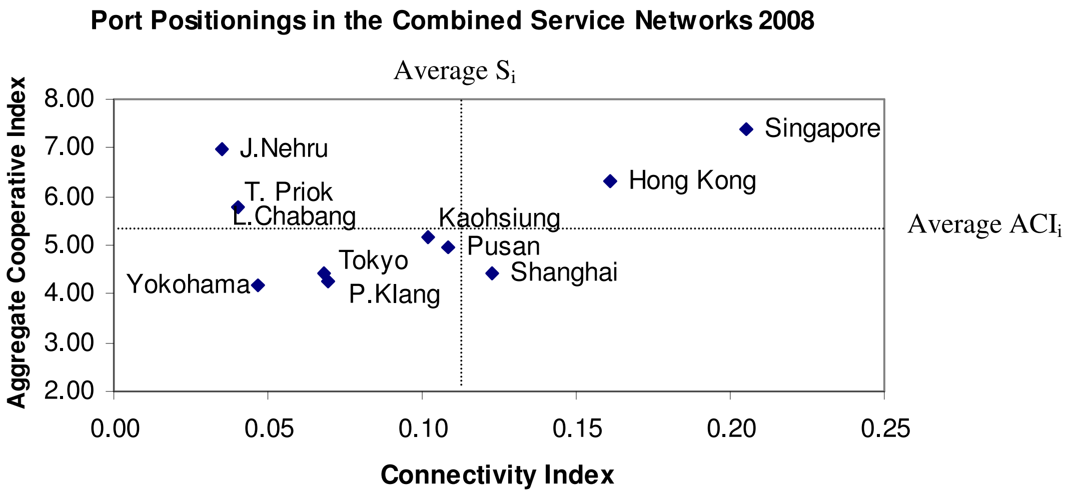


Figure 3-9 Port Classifications in the NHPA Framework (Consolidated, 2008)

3.4.3 Key Competitiveness Factors Influencing Port Competitiveness

Since the accessibility of a port is a result of carriers' port choice in their service networks, the port connectivity could be representative of a port's competitiveness. Hence, we proposed the use of connectivity as a measure of port competitiveness. The following factors are identified from the port literature to have potentially significant effect on port connectivity: (1) number of port calls; (2) draught; (3) national trade volume; (4) port cargo traffic; (5) turnaround time; (6) total annual operating hours; (7) average port charge per vessel; and (8) inter-modal transport capabilities in ports.

The number of port calls (x_1) is a central consideration to carriers when selecting their stopover ports because it affects the potential traffic that carriers can intercept and the connecting time required for them to connect to vessels that lead to their destinations (Slack 1985; Tiwari et al. 2003). As draught (x_2), determines the maximum ship size to berth at a port, increasing vessel size poses a challenge to ports that are geographically located in shallow waters (Baird 1996).

Given that the port and maritime industry is characterized by scale economies in which large volume spreads out fixed cost and increases profits, trade volume (x_3) is another major factor affecting the attractiveness of a port to carriers (Song and Yeo 2004). Affluent economies or economies that are situated favorably near axes of major trading routes engage in higher trade volume, which translates into higher cargo traffic at their major ports. Port cargo traffic (x_4) refers to the cargo throughput (measured in TEUs) that goes through a port, including transshipment traffic. In Blonigen and Wilson (2006), volumes through ports are used to reflect aggregate individual port choice. Together, the variables x_3 and x_4 implicitly take the location factor of a port into account by considering port traffic as a form of gravitational load[7] that arises from the centrality and intermediacy of the port.

Talley (2006) highlighted the importance of port efficiency in carriers' choice of ports, noting that the port loading and unloading rates are analogous to speed of movement for a vessel. Efficient ports are characterized by short turnaround time (x_5) that is influenced by other factors such as the availability of up-to-date physical facilities, labor productivity, speediness in custom services etc. (Sanchez et al. 2003).

To reduce unproductive waiting time and enable quicker turnaround, some ports operate on a 24-hour round-the-clock basis to provide convenient times[8] for anchoring and unloading of vessels. As a measure for convenience, our study computes the total annual operating hours (x_6) by multiplying together the average daily operating hours and the annual number of working days of the port. Port charges represent the monetary cost of using the port. The average port charge per vessel (x_7),

[7] According to Hayuth and Fleming (1994), centrality generates true O-D container traffic from and to the hinterland whereas intermediacy generates long-distance in-transit and transshipment traffic

[8] The survey in Murphy and Daley (1994) revealed that convenient time is one of the most important criteria considered by a carrier when selecting a port of call.

which includes charges on vessels, charges on containers, service charges etc, is used in this study. Inter-modal transport capabilities (x_8) in ports facilitate the handling of containerized imports and exports. Hayuth (1991) believed that a carrier may select a port, not on the basis of its performance, reputation, or cost of services, but on the availability of greater inter-modal coordination which will result in a lower total cost under one bill of lading for a door-to-door delivery. The numerical data of these port attributes for major ports in Asia is given in Table 3-8

Table 3-8 Port Attributes Data of Major Asian Ports 2004

	Traffic[1]	Connectivity[2]	Operations[2]	Max Vessel Size[1]	Inter-modal Link[1]		Trade[3]	Efficiency[4]	Cost[4]
Port	TEUs ('000)	Port Calls (per year)	Days* hrs	Draught (m)	Airport (km)	Rail (km)	Vol (US$ b)	Turnaround time (days)	Port Charges (US$)
Hong Kong	21,984	92,300	362*24	15.50	-	N.A	525	2	210
Singapore	20,600	174,620	365*24	15.00	25	-	332	2	117
Pusan	11,430	83,547	351*22	14.50	11	N.A	478	4	100
Gwang Yang	1,320	-	351*24	-	N.A	N.A	478	4	110
Incheon	935	47,600	351*20	13.00	30	N.A	478	4	100
Shanghai	14,557	55,000	361*24	9.50	27	0	952	7	110
Yantian	-	-	365*24	14.00	N.A	0	952	7	110
Kaohsiung	9,710	36,500	353*24	15.00	2	1	325		-
Keelung	2,070	9,400	352*24	10.35	65	0	325		-
Port Klang	5,243	12,000	347*24	13.40	50	-	213	7	65
Tanjung Pelepas	4,020	3,190	313*08	14.40	40	0	213	6	85
Jawaharlal Nehru	2,370	-	360*24	12.00	60	0	166		-
Chennai	600	-	344*24	16.20	19	2.5	166		-
Tanjung Priok	3,597	7,150	361*24	10.60	25	0	115	5	92
Tanjung Perak	1,695	-	309*06	-	N.A	N.A	115	5	92
Laem Chabang	3,529	4,650	349*8.5	13.00	-	0	190	4	93
Bangkok	1,318	2,950	349*24	8.50	25	15	190	4	93
Manila	2,696	-	362*24	9.00	10	2	83	7	95
Davao	226	-	356*24	10.00	2	N.A	83	-	-
Yokohama	2,717	42,200	344*24	12.00	N.A	0	1035	2	350
Tokyo	3,358	33,500	346*24	13.00	10	0	1035	2	350
Kobe	2,177	-	365*24	-	3	N.A	1035	2	300

Note: 'N.A' indicates the unavailability of facility; '-' indicates that figures on actual distance is not published

Source: [1]Containerisation International Yearbook (2006)
[2]Fairplay Ports Guide (Accessed online March 2007)
[3]World Competitiveness Yearbook (2006)
[4]Lee et al (2006)

Normalizing the port variables[9] in Table 3-8 and using Varimax rotation in conjunction with factor analysis, we obtain the factor loadings in Table 3-9.

Table 3-9 Rotated Factor Loadings and Communalities[10] (Varimax Rotation)

	Factor Loadings			Communality
Variable x_i	**Factor 1**	**Factor 2**	**Factor 3**	
Port Traffic (TEUs)	0.090	-0.864	-0.264	0.825
Number of Port Calls	0.246	-0.892	-0.199	0.896
Operations hours	0.416	-0.174	-0.787	0.823
Draught	-0.049	-0.793	0.466	0.848
Inter-modal Transport Facilities	-0.390	-0.036	-0.758	0.729
Trade	0.870	0.063	-0.129	0.777
Turnaround time	0.767	-0.484	0.103	0.832
Port Charges	-0.950	0.154	-0.074	0.932
Variance	2.6437	2.4652	1.5534	6.6623
% Var	0.330	0.308	0.194	0.833

Trade volume, turnaround time and port charges, is found to load heavily on factor 1. Port traffic, number of port calls and draught load on factor 2 while port operations hours and the presence of inter-modal transfer[11] load on factor 3 Thus, factors 1, 2 and 3 relates to the cost and time efficiency of the port, scale economies offered by the port, the convenience in using the port respectively.

[9] While the main purpose of standardization (i.e., dividing each observation point by score of the best performer in the dimensions) is to avoid dominance of measures with bigger figures, we also convert the negative scores in factors 2 and 3 into positive ones for ease of interpretation in the process. We need to exercise some caution when we normalize scores with respect to the best performing port here since best performers in port calls, operations, draught, inter-modal facilities, trade are represented by largest numerical figures whereas best performers in turnaround time and port charges are represented by the smallest numerical figures.

[10] For standardized variables **X**, the square of the correlation coefficient, λ_i^2 , known as the communality of x_i gives the proportion of variation in x_i accounted for by the common factor ξ. This common factor model, comprising 8 variables and 3 common factors, can be written in matrix notation form as $\mathbf{X} = [\xi_1\ \xi_2\ \xi_3]\mathbf{A}_c' + [\delta_1\ \delta_2\ \delta_3]$ where δ_i are the specific factors and $\mathbf{A}_c$ is a 8 by 3 matrix of coefficients.

[11] For simplicity, we use a binary variable (0, 1) to denote the presence of rail and airport facilities since their distances from port is not available for all the observations in the sample.

Table 3-10 Factor Score Coefficients

Variable	Factor1	Factor2	Factor3
TEUs	-0.079	-0.368	-0.143
Port Calls	-0.017	-0.362	-0.098
Operations	0.140	0.000	-0.499
Draught	-0.118	-0.376	0.325
Inter-modal	-0.178	-0.044	-0.495
Trade	0.370	0.146	-0.074
Turnaround	0.258	-0.119	0.091
Charges	-0.377	-0.053	-0.065

In order to determine the sample ports' locations in the reduced factor space, we compute the factor scores[12] for each port from the factor score coefficients in Table 3-10.

Table 3-11 Factor Scores of Selected Ports

Port	Factor 1	Factor 2	Factor 3
Hong Kong	0.8454	-0.7534	-0.4813
Singapore	0.8325	-1.0819	-0.6427
Shanghai	0.4758	-0.5491	-0.8845
Pusan	0.4924	-0.7246	-0.4723
Port Klang	0.1337	-0.7766	-0.6631
Tanjung Pelepas	0.0905	-0.6981	-0.2875
Tanjung Priok	0.1764	-0.6201	-0.7120
Laem Chabang	0.1791	-0.4844	-0.0110
Tokyo	0.6697	-0.1869	-0.6553
Yokohama	0.7062	-0.0206	-0.3625
Bangkok	0.1685	-0.5000	-0.7377
Incheon	0.3244	-0.4732	-0.4273
Mean	0.4246	0.5724	0.5281
Median	0.4001	-0.5846	0.5620
Standard Deviation	0.2835	0.2783	0.2375

From Table 3-11, we observe that Hong Kong and Singapore ports are characterized by high efficiency and scale economies. While the Japanese ports (Tokyo and Yokohama) outperform Shanghai and Pusan in terms of efficiency, Shanghai and Pusan are able to offer greater scale economies to shipping lines. Smaller ports like Bangkok, Klang and Tanjung Priok, though comparatively less efficient, provide good convenience to users. Comparing port's performance in terms of scale

[12] The factor scores for each individual port is estimated from $[\xi_1\ \xi_2 \ldots \xi_c] = \mathbf{X}\mathbf{R}^{-1}\ \mathbf{A}_c$ where $\mathbf{R}$ is the sample correlation matrix.

economies and conveniences, the Korean ports (Pusan and Incheon) are seen to be well-balanced on these two measures.

Denoting the three broad, mutually preferentially and independent dimensions port efficiency, scale economies and convenience as F_1, F_2 and F_3 respectively and standardizing the input data, we obtain the non-linear logit model for connectivity of port *i* as

$$S_i = \frac{e^{-4.099 + 1.372 F_{i,1} + 1.148 F_{i,2} + 0.445 F_{i,3}}}{1 + e^{-4.099 + 1.372 F_{i,1} + 1.148 F_{i,2} + 0.455 F_{i,3}}} + \varepsilon_i$$, where ε_i is the error term.

There is a good fit between the connectivity index and the scores on the three key operating dimensions[13]. The coefficients of all the three explanatory variables report the expected signs, with efficiency and scale economies being statistically significant at $\alpha = 0.005$. For a non-compensatory aggregation function, the coefficients of the independent dimensions are interpreted as the importance of the dimension in question relative to other dimensions in the model. As such, efficiency represents the key element in which a successful port must be able offer to its shippers. Scale economies is another dimension that a port would need to achieve to stay competitive. These imply that favorable natural port conditions such as large country trade volume and deep waters are very important in attracting port calls. Convenience turns out to be less essential, which may possibly be attributed to the fact that the binary data merely reflect the presence of inter-modal facilities without considerations of the proximity and capacity of these supporting infrastructures.

[13] R-square value and adjusted R-square values are 0.888 and 0.822 respectively

3.4.4 Importance of Inter-port Relationship to Port Traffic

In essence, port cooperation index, c'_{ij}, and the aggregate cooperative index, ACI, used in our analysis are functions of the direct and indirect links between the port and other ports in the region. The routing decisions of carriers are typically made in view of the operating effectiveness and the quality of service provided to shippers. More specifically, a carrier weighs the tradeoffs between cargo shipping cost on line-haul legs of the network against that on direct shipping to its destination. The average shipping cost per TEU tends to decrease on line-haul legs of a hub-and-spoke network but since cargo originating in feeder ports must be transshipped through a hub, extra shipping distance, shipping time, port charges for loading and unloading will be incurred. The quality of service rendered to shippers will also be undermined by the higher inventory cost that arises from delays in the transshipment process and longer distance.

As an empirical verification of the importance of inter-port cooperation to a port within the carrier's hub-and-spoke network, an explanatory model is derived for the port traffic (x_4) in terms of the ACI, number of port calls (x_1), draught (x_2), trade volume (x_3), turnaround time (x_5), port charges (x_7). Since operation hours (x_5) and inter-modal transport capabilities (x_8) are found to be less important in section 3.4.3 and Lee et al. (2008), these variables are omitted. The model[14] is given as:

$$x_{4,i} = -73515.990 + 8579.459ACI_i + 1901.157x_{2,i} + 33.482x_{3,i} - 1348.699x_{5,i} - 58.515x_{7,i}:$$

The traffic at port i is noted as being positively and significantly related to its ACI at $\alpha = 0.005$. Such findings are reasonable since cooperative arrangements between major and feeder ports in a maritime hub-and-spoke network will facilitate freight

[14] R-square and adjusted R-square are 0.927 and 0.835 respectively

consolidations and allow for economies of scales. As expected, cargo traffic increases with the draught and trade volume but decreases with turnaround time and port charges. The latter is the least influential factor in determining the traffic at a port. Such observations are congruent with Murphy et al. (1991), Tongzon (1995) and others who advocated that port charges are a small proportion of total transport costs and their overall impact on port choice decisions could have been offset by other more significant indirect costs of transport and superior services.

3.5 Conclusions

This chapter develops the NHPA model from a network perspective via a simultaneous consideration of connectivity and cooperative indices. The NHPA model provides a platform for the analysis of ports' potential to be developed into a global or regional hub port and the sustainability of hub status for existing hub ports. The computation of the connectivity and cooperative indices are illustrated in three case studies involving major carriers in the maritime industry. The global hub ports in hub-and-spoke networks of the leading carriers are found to be Singapore, Hong Kong, Shanghai, Pusan and Kaohsiung. Of these ports, Singapore and Hong Kong ports are the more sustainable ones due to the cooperative relationships these ports engaged with other major Asian ports. Jawaharlal Nehru, Laem Chabang and Tanjung Priok are the regional hub ports. On observation that there is a general trend towards more competition rather than cooperation among Asian ports (owing possibly to overlapping hinterlands), an assessment of port preferences is carried out through a logit model that reveals port efficiency and scale economies to be the most important dimensions in determining a port success as a hub port. The importance of maintaining strong inter-port cooperation has also been empirically verified. Among important port attributes such as time and monetary cost of using the ports and environmental conditions, a high port cooperation index is demonstrated as the most influential factor in port cargo traffic. Nonetheless, we caution that care should be exercised in interpreting the relative magnitude of the various port qualities on port competitiveness due to the small sample and findings may not be generalizable beyond Asia. Also, while the connectivity index within the NHPA model does provide a basic measure of port accessibility in a network sense, it takes no account of capacity.

Similarly, the viability of an air hub is jeopardized if airlines decide to bypass transit airport and offer direct connections in some city-pair markets to decrease the required time to destination and increase convenience to passengers. We could conduct a similar study in the context of the airport industry by replacing the seaport-specific variables with the relevant airport-specific variables as in Table 3-12 below. The required data on the above variables are readily obtainable from annual publications by the Air Transport Research Society and International Air Transport Association such as the Airport Benchmarking Reports and World Air Transport Statistics. The former source provides detailed airport related information on many airport operations aspects, while the latter source includes an assessment of airport connectivity and the quality of these connections. We conjecture that the results may be somewhat similar except that airport efficiency may assume much higher importance than scale economies as time is attached greater importance compared to cost in air transport.

Table 3-12 Seaport Specific versus Airport Specific Variables

Aspect	**Seaport Industry**	**Airport Industry**
Network representation	Liner companies schedules	Airlines companies schedules
Traffic	Sea cargo (TEUs)	Airfreight (Tonnes)
Connectivity	Number of port calls	Number of aeronautic movements
Operations hours	Daily operation hours* operating days per year	Daily operation hours* operating days per year
Maximum vessel/ aircraft size	Depth of water (i.e., draught)	Length of runway
Inter-modal Facilities	Presence of rail and airport	Presence of rail and seaport
Port Efficiency	Average turnaround time per vessel	Flight delays in landing and taking off
Cost incur in port use	Average port charge per vessel	Aeronautic charge per flight

Rather than repeating the steps in this chapter mechanically, we derive the joint optimal pricing and capacity investment rules for airports that are competing for connecting traffic as hub airports in the next chapter using a modeling approach.

CHAPTER 4

THE CHANGING LANDSCAPE OF THE AIRPORT INDUSTRY AND ITS STRATEGIC IMPACT ON AIR HUB DEVELOPMENT IN ASIA

4. Introduction

Since the introduction of the hub-and-spoke concept in the late 1970s, most global airlines have adopted the hub-and-spoke network in their flight schedules. Consequently, airports facilitating airline hub functions were able to increase air traffic volume significantly (Kraus and Koch 2006). Despite the fact that the recent market entry of low cost carriers (for example Air Asia, Tiger and Value Air in Singapore, One Two-Go by Orient Thai Airlines, Thai AirAsia and Nok Air in Thailand, Hansung Air and Jeju Air in South Korea, Skymark Airlines and Star flyer in Japan, Spring Airlines in China and Viva in Macau) has re-strengthen point-to-point links between secondary airports, it is observed that hub airports[1] still dominate the global ranking of airports (passengers, air cargo and aircraft movements). As airlines will make considerable investments in their hub airports in order to secure reliable resources and ground services, an airport would almost be guaranteed traffic

[1] Button (2002) defined a hub to be one with entailing carriers feeding three or more banks of traffic daily through an airport from some 40 or more cities. Alternatively, the Transportation Research Board (1991) defined a hub as one with a major carrier accounting for more than 50 percent of all local traffic or two carriers accounting for more than 75 percent of all local traffic.

flow, thereby stable revenue and profits upon becoming a hub for a major airline. In addition, for public-owned airports, positive spillover of economic activities of a hub airport to local economies is also a desired objective.

Airports compete for airlines to become hub airports. Major airports such as Frankfurt, Heathrow and Changi derive much of their positioning as hubs for the reason that they are hosts to one or more principal airlines. A central geographical location is an important factor when airlines select their hub airports in continental networks but this location aspect becomes less critical when inter-continent networks is concerned (Oum and Zhang 2001). Rather, other factors such as capacity of airport, costs of local labor and airport charges, congestions are essential considerations to the airlines. Oum (2008) highlighted that open skies (or single) market will induce major Asian airlines to set up multiple hub traffic collection and distribution networks. While each airline will base their super-hub in their home country, these airlines would shift their operations and create mini-hubs in major population centers in other countries where cost are low. Moreover, consolidations in the airline industry have increased the bargaining powers of airlines vis-à-vis airports. Some examples of consolidation among airlines are Air China, China Eastern Airlines and China Southern Airlines which were established through mergers with smaller state-owned airlines since 2005. In Japan, Japan airlines and Japan Air System were merged under a single umbrella in 2002. These lead to intensifying competition in the airport industry, in which airports seek to charge attractive rates and invest into adequate capacity to become the preferred hub airports for airlines.

Against this backdrop, there is concern that clusters of airports have come into sight with each of them attempting to develop route connectivity and air traffic from the limitations of a finite market (Ringbeck et al. 2006). The traditional view is to consider the aggregate capacities of the main airports in a cluster and to relate this to the size of the underlying trends of route development. On this view, the experience will be painful for the weaker airports in a cluster because there will be some transfers and re-distribution of traffic. While some of these arguments may be persuasive, Wei (2006) suggested that there is a tendency to overlook the fact that an increase in airport capacity may spawn its own demand and the additional demand may in some cases more than mitigate the attrition in air traffic volumes. In fact, the competition among airports in a cluster may raise productivity and service quality and, more importantly, drive the development of new routes and connectivity. For example, the mega cluster of airports in the Gulf States have contributed to the rapid growth in routes between Asia and the Middle East and enhanced connectivity for carriers plying between destinations in Africa and Asia. Furthermore, although the arrivals of low cost carriers take away some traffic previously served by the big carriers, their net effect is to make air travel more affordable and raise substantially the volume of passengers served. While the jury is still out on the magnitude of their impact, it is no doubt the emergence of the low cost carriers will raise the efficiency and affordability of air travel and this will, in the process, accentuate the demands for airport capacity and change the dynamics of the airport business.

The increase of airport capacity is seen to be urgent and important because capacity limitation and congestion may be a major potential impediment to air transport growth. Governments and airport operators experience perennial tensions in comparing the case for stretching existing facilities with that for the expansion of new facilities. While this problem is, perhaps, more prevalent in Europe where land restrictions new noise standards impose severe constraints on the scale of airport development, the reality that airport expansion and development projects absorb considerable land and financial resources cannot be understated. In recent years, the outlay to develop a new airport or upgrade an existing airport has increased significantly with at least two new cost drivers becoming very prominent. The first relates to the need for any new airport to address the whole dimension of security threats which have been identified following the 911 events. These have to be factored into the designs relating to runway and vehicular approaches to the airport, the circulation and layouts of terminal buildings and the introduction of new security and baggage handling systems and processes. The second cost driver arises from the provision of facilities to enable an airport to deliver higher service and performance levels. One example is the service demands with the arrival of the new age of mega aircraft in the mode of the A380s and the Boeing Dream Liner. Any new airport with pretensions to be an air hub can no longer rely on remote stands but to offer at least 80 percent full contact gate facility if it intends to mount a credible pitch for connectivity.

In Asia, construction and development of huge airports have continued since 1990s as shown in Table 4-1. Currently, the construction cost is between US$25 and US$30 million per million passengers per annum (mppa) for an international airport terminal building in the 15 to 30 mppa range[2]. Thus, a terminal building with a capacity of 25 mppa will be expected to cost between US$620 and US$750 million. This order of capex transforms into a whole complexion of airport development financing and leads to a surge in airport privatization programs and the use public-private partnerships in financing landscape of airport developments. The idea that an airport is a sacrosanct infrastructure on which considerations of national security and sovereignty reigns and the ownership of an airport should be left largely in the hands

[2] According to Changi International, this unit cost relates to the construction cost of the basic terminal building only, including support systems such as building services and baggage handling but excludes interior fit out costs and consultancy fees.

of the government or at least be government controlled is fast changing. Some of the major airports in emerging economies such as China and India such as Beijing, Shanghai, Shenzhen, New Delhi and Mumbai have already developed significant experience in this direction.

Table 4-1 Major Airport Developments and Expansions in Asia, 1994 – 2008

Airport	Date of Completion	Purpose of Development	Estimated cost
Osaka – Kansai	Sep 1994	New airport to serve the international traffic previously handled by Osaka Int. airport	USD 20 billion
Kuala Lumpur	Jun 1998	New airport to replace Subang airport	USD 3.5 billion
Hong Kong – Chek Lap Kok	Jul 1998	New airport to replace Kai Tak airport	USD 20 billion
Shanghai – Pudong	Oct 1999	New airport to serve the international traffic previously handled by Shanghai Hongqiao Int.	USD 1.7 billion
Seoul – Incheon	Mar 2001	New airport to replace Gimpo Int.	USD 5.4 billion
Guangzhou – Baiyun	Aug 2004	New airport	USD 2.4 billion
Nagoya – Chubu	Feb 2005	New airport	USD 7.3 billion
Kobe	Feb 2006	New airport	USD 2.9 billion
Kansai	Aug 2007	Addition of runway	USD 8.0 billion
Beijing - Capital	Aug 2008	Addition of the world's biggest passenger terminal	USD 3.0 billion

In view of the high cost commitment, airport expansion and development are to be planned with development financing in mind. While there is some consensus on the capability of airport to serve aircraft of a size which is sufficient to deliver economies of scale for the carrier and the provision of a terminal and apron configurations that will allow for quick aircraft turnarounds[3], the emergence of infrastructure funds from the private sector has now imposed new benchmarks for financial performance of airports. Investment returns on airports are being compared with those generated by utilities. In time, airports may be seen increasingly as an asset

[3] Industrial practitioners suggested that the benchmark for this is 30 minutes at the 2006 conference on global airport development held in Rome.

class on its own with more interesting potential for revenue growth (chapter 7 will discuss this issue in greater depth).

The main objective of this chapter is to examine how the pursuit of an air hub development strategy will affect an airport's pricing and capacity investment decisions, recognizing that it is through route structures that airports compete for airlines and air hub status. To achieve this objective, we model competing airports as imperfect/ non-identical substitutes offering different net utility after accounting for price and delay and depict airline choice of airports by a multinomial logic (MNL) model. Route alternatives[4] are formed when different airlines choose different transit airports that give them the highest utility (or net gain) to serve cargo market of a particular origin-destination pair. In addition, we add three complications to the model setup in the existing studies. An important one is to allow for interdependency between airport pricing and capacity investment[5], which has the important implications on an airport's profitability that depends on airlines willingness to pay[6]. The second extension is to consider partial privatization[7] of airports. In Asia, Beijing

[4] The literature survey in Basso and Zhang (2007) identified that there were no route structure decisions on the part of the airlines in Oum et al. (1996) and Brueckner (2005) which studied a network of airports. While Pels (1997) considered route structure decisions, capacity choices are excluded.

[5] Zhang and Zhang (2003) and Oum et al (2004) made an implicit assumption that price and capacity investment decisions in an airport are independent of each other.

[6] While the inherent differences among airports may accrue them some extent of monopoly power, the issue of competition cannot be ignored as expansion moves by an airport may evoke retaliatory actions from competing airports that are unwilling to lose their market shares or to give up their own position as gateway to their regions. The resultant increase in airport capacities in the aggregate industry will suppress prices that an airport can command, with price pressure further intensified as a consequence of the wider array of airports from which airlines are free to choose. On the other hand, prices may also arise with increased capacity as delay reduces and service improves.

[7] Vasigh and Gorjidooz (2006) exemplified that government only sell a portion of the ownership and maintain the rest of the business interest for direct influence in airport management or for using the sale proceeds to finance airport expansions in some of the airport privatization cases. Oum et al. (2008) found that the proportion of private ownership in airports affect their efficiency. Prior to Oum et al, analytical studies by Zhang and Zhang (2003), Oum et al. (2004) and Basso and Zhang (2007) so forth have considered airports that are either purely public or purely private.

Capital International Airport, Shanghai Pudong Airport, Malaysian airports under the Malaysia Airports Holdings Berhad have been partially privatized. Singapore Changi and Tokyo Narita airports are expected to be privatized in the near future. As privatization gains momentum, it will be meaningful to factor in the possibility of airports having mixed ownership into the modeling and analysis. The third extension is to consider and compare the effect of downstream market structures on airport's capacity demands and airport pricings.

While serving super-hub roles for national flag carriers, Oum (1997, 2008) remarked that it must attract as many foreign carriers to use the airport as mini-hub and these foreign carriers would preferably include successful low cost carriers. The presence of low cost carriers encourage price and service competition among airlines and discipline full service airlines to stay efficient, and therefore enhancing airline-induced airport efficiency and improving airport profitability and consumer welfare. Thus, the second objective of this chapter is to explore into the possibility of having budget terminals[8] or secondary airports (which is more prevalent in North America) to co-exist profitably with hub airports and the demand and supply conditions under which an airport will be more profitable serving the respective markets. At the demand side, airlines' willingness to pay is higher for airports that offer good connectivity, safety reputations, operating hours etc, and differ between full service airlines and low cost carriers. At the supply side, airports face different cost structures that translate into varying levels of ease and success to transform these airports into an air hub. Previous studies that considered multiple airports like

[8] Typically an airport remodels its operations by offering low cost carriers the flexibility to choose from a menu of ground facilities and services instead of delivering these as a standard package. These options provide low cost carriers with the latitude to cost differentiate and capitalize on its understanding of the particular requirements of each sector of service. In Singapore and Malaysia, a dedicated budget terminal is developed in Changi and Kuala Lumpur airports where the basic operational processes can be transacted on a more cost competitive basis.

Bruckner (2002), Zhang and Zhang (2006) and De Borger and Van Dender (2006) assumed these airports to be either perfect substitutes or complements to one another. An exception is Basso and Zhang (2007) who modeled that the airlines utility derived from nearer airports are higher due to transportation cost. However, common in these studies, the intrinsic qualities and endowments of airports are assumed to be the same and costs are governed by constant economies of scale.

The rest of the chapter will be organized in the following manner: Section 4.1 discusses the literature on airport pricing and capacity investments in brief. Section 4.2 develops the model that describes behavior of airlines serving a differentiated and undifferentiated cargo market using service inputs provided by non-identical airports that differ in prices and services. Section 4.3 analyzes the pricing and capacity decisions of airports, which serve a differentiated downstream transport service market through output of airlines intermediaries. This is followed by the derivations of airlines output and demand for airport capacity in an undifferentiated cargo service market where shippers are indifferent among airlines and airlines choose the airports based on price, so long as the cargo can reach its destination on time. Section 4.4 examines the conditions under which airports will be more profitable to operate a budget terminal (or as a secondary airport) compared to super hub airports, when airlines place different valuations on price and service. Section 4.5 concludes the chapter.

4.1 Literature Review

There is a large body of literature on airport pricing and/or capacity investment. Basso and Zhang (2007) provided a very comprehensive survey on the literature of airport pricing and identified the traditional approach and vertical approach as two main approaches adopted in the analyses. The authors defined the traditional approach as one that follows a partial equilibrium analysis in which an airport's demand is directly a function of the airport's own decisions and the derived characteristics of the airport's demand from airlines and the end consumers are not formally recognized. Whereas, the vertical approach is one that recognizing that airports provide essential service inputs required by airlines to move passengers or cargo outputs. The key difference between the traditional approach and the vertical approach is that the behaviors of downstream players are explicitly modeled in the latter.

Similarly, papers that simultaneously consider airport pricing and capacity investments use similar approaches. Some of those papers that used the traditional approach are Oum and Zhang (1990), Zhang and Zhang (2003), Oum et al (2004) and De Borger and Van Dender (2006). Oum and Zhang (1990) first studied the aeronautic pricing and timing of runway expansion when capacity is lumpy and the airport is wholly public-owned. Zhang and Zhang (2003) compared the aeronautic and concessionary prices and timings of lumpy capacity expansion in a private, unregulated airport and a public airport restricted by a budget constraint against a public airport. Oum et al. (2004) investigated the effects of aeronautic and concessionary service demand complementarity on the pricing in public, private unregulated and private regulated airports when capacity investment is divisible. Considering multiple competing airports that are perfect substitutes, De Borger and Van Dender (2006) compared aeronautic pricing and divisible capacity investments under different airport market structure (namely, a monopoly versus a duopoly) against the social optimal. Common in all these papers, the airports under study are either fully private or public such that private airports maximize profit whereas public airports maximize social welfare. Airport demand is modeled as a function of aeronautic prices and delay. Capacity investment is governed by constant economies of scale and decreases full price through delay reductions, with aeronautic price and capacity decisions being independent of each other.

Meanwhile, other researchers adopt the vertical approach in which airports provide indistinguishable service inputs to airlines. Starting with a single airport, Brueckner (2002) compared the extent of congestion aeronautic pricing during peak period under different airline market structure (like competitive, monopoly and cournot oligopoly) and fixed airport capacity. Zhang and Zhang (2006) examined the effect of airline market structure on airport aeronautic pricing and divisible capacity investment in a private or public airport (with and without budget constraint) when airlines' outputs are perfect substitutes to one another. Extending to multiple airports, Brueckner (2005) examined if the flight-share rule for congestion pricing established in Brueckner (2002) will continue to hold in a network setting where flights connect two complementary airports in which either one or both are congested. Pels and Verhoef (2004) examined the effect of market power distortions on optimal congestion (aeronautic) pricing when airlines are perfect substitutes to each other and passengers are pure price taker. Modeling two competing identical airports located some distance away from each other and servicing airlines operating under cournot market structure, Basso and Zhang (2007) compared aeronautic prices, runway capacity and congestion delays under a monopoly and duopoly airport market structure, and market power in airline's final consumer market, where demand from final consumer is a function of price, delay and distance cost.

Nonetheless, analytical work on the issue of air hub development is at a minimal even though there have been some case studies and empirical work such as Button (2002) and Kraus and Koch (2006). Similarly, research works that address the impact of low cost carriers on airport dynamics are generally descriptive documentation (for examples, Pantazis and Liefner, 2006; Gillen and Lan, 2004).

4.2 The Model

The model takes a vertical approach that examines joint market equilibrium for airport pricing and capacity decisions. Since airlines' demand for airport services is a derived demand from the passengers and air cargo market, we study a two-stage game and solve for joint airport price and capacity equilibrium using backward induction. In the first stage, each of the M non-identical airports decides on price and capacity. In the second stage, each of the N combination airlines[9] chooses the frequencies of flights in the transit airports for a particular origin-destination (O-D) pair according to a MNL model[10] with parameters that consist of net utility computed as airlines willingness to pay[11] less airport price and delay (commonly known as full price). Airports that offer greater net utility to airlines are expected to be more attractive. Suppose if airlines serve a perfectly competitive cargo market with homogenous services to shippers, airlines will then select their transit airports based on price so long as it reaches its

[9] Compared to pure cargo airlines that use freighter aircraft, combination airlines carry cargo in the belly compartment of their passenger aircrafts or at the back section of "Combi" aircraft. Zhang and Zhang (2002) noted that more than 55 percent of the airfreight is carried in the belly compartments of passenger aircrafts in Hong Kong. For the major Asian airlines, revenue from cargo constitutes between 16.5 percent and 34 percent of the airlines total revenue.

[10] Hess and Polak (2005) examined the effect of airport attributes such as fare, frequency, access-journey time on travelers' choices of airport using MNL model. Prior research that have used the MNL model includes Skinner (1976), Harley (1987), Ashford and Benchemam (1987) and Windle and Dresner (1995). These studies shared a common focus in their modeling passenger choices of airport and derived the value of various airport attributes to business and leisure travelers. Hence, although the idea of modeling airport choice using MNL model is not new, the important intermediate link between airlines and airport has been neglected in the current literature.

[11] The concept of willingness to pay in the context of airlines-airport is first introduced by DeBorger and Van Dender (2006) who represented airlines' aggregate willingness to pay as an aggregate inverse demand function and equated the willingness to pay with total price and time cost at equilibrium. This implies that there is no consumer surplus - a condition that can only exist where airports are allowed to practise price discrimination and charge airlines according to their willingness to pay, thereby capturing all consumer surplus.

destination on time. Before we describe the market structures and the demands for the airport's and airlines services in their differentiated and undifferentiated downstream markets in sections 4.2.1 and 4.2.2 below, we introduce the notations adopted in our model for $1 \leq i, j \leq M$ and $1 \leq k \leq N$ as follow:

Notations

K_i : Capacity in airport *i*, in terms of flights that can be handled per period of time

P_i : Aeronautic price per unit of capacity in airport *i*

Q_i : Demand for airport *i*, in terms of flights per period of time

$D_i(Q,K)$: Delay cost at airport *i*, given demand and capacity

ρ_i : Full price charge in airport *i*, i.e., $\rho_i = P_i + D_i(Q,K)$

w_i : Airlines' willingness to pay (also referred to as the airlines' reservation price) for a unit of capacity in airport *i*

β_i : Airlines' marginal willingness to pay for an additional unit of capacity in airport *i*

$\gamma_{i,j}$: Airlines' marginal willingness to pay for a unit of capacity in airport *i*, with an additional unit of capacity at airport *j*

s_i : Airlines' surplus, defined as airlines willingness to pay less full price (i.e., $s_i = w_i - \rho_i$)

f_t : Cargo fare in an undifferentiated market of a particular origin-destination at time *t*

θ : Price elasticity of the cargo service

$q_{i,k}$: Number of airline *k*'s flights flown through airport *i*

b: Utility for using the reference airport that provides basic services.

z: The degree to which external preferences, not included in the model, influences airport choice

4.2.1 Differentiated Downstream Market

In an oligopolistic airport industry consisting of a reference airport and *M* competing non-identical airports, airlines' aggregate willingness to pay w_i function for a unit of airport *i*'s facilities is assumed to take the form:

$$w_i = \alpha_i - \beta_i K_i - \sum_{\substack{j=1 \\ j \neq i}}^{M} \gamma_{i,j} K_j \tag{4.1}$$

where α_i is the intercept term. There is no sign restriction on β_i that measures the marginal airlines' willingness to pay[12] for each additional unit of the capacity in the airport *i*, given the aggregate market capacity of airports competing in the market. If β_i is positive, an increase in K_i will reduce w_i due to excess capacity. On the other hand, if β_i is negative, w_i will increase as service improves with a larger K_i . For $\gamma_{i,j}$ that measures the elasticity of the airlines' willingness to pay for each unit of capacity in airport *i* with respect to an increased unit of capacity in a competing airport *j*, $\gamma_{i,j} = 0$ if airport *j* is not a competitor to airport *i* and changes in the capacity of airport *j* will have no effect on airport *i*. In the absence of regional competition (i.e., $\sum_{j \neq i}^{M} \gamma_{i,j} = 0$ in eqn. 4.1), the scarcity of capacity in a monopolist leads slot constraints that push up aeronautic prices. On the other hand, for $\gamma_{i,j} < 0$ airport *i* is in cooperative relationship with airport *j*. Increase in capacity of airport *j* will enhance the services of the airport which stimulate a larger volume of through traffic and higher willingness to pay for capacity in airport *i* (vice versa). We also require

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[12] Microeconomics theory postulates that demand elasticity tends to increases with supply *K*. In this model, we make a simplifying assumption that β is constant and independent of *K*. But noting that each airport is non-identical to another, β_i differs according to airports.

$|\beta_i| > |\gamma_{i,j}|$ to denote that the willingness to pay for facilities at airport i is less significantly affected by expansions in other airports[13].

Passengers have different preferences for transit points, which give rise to different demands and profitability on different routings for the same origin-destinations pair. These diverse preferences may stem from location-related weather conditions, shopping facilities at airports or the proportion split of their entire flight journey between the first and second leg. In other cases, a choice of different transit points result in cost differences due to airport charges and delay (or capacity congestion). Furthermore, since airlines operate in a hub-and-spoke network, the interconnectedness of an airport's network gives rise to the connectivity considerations in terms of range of destinations served and frequencies of connecting flights for other origin-destination pairs. As such,

$$w_i = P_i + D_i(Q,K) + s_i \qquad s_i \geq 0 \tag{4.2}$$

Eqn. (4.2) states that airlines' willingness to pay w_i is made up of airport aeronautic charges P, delay cost $D_i(Q,K)$ and a third component s_i which represents the amount of economic rent airport i possesses. The first two elements are captured as the full price ρ paid to an airport such that $\rho_i = P_i + D_i(Q,K)$. Delay cost, as represented by $D_i(Q,K)$, is a function of traffic Q and capacity K. A substantial part of s_i may be attributed to location factors such that airports situated at strategic locations are able to attract a larger pool of passengers and airlines user-base, increasing passenger loads,

[13] Considering that freight forwarders (the airlines' customers) are traditionally based at the main airports do not want to fragment their flow of freight and go new places, Gardiner (2005) advocated that traditional airports that have long served air cargo that the airlines wish to operate have made it difficult for other airports to attract airlines. This is apparently true observing that airlines are undeterred in continuing their uses of main airports, for examples Heathrow in London and Narita in Tokyo, despite the presence of cheaper and less congested airports in the region.

facilitating airport connectivity and reducing transit time for airlines. For demand to be effective, it is also necessary that $w_i \geq P_i + D_i(Q, K)$. In other words, we require $s_i \geq 0$.

Equating (4.1) and (4.2), we obtain

$$s_i = \alpha_i - \left(\beta_i K_i + \sum_{j \neq i}^{M} \gamma_{i,j} K_j \right) - P_i - D_i(Q, K) \tag{4.3}$$

s_i is non-increasing in β, γ, K, P and D.

Eqn. (4.3) can be re-expressed as

$$s_i = w_i - \rho_i \tag{4.4}$$

Eqn. (4.4) says that if airport i charges airlines ρ_i for a unit of the airport aeronautic service, airlines will enjoy a surplus that is equal to their willingness to pay less the full price charged. This is congruent with microeconomic theory's definition of consumer surplus.

Since all airports charge the same full price in equilibrium[14], airlines choose airport not just on ρ but also s. If airports i and j offer s_i and s_j that are equal, these airports are perfect substitutes to each other (i.e., $w_i = w_j$ for $\rho_i = \rho_j$ in equilibrium) and airlines are indifferent between the two airports. For s_i greater than s_j, airport i is a preferred airport (i.e., $w_i > w_j$). Although airports may not raise their prices above the market rates due to competitive pressure, the economic rents enjoyed by these airports are passed onto airlines as surplus (as in eqn. 4 above) and translated into higher demands. Similar to Zhang and Zhang (1997), concessionary prices are not incorporated into the airline's decision process in airport selection as such prices do

[14] Airports that provide speedy service can command higher aeronautic prices, whereas airports with longer delays compensate for the lower service quality with lower prices.

not affect airlines' and shippers' decisions on whether to ship or not. Specifically, we apply a random utility model such that the utility an airline derives from airport *i* is

$$U_i = \kappa + x_i - P_i + \varepsilon_i \quad (4.5)$$

where κ is the value any airline derives from the service of a basic reference airport, x_i is a airport-specific outcome representing the amount by which the quality of service from airport *i* exceeds the quality of this basic service, P_i is the aeronautic price charge by airport *i* and ε_i captures randomly distributed airlines' preference for specific airports. This random utility model implies that an airline has airport-specific preferences that are randomly distributed in the population of airlines, not that airlines choose airports randomly. Eqn. (4.5) can be rewritten as

$$U_i = \kappa + s_i + \varepsilon_i \quad (4.6)$$

Eqn. (4.6) follows from (4.4). Since $\rho_i = D_i + P_i$, $s_i = w_i - D_i - P_i$. Replacing $w_i - D_i$ by x_i, we have $s_i = x_i - P_i$.

When airlines choose among the *M* airports including none at all (i.e., choose the reference airport) to maximize their own profits and the randomly distributed preferences fall in a double-negative exponential distribution, the demand for each airport *i* (denoted as $Q_i\,(w,\rho)$) follows a multinomial logit (MNL) equation widely used in Economics (McFadden, 1974):

$$Q_i(w,\rho) = \frac{e^{zU_i}}{\sum_{i=1}^{M} e^{zU_i} + b} \qquad z \geq 0 \quad (4.7)$$

For low values of *z*, the effect of external preferences on utility is larger and market shares tend to equalize across competing airports. On the other hand, *z* values are large when the effect of external preferences on utility is small and market share differences among airports are more responsive to differences in airports' price and offerings.

4.2.2 Undifferentiated Downstream Market

For $i \in I$ where I is the set of M airports that allows on-time delivery of cargo to its destination, the relationship between an airline k's output and the aggregate industry's output takes the following form:

$$\sum_{i=1}^{i=M} q_{i,k} = \delta \sum_{i=1}^{i=M} \sum_{k=1}^{N} q_{i,k} \qquad \delta \geq 0 \quad (4.8)$$

The L.H.S of (4.8) shows the total output, through all the M airports, by a specific airline k. If airline k serves a perfectly competitive downstream market, this output will form a negligible proportion δ of the aggregate industry's supply consisting of N servicing airlines and M airport alternatives.

The demand from the air cargo market for a flight on a particular O-D route (including transit traffic) at a particular time, follows the inverse function below:

$$f_t = A + \eta_t - \theta \sum_{i=1}^{M} \sum_{k=1}^{N} q_{i,k} \qquad (4.9)$$

where θ measures the price elasticity of the cargo service demand.

Eqn. (4.9) says that at any one time t there is a single prevailing fare f_t in the market that airlines can charge to shippers. This assumption is valid in a highly competitive air cargo market where Gillen and Lall (1997) noted that it is very difficult for airlines to pass on the extra cost to the freight shippers since shippers regard airlines cargo services as homogenous[15] and have no particular preference for airlines or the route it takes for the cargo to reach its destination. Meanwhile, assuming that they can sell all

[15] It does not matter which airlines send the cargo and through which route (i.e. the intermediary airport) so long as the cargo reaches it destination on time.

their outputs at the prevailing market fare, airlines have no incentive to charge at a lower fare.

The intercept in (4.9) has a stochastic element with two equally likely realizations: $\eta_t \in \{-a, a\}$ for a < A. $\eta = a$ denotes the high demand at time *t* which occurs with probability of $\Pr_H$ whereas $\eta = -a$ denotes low demand state which occurs with a probability of $\Pr_L$. Thus, for airport *i*'s service to be economically affordable to airline *k*, we require *A* to be greater than the unit cost of capacity, $A > P_i$. For the airline's output to be marketable, the demand for route should be also sufficiently high such that $\Pr_H > P_i / A$. Since competitions between airports are limited to those which are sufficiently competitive, we need to impose the restriction that net present value of uncompetitive airport-airlines' output must be negative. Uncompetitive airport-airlines outputs are not marketable, $\Pr_L < P_i / (A + a)$. For notational simplicity, we consider the case in which $\Pr_H \to 1$ and $\Pr_L \to 0$. In other words, we make an implicit assumption that f_t is at least able to cover the variable cost of the airlines (i.e., the aeronautic charge P_i per flight at airport *i*) for the airlines to serve the market.

For the given fare f_t, each airline *k* will select $q_{i,k}$ so as to maximize its net revenue (defined as the total fares less aeronautic charge and other operating costs). The summation of *j* across all *N* airlines gives the aggregate demand function for airport *i*. (i.e., $Q_i = \sum_{k=1}^{N} q_{i,k}$)

4.3 Pricing and Capacity Decisions at an Airport hub

4.3.1 Differentiated Downstream Market

We derive the optimal pricing and capacity for airport i' in a *differentiated* market where airports are non-identical. Each airport offers two primary types of services – aeronautic and concessionary services. As mentioned in section 4.2.1, the demand for airport i''s aeronautic services $Q_{i'}(w, \rho)$ follows a MNL function that depends on the airlines' willingness to pay for the services of the airport less the full price. Concessionary services represent another major source of airport revenue. For a concessionary charge of $p_{i'}$ per unit of concessionary service, concessionary prices do not affect demand for airport's aeronautic service but the demand for airport i''s concessionary services by an average flight depends on p through the function $X_{i'}(p)$.

The airport incurs fixed and operating costs when providing aeronautic and concessionary services. Fixed cost pertains to the financing cost on physical capacity is given by $r_{i'}K_{i'}$. $c_{i'}(Q)$ and $c_{i'}(X)$ are the airport's variable cost for providing $Q_{i'}$ units of aeronautic services and $X_{i'}$ units of concessionary services respectively. The airport is governed by ϕ degree of public ownership, for which the objective of social welfare maximizations is assumed to take on proportional priority in addition to profit maximization. If $\phi = 0$ ($\phi = 1$), the airport is fully privatized (public owned) and concerns itself with profit (social) maximization. Further assuming that capital investment in an airport is divisible[16], the airport i's objective function [17] is expressed as follows:

[16] Although the lumpiness of airport physical capital, our assumption is not invalid considering the possibility of the traffic control system can be used.

[17] Oum et al (2004) and Zhang and Zhang (2006) have presented a slight variation of the airport pricing model by considering the objectives of fully private and public airport separately.

$$\Pi_{i'} = \phi_i \int_{\rho}^{\infty} Q_{i'}(w,\xi)d\xi + \left(P_{i'}Q_{i'}(w,\rho) - c_{i'}(Q) - r_{i'}K_{i'}\right) + \left(\phi_i \int_{p}^{\infty} X_{i'}(\xi)d\xi + p_{i'}X_{i'}(p) - c_{i'}(X)\right)Q_{i'}(w,\rho)$$

(4.10)

In (4.10), the airlines' surplus $\int_{\rho}^{\infty} Q_{i'}(w,\xi)d\xi$, together with aeronautic profits $\left(P_{i'}Q_{i'}(w,\rho) - c_{i'}(Q) - r_{i'}K_{i'}\right)$, gives the total social welfare of airport *i*''s aeronautic activities. Likewise, $\left(\phi \int_{p}^{\infty} X_{i'}(\xi)d\xi + p_{i'}X_{i'}(p) - c_{i'}(X)\right)$ when multiplied by the number of flights gives the total social welfare of airport from its concessionary services.

Proposition 4-1: *Aeronautic prices increase with the demand and value of aeronautic services relative to the competition and/or variable cost of aeronautic service provisions but decreases with profitability of concessionary services. Increase public ownership increases aeronautic charge if marginal full revenue from an additional flight is higher than the consumer surplus in concessionary services. At profit maximization, the aeronautic price is* $P_{i'} = \frac{E}{z\left(E - e^{zU_{i'}}\right)}\left[\left(1 - \phi\frac{\partial \rho_{i'}}{\partial P_{i'}}\right) - \left(r_{i'}\frac{\partial K_{i'}}{\partial P_{i'}}\right)\frac{E}{e^{zU_{i'}}}\right] + c_{i'}^{'}(Q) - \left[\phi\int_{p}^{\infty} X_{i'}(p)dp + p_{i'}X_{i'}(p) - c_{i'}(X)\right]$

Proof:

Differentiating (4.10) *w.r.t* $P_{i'}$,

$$\frac{\partial \Pi_{i'}}{\partial P_{i'}} = -\phi Q_{i'}\frac{\partial \rho_{i'}}{\partial P_{i'}} + Q_{i'} + P_{i'}\frac{\partial Q_{i'}}{\partial P_{i'}} - c_{i'}^{'}(Q)\frac{\partial Q_{i'}}{\partial P_{i'}} - r_{i'}\frac{\partial K_{i'}}{\partial P_{i'}} + \frac{\partial Q_{i'}}{\partial P_{i'}}\left[\phi\int_{p}^{\infty} X_{i'}(p)dp + p_{i'}X_{i'}(p) - c_{i'}(X)\right]$$

(4.11)

Setting (4.11) to zero

$$P_{i'}\frac{\partial Q_{i'}}{\partial P_{i'}}=\phi Q_{i'}\frac{\partial \rho_{i'}}{\partial P_{i'}}-Q_{i'}+c_{i'}^{'}(Q)\frac{\partial Q_{i'}}{\partial P_{i'}}+r_{i'}\frac{\partial K_{i'}}{\partial P_{i'}}-\frac{\partial Q_{i'}}{\partial P_{i'}}\left[\phi\int_{p}^{\infty}X_{i'}(p)dp+p_{i'}X_{i'}(p)-c_{i'}(X)\right]$$

which simplifies to

$$P_{i'}=\left\{\phi Q_{i'}\frac{\partial \rho_{i'}}{\partial P_{i'}}-Q_{i'}+r_{i'}\frac{\partial K_{i'}}{\partial P_{i'}}\right\}\frac{\partial P_{i'}}{\partial Q_{i'}}+c_{i'}^{'}(Q)-\left[\phi\int_{p}^{\infty}X_{i'}(p)dp+p_{i'}X_{i'}(p)-c_{i'}(X)\right] \quad (4.12)$$

Furthermore, differentiating (4.7) *w.r.t.* $P_{i'}$ yields

$$\frac{\partial Q_{i'}}{\partial P_{i'}}=\frac{(-z)e^{zU_{i'}}\left(\sum_{i=1}^{M}e^{zU_{i'}}+b\right)-e^{zU_{i'}}\left(-ze^{zU_{i}'}\right)}{\left(\sum_{i=1}^{M}e^{zU_{i}}'+b\right)^{2}}=\frac{-ze^{zU_{i'}}\left(E-e^{zU_{i'}}\right)}{E^{2}} \quad (4.13)$$

where $E=\sum_{i=1}^{M}e^{zU_{i}}+b$

Also, since $Q_{i'}=\dfrac{e^{zU_{i'}}}{\sum_{i=1}^{M}e^{zU_{i}}+b}=\dfrac{e^{zU_{i'}}}{E}$, (4.12) can be written as

$$P_{i'}=\frac{E}{z\left(E-e^{zU_{i'}}\right)}\left[\left(1-\phi\frac{\partial \rho_{i'}}{\partial P_{i'}}\right)-\left(r_{i'}\frac{\partial K_{i'}}{\partial P_{i'}}\right)\frac{E}{e^{zU_{i'}}}\right]+c_{i'}^{'}(Q)-\left[\phi\int_{p}^{\infty}X_{i'}(p)dp+p_{i'}X_{i'}(p)-c_{i'}(X)\right] \quad (4.14)$$

The first term in (4.14) expresses the value of airport *i*'s service relative to the industry such that it will enjoy higher demand and aeronautic prices if it offers higher value. This term is adjusted by factors in second square bracket that consider the effect of aeronautic price on full price (weighted by the degree of public ownership) and marginal change in capacity investment cost due to a unit change in price for a given demand level. Increases in variable cost of aeronautic service provisions $c_{i'}^{'}(Q)$ unambiguously increase prices. If an airport's profitability can be enhanced through a cross-subsidization of aeronautic operations from its concessionary operations, an airport will decrease $P_{i'}$ when concessionary profit $(p_{i'}X_{i'}(p)-c_{i'}(X))$ per flight increases. This reflects the complementary demand effects between aeronautic and concessionary services as in Oum et al (2004). An airport, by decreasing its aeronautic price, stimulates increases in number of flights and demand for its concessionary services. In terms of ownership structure, increase in public ownership ϕ will increase aeronautic charge if marginal full revenue[18] from an additional flight $\phi Q_{i'}\frac{\partial \rho_{i'}}{\partial Q_{i'}}$ is higher than the consumer surplus in concessionary services $\phi\int_{p_{i'}}^{\infty} X_{i'}(p)dp$ from (4.12).

Proposition 4-2: *Independent of downstream demand conditions, increase public ownership* ϕ *in airport decreases concessionary prices,* $p_{i'} = c_{i'}^{'}(X)-(1-\phi)\left(\frac{X_{i'}(p)}{X_{i'}^{'}(p)}\right)$ *for* $X_{i'}(p)\geq 0$ *and* $-\infty \leq X_{i'}^{'}(p)\leq 0$

Proof:

Differentiating (4.10) *w.r.t* $p_{i'}$ and setting to 0,

$$Q_{i'}(w,\rho)\left[(p_{i'}-c_{i'}^{'}(X))X_{i'}^{'}(p)+(1-\phi)X_{i'}^{'}(p)\right]=0 \tag{4.15}$$

It follows from (4.15) that

$$p_{i'} = c_{i'}^{'}(X)-(1-\phi)\left(\frac{X_{i'}(p)}{X_{i'}^{'}(p)}\right) \tag{4.16}$$

Since $X^{'}(p)$ represents the change in demand for a unit change in price, it is necessary that $-\infty \leq X^{'}(p)\leq 0$ which implies $\frac{X_{i'}(p)}{X_{i'}^{'}(p)}\leq 0$ in (4.16). This implies that $p_{i'}$ is lower

[18] By having $\rho = P + D$, our model assumes that an airport that offers less delay are able to command higher aeronautic price since ρ are same across airports at equilibrium. Hence, it is reasonable that the full price (and hence full revenue) and not just aeronautic price/ revenue enters into the equation in view of the trade off monetary charge and delay cost.

for large values of ϕ. Thus, we conclude that an airport with greater public ownership charges lower concessionary prices. These results are congruent to earlier studies by Zhang and Zhang (1997; 2004) and Oum et al (2004). Eqn. (4.16) is independent of downstream market characteristics due to the setup of the model which does not incorporate concessionary prices into the decision process of an airline when selecting transit airports.

Proposition 4-3: *The optimal capacity in an airport, given by*

$$r_{i'} = \frac{1}{E}\left\{ e^{zU_{i'}}\left[1-\phi\frac{\partial\rho_{i'}}{\partial P_{i'}}\right]\frac{\partial P_{i'}}{\partial K_{i'}} - \frac{z\beta\left(E-e^{zU_{i'}}\right)}{E}\left[P_{i'} - c_{i'}^{'}(Q) + \phi\int_{p}^{\infty} X_{i'}(p)dp + p_{i'}X_{i'}(p) - c_{i'}(X)\right]\right\},$$

increases with public ownership, capacity-induced aeronautic and concessionary profits, airport's economic rent but inversely related to airlines elasticity on willingness to pay.

Proof:

Differentiating (4.10) *w.r.t* to $K_{i'}$, we obtain

$$\frac{\partial\Pi_{i'}}{\partial K_{i'}} = -Q_{i'}\phi\frac{\partial\rho_{i'}}{\partial K_{i'}} + P_{i'}\frac{\partial Q_{i'}}{\partial K_{i'}} + Q_{i'}\frac{\partial P_{i'}}{\partial K_{i'}} - c_{i'}^{'}(Q)\frac{\partial Q_{i'}}{\partial K_{i'}} - r_{i'} + \frac{\partial Q_{i'}}{\partial K_{i'}}\left[\phi\int_{p}^{\infty} X_{i'}(p)dp + p_{i'}X_{i'}(p) - c_{i'}(X)\right]$$

Setting $\frac{\partial\Pi_{i'}}{\partial K_{i'}} = 0$

$$r_{i'} = -Q_{i'}\phi\frac{\partial\rho_{i'}}{\partial K_{i'}} + P_{i'}\frac{\partial Q_{i'}}{\partial K_{i'}} + Q_{i'}\frac{\partial P_{i'}}{\partial K_{i'}} - c_{i'}^{'}(Q)\frac{\partial Q_{i'}}{\partial K_{i'}} + \frac{\partial Q_{i'}}{\partial K_{i'}}\left[\phi\int_{p}^{\infty} X_{i'}(p)dp + p_{i'}X_{i'}(p) - c_{i'}(X)\right]$$

Collecting terms

$$r_{i'} = -Q_{i'}\phi\frac{\partial\rho_{i'}}{\partial K_{i'}} + Q_{i'}\frac{\partial P_{i'}}{\partial K_{i'}} + \frac{\partial Q_{i'}}{\partial K_{i'}}\left[P_{i'} - c_{i'}^{'}(Q) + \phi\int_{p}^{\infty} X_{i'}(p)dp + p_{i'}X_{i'}(p) - c_{i'}(X)\right] \qquad (4.17)$$

Eqn. (4.17) shows that capacity investment increases with public ownership ϕ as consumer surplus in concessionary services $\int_{p}^{\infty} X_{i'}(p)dp$ brought about by additional flights $\frac{\partial Q_{i'}}{\partial K_{i'}}$ and reduced delay $\frac{\partial \rho_{i'}}{\partial K_{i'}}$ are taken into consideration when making capacity investment. Independent of ownership, capacity investment increases as if capacity expansion can increase aeronautic revenue $Q_{i'}\frac{\partial P_{i'}}{\partial K_{i'}}$ and/or stimulate demand (i.e., $\frac{\partial Q}{\partial K} > 1$). The effect of the latter on capacity investment will be more significant if aeronautic and concessionary profits are high.

Differentiating (4.7) w.r.t. $K_{i'}$, we obtain

$$\frac{\partial Q_{i'}}{\partial K_{i'}} = \left[-z\beta_{i'}\left(\sum_{i \neq i'}^{M} e^{zU_i} + b \right) \right] / \left(\sum_{i=1}^{M} e^{zU_i} + b \right)^2 = \frac{-z\beta_{i'}\left(E - e^{zU_{i'}}\right)}{E^2} \tag{4.18}$$

where $E = \sum_{i=1}^{M} e^{zU_i} + b$

Substituting $Q_{i'} = \frac{e^{zU_{i'}}}{E}$ and (4.18) into (4.17)

$$r_{i'} = \frac{1}{E}\left\{ e^{zU_{i'}}\left[1 - \phi\frac{\partial \rho_{i'}}{\partial P_{i'}}\right]\frac{\partial P_{i'}}{\partial K_{i'}} - \frac{z\beta_{i'}\left(E - e^{zU_{i'}}\right)}{E}\left[P_{i'} - c_{i'}^{'}(Q) + \phi\int_{p}^{\infty} X_{i'}(p)dp + p_{i'}X_{i'}(p) - c_{i'}(X)) \right] \right\} \tag{4.19}$$

We further infer from (4.19) that whether the optimal airport capacity level K_i will increase with the utility $U_{i'}$ it offers to airlines (or economic rent element $s_{i'}$) depends on the sign of $\beta_{i'}$. Under circumstances where $\beta_{i'}$ is negative, the optimal airport capacity will increase as airlines are willing to pay for the extra capacity. This result contrasts with the existing airport capacity investment literature[19] such as Zhang and Zhang (2003) and Oum et al. (2004) who established that capacity investment in airport is set such that the marginal benefit (i.e., reduction in delay) equal to marginal cost financing when airport aeronautic price and capacity decisions are independent and demands for airport services depend on the full price.

4.3.2 Undifferentiated Downstream Market

We derive the optimal output for an airline k' in an *undifferentiated* cargo service market given the profit function of airline k' at time t as follows

$$\pi_{i',k'}(t) = R_t q_{i',k'}(t) + f_t q_{i',k'}(t) - P_{i'}(t) q_{i',k'}(t) - c_f \qquad \forall i \in M \quad (4.20)$$

where $q_{i'k'}$ is the number of flights flown by airline k' using airport i', R is the passenger revenue per flight, f is the cargo revenue per flight and c_f is the fixed industry-specific cost. Since airports do not practise price discrimination among airlines-user, $P_{i'}(t)$ is uniform across flights from all airlines at a specific time t. For notational simplicity, we omit the t dimension in the equations that follows

Let $\hat{Q} = \sum_{k=1}^{N} \sum_{i=1}^{M} q_{i,k}$ and substituting eqn. (4.9) into the profit function, we get

$$\pi_{i',k'} = \left[R + A + \eta - \theta \hat{Q}\right] q_{i',k'} - P_{i'} q_{i',k'} - c_f$$

[19] In Oum et al. (2004), the first order derivative of $\rho = P + D(Q,K)$ *w.r.t.* K is given as $\frac{\partial \rho}{\partial K} = \frac{\partial D}{\partial K}\left[1 - \frac{\partial Q}{\partial \rho}\frac{\partial D}{\partial Q}\right]^{-1}$. From this, we infer that Oum et al. had made an implicit assumption that a change in K has no effect on P (or vice versa) and increases in K will reduce full price by alleviating delay. Similarly, in Zhang and Zhang (2003), the differentiation of $\rho = P + D(Q,K)$ w.r.t. P will yield $\frac{\partial \rho}{\partial P} = 1 + \frac{\partial D}{\partial Q} \cdot \frac{\partial Q}{\partial P}$ only in the special case $\frac{\partial K}{\partial P} = 0$. In section 4.4, we examine the strategic implication when capacity investment in airports can raise aeronautic prices. That is, $\frac{\partial K}{\partial P} \neq 0$

Splitting $\hat{Q} = \sum_{k=1}^{N}\sum_{i \neq i'}^{M} q_{i,k} + \sum_{k \neq k'}^{N} q_{i',k} + q_{i',k'}$,

$$\pi_{i',k'} = [R + A + \eta]q_{i',k'} - \theta\left[\sum_{k=1}^{N}\sum_{i \neq i'}^{M} q_{i,k} + \sum_{k \neq k'}^{N} q_{i',k} + q_{i',k'}\right]q_{i',k'} - P_{i'}q_{i',k'} - c_f$$

Rearranging,

$$\pi_{i',k'} = [R + A + \eta]q_{i',k'} - \theta\left[\sum_{k=1}^{N}\sum_{i \neq i'}^{M} q_{i,k} + \sum_{k \neq k'}^{N} q_{i',k}\right]q_{i',k'} - \theta q_{i',k'}^2 - P_{i'}q_{i',k'} - c_f$$

Taking the first order derivative and setting to zero,

$$\frac{\partial \pi_{i',k'}}{\partial q_{i',k'}} = [R + A + \eta] - \theta\left[\sum_{k=1}^{N}\sum_{i \neq i'}^{M} q_{i,k} + \sum_{k \neq k'}^{N} q_{i',k}\right] - 2\theta q_{i',k'} - P_{i'} = 0$$

Replacing $\sum_{k=1}^{N}\sum_{i \neq i'}^{M} q_{i,k} + \sum_{k \neq k'}^{N} q_{i',k'} + q_{i',k'}$ by $\hat{Q}$,

$$\frac{\partial \pi_{i',k'}}{\partial q_{i',k'}} = [R + A + \eta] - \theta\hat{Q} - \theta q_{i',k'} - P_{i'} = 0$$

Solving for $q_{i',k'}$,

$$q_{i',k'} = \frac{1}{\theta}[R + A + \eta - P_{i'}] - \hat{Q} \tag{4.21}$$

Eqn. (4.21) shows that airline k''s output produced using airport i''s facilities is decreasing in demand elasticity θ, industry output $\hat{Q}$ and airport charge $P_{i'}$ but increasing in passenger revenue R and cargo market demand $(A+\eta)$.

Summing across all N airlines,

$$Q_{i'} = \sum_{k=1}^{N} q_{i',k} = \frac{N}{\theta}\left[R + A + \eta - \theta\hat{Q} - P_{i'}\right] \tag{4.22}$$

Eqn. (4.22) gives the total demand for airport i' in terms of number of flights[20]. The optimal aeronautic price and capacity levels can be obtained by substituting (4.22) into (4.12) and (4.17) respectively. Concessionary service charge is similar to (4.16) established in the preceding section.

4.4 Strategic Directions

Airports that aspire to be developed into hub airports seek to offer premium service to users and provide adequate facilities to ensure smooth flow of traffic. On the other hand, some airports may find it more profitable to operate as secondary airports especially with the emergent of low cost carriers in the Asia Pacific region. These airports make lower investments in capacity to achieve high utilization for their assets, which is critical for cost control. According to Gillen and Lall (2004), the minimization of capacity also reduces associated variable cost such as those of labor and maintenance. In this section, we explore into the conditions that determine the appropriateness of these strategies.

Lemma 4-1: *For full prices on a particular O-D pair that are equal across airports at industry equilibrium,* $D_i(Q,K)+P_i = D_j(Q,K)+P_j$ *where* $D_i(Q,K) > D_j(Q,K)$ *and* $P_i < P_j$*, the actual full price of these airport services perceived by airlines differ according to the time sensitivity* ν *and price sensitivity (1-*ν *) in the markets which they served such that*

(i) $\tilde{\rho}_i = \nu D_i(Q,K) + (1-\nu)P_i < \tilde{\rho}_j \quad \forall 0 < \nu < 0.5$ *; and*

(ii) $\tilde{\rho}_j = \nu D_j(Q,K) + (1-\nu)P_j < \tilde{\rho}_i \quad \forall \nu > 0.5$

[20] As in Zhang and Zhang (2006), if all flights use identical aircraft and have the same load factors, this measure is equivalent to the number of passengers/ volume of cargo traffic.

Proposition 4-4: *Denote g as ratio of the time sensitive to price sensitive demands, and h as the fraction of airports operating as a secondary airport. For an airport industry that satisfies the set of following conditions:*

(i) Cost- justified value adding airport service $x_i - P_i > x_{i-1} - P_{i-1}$*; and*

(ii) Monotonic increasing convex cost function, $r(\underline{K}) < r(\overline{K})$*; and*

(iii) Imperfect competitive competition $w_j - r(\overline{K}) \neq 0$ *and* $w_i - r(\underline{K}) \neq 0$,

the total profit in an airport industry is maximized at the point where

$$h = \left(\left[\left(\frac{w_j - r(\overline{K})}{w_i - r(\underline{K})} \right) \left(\frac{g}{g+1} \right) \left(\frac{\underline{K}}{\overline{\overline{K}}} \right) \right]^{1/2} + 1 \right)^{-1}$$

Proof:

Assume that $x_i - P_i > x_{i-1} - P_{i-1}$ [21] , the resultant utility level U_i depends on the value airlines placed on the incremental service relative to price according to Lemma 1. If an airline deals with time sensitive traffic, greater pressure is being put on delay $D(Q,K)$ and less on the ticket price P. Then the airline will derive greater incremental utility by using airport *i (i.e.,* $U_i > U_{i-1}$) . On the other hand, for an airline that deals with price sensitive traffic, it will derive less incremental utility by using airport *i (i.e.,* $U_i < U_{i-1}$). We let the ratio of the time sensitive to price sensitive demands to be represented by g. Denote w_i and w_j as the reservation prices of airlines serving the price sensitive and time sensitive markets such that w_j is higher than w_i. Assuming that no airport will charge below the reservation price of the price sensitive users[22] w_i,

[21] If the service increment is less than cost increments (i.e., $x_i - P_i < x_{i-1} - P_{i-1}$), then it may or may not be profitable for the airport *i* to competing on service depending on other factors such as the cost efficiency of competing airports in raising service levels and airline valuation on superior service.

[22] Even if there is an airport charging less than the reservation price, airlines may encounter inconvenience (or search cost in the marketing literature).

the only airlines that might use the airports that charge in excess of w_i are those with reservation price w_j. For an airport charging a price above w_i but below w_j, we assume that a small increase in price loses no users. It is then logical for all airports with price above w_i to charge w_j. Thus, there are only three possible equilibria: all airports charging price w_i, all airports charging w_j and some airports charging each of these prices.

We examine the two-price equilibrium to check for the conditions under which it is feasible for some airports to pursue a hub strategy and others to pursue a secondary airport strategy. Using *h* to denote the fraction of airports charging the lower price, all those traffics that are price-sensitive and some time-sensitive traffic will use these airports. The other $(1-h)$ fraction of the airports will capture the remaining market. In order to charge at a higher price, airport will need to invest in more capacity to provide more speedy service. Let $\underline{K}$ and $\overline{K}$ denote the average amount of capacity available in each of the secondary and hub airports respectively. Because *r(K)* is increasing in *K*, we require $r(\underline{K}) < r(\overline{K})$ and write the equal profit condition as

$$\left(w_i - r(\underline{K})\right)\left(\frac{1+g}{Mh\underline{K}}\right) = \left(w_j - r(\overline{K})\right)\left(\frac{g}{M(1-h)\overline{K}}\right) \tag{4.23}$$

The LHS of (4.23) gives the aeronautic profit accrued to an average secondary airport and the RHS gives the aeronautic profit accrued to an average hub airport. Under stable market conditions, the profitability of airports operating on either strategy should be equal so that there is no tendency for airports to change their long-term strategy. The total airport industry's profit is given as:

$$z = \left(w_i - r(\underline{K})\right)\left(\frac{1+g}{Mh\underline{K}}\right) + \left(w_j - r(\overline{K})\right)\left(\frac{g}{M(1-h)\overline{K}}\right)$$

Differentiating *z* w.r.t. *h*,

$$\frac{\partial z}{\partial h} = -\left(w_i - r(\underline{K})\right)\left(\frac{1+g}{Mh^2\underline{K}}\right) + \left(w_j - r(\overline{K})\right)\left(\frac{g}{M(1-h)^2\overline{K}}\right)$$

Set $\frac{\partial z}{\partial h} = 0$ and rearranging,

$$\left(\frac{1-h}{h}\right)^2 = \left(\frac{w_j - r(\overline{K})}{w_i - r(\underline{K})}\right)\left(\frac{g}{g+1}\right)\left(\frac{\underline{K}}{\overline{K}}\right)$$

$$\frac{1}{h} = \left[\left(\frac{w_j - r(\overline{K})}{w_i - r(\underline{K})}\right)\left(\frac{g}{g+1}\right)\left(\frac{\underline{K}}{\overline{K}}\right)\right]^{1/2} + 1 \qquad (4.24)$$

From (4.24), we see that *h* increases as (i) $w_i - r(\underline{K})$ increases relative to $w_j - r(\overline{K})$; (ii) g decreases; and (iii) $\overline{K}$ increases relative to $\underline{K}$. Hence, the proportion of secondary airports will increase when the gap between reservation prices of the price sensitive and time sensitive traffic narrows or cost rises sharply with airport size, the market for price sensitive becomes bigger and/or larger incremental capacities are required to provide timely service to the time sensitive traffic.

The above results are valid if and only if (4.24) is defined. In order for (4.24) to be defined, we need to establish that $\left(\frac{w_j - r(\overline{K})}{w_i - r(\underline{K})}\right)\left(\frac{g}{g+1}\right)\left(\frac{\underline{K}}{\overline{K}}\right) \geq 0$. Economic viability requires that (i) $\left(w_i - r(\underline{K})\right)\left(\frac{1+g}{Mh\underline{K}}\right) \geq 0$ and (ii) $\left(w_j - r(\overline{K})\right)\left(\frac{g}{M(1-h)\overline{K}}\right) \geq 0$. Restricting ourselves to non-negative variables of *g*, *M*, *h*, $\underline{K}$ and $\overline{K}$ (i.e., $g \geq 0$, *M* > *0*, $\underline{K} > 0$, $\overline{K} > 0$), we verify that $\left(\frac{w_j - r(\overline{K})}{w_i - r(\underline{K})}\right)\left(\frac{g}{g+1}\right)\left(\frac{\underline{K}}{\overline{K}}\right) \geq 0$ is true.

The problem of eliciting the conditions under which it is feasible for hub and secondary airports to co-exist, is equivalent to finding the conditions under which h is strictly more than 0 but less than 1 (i.e., $0 < h < 1$). That is,

$$1 < \frac{1}{h} = \left[\left(\frac{w_j - r(\overline{K})}{w_i - r(\underline{K})}\right)\left(\frac{g}{g+1}\right)\left(\frac{\underline{K}}{\overline{K}}\right)\right]^{1/2} + 1 < \infty$$

$$0 < \left[\left(\frac{w_j - r(\overline{K})}{w_i - r(\underline{K})}\right)\left(\frac{g}{g+1}\right)\left(\frac{\underline{K}}{\overline{K}}\right)\right]^{1/2} < \infty \qquad (4.25)$$

Since $\underline{K} \neq 0$ if $h \neq 0$ and $\overline{K} \neq 0$ if $h \neq 1$, it follows that the inequality in (4.25) holds if (i) the airport industry is not perfectly competitive in both the hub and secondary airport sectors (i.e., $w_j - r(\overline{K}) \neq 0$ and $w_i - r(\underline{K}) \neq 0$) and (ii) there exists a certain proportion of price sensitive traffic g (i.e., $g \neq 0$).

Proposition 4-5: *Suppose the airport is governed by convex delay-alleviating and capacity investment cost functions in the form* $D_i(Q,K) = -\tau_i K^2 + Q$ *and* $r_i(K) = r_i K^2 + c_a$, *then the optimal capacity investment in airport i is given by* $K_i = \sqrt{\frac{Q - c_a}{r_i + \tau_i}}$. *Assuming that* $w(K) > r(K)$, *it follows that* $K_2 > K_1$ *for* $r_1 > r_2$ *and/or* $\tau_1 > \tau_2$,.

Proof:

For a convex delay function, we make the standard assumptions that

$$\text{i.e.,} \quad \frac{\partial D(Q,K)}{\partial Q} > 0, \ \frac{\partial D^2(Q,K)}{\partial Q^2} > 0, \ \frac{\partial D(Q,K)}{\partial K} < 0 \text{ and } \frac{\partial D^2(Q,K)}{\partial Q \partial K} > 0$$

The first two conditions assert that increase in traffic volume Q (with capacity K unchanged) increases delay D at an increasing rate. The third condition states that increase in capacity *K* decreases delay *D*. The fourth condition maintains that more volume increases delay but such delay is less severe when there is more capacity.

Whether an airport will be better off as a hub airport or secondary airport depend on the relative slopes of the delay-alleviating function (i.e., $\frac{\partial D(Q,K)}{\partial K}$) and the capacity investment cost function (i.e., $r'(K)$). Denote the capital investment cost as a quadratic function in the form: $r_i(K) = r_i K^2 + c_a$ such that $r_1(K)$ is more convex than $r_2(K)$. Given a delay function $D(Q,K) = -\tau K^2 + Q$, the optimal $K_i = \sqrt{\frac{Q - c_a}{r_i + \tau}}$ for $w(K) > r(K)$. Hence, $K_2 > K_1$ where $r_1 > r_2$ implying that decreases in the convexity of the cost function (i.e., economies in scale) increase optimal *K**. The converse is true. The optimal *K** will increase when delay decreases sharply for a given capacity investment cost function. A diagrammatic depiction is below:

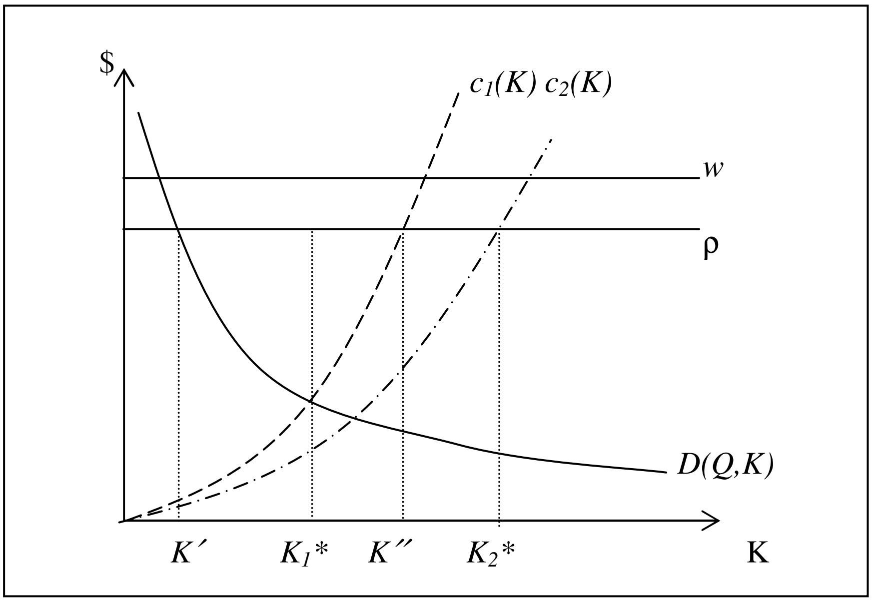

Figure 4-1 Optimal capacity for a cost function with different degrees of convexity

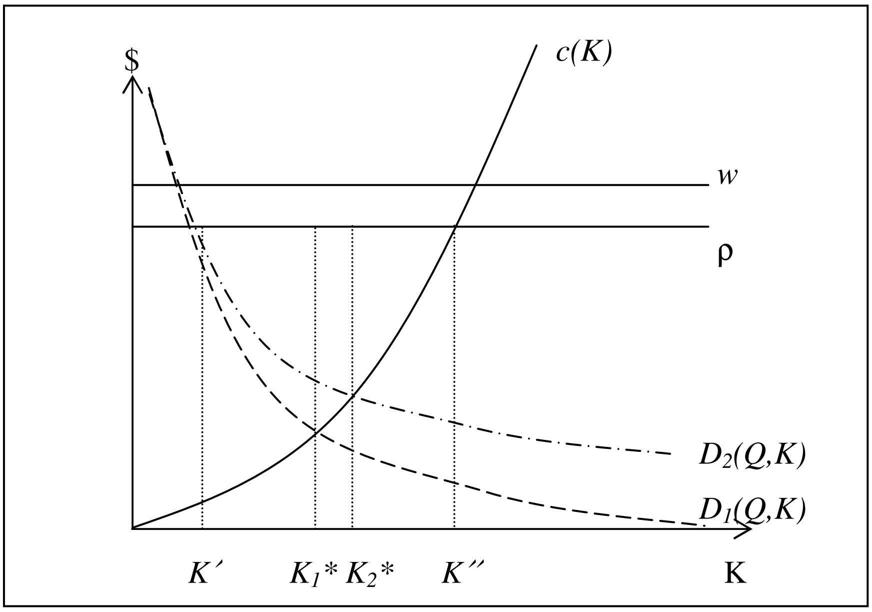

Figure 4-2 Optimal capacity for a delay function with different degrees of convexity

4.5 Conclusions

In summary, analytical results in this chapter show that in an oligopolistic industry where non-identical airports are valued for their intrinsic qualities in addition to price competitiveness, aeronautic prices increase when the service utility to airlines increases, marginal variable cost of aeronautic operations increases and/or concessionary profits decrease. Increase public ownership increases aeronautic charges but decreases concessionary charges with public ownership if total airlines revenue is higher than the consumer surplus in concessionary services. On contrary to existing findings in Zhang and Zhang (2003) and Oum et al (2004) where optimal capacity occurs at the point that the marginal benefit (i.e., reduction in delay) equals to marginal cost financing when airport pricing and capacity modeled as independent decisions, we found that the optimal capacity level in an airport will depend on airlines' marginal willingness to pay for an additional unit of capacity. More specifically, the optimal capacity investment in an airport increases as capacity-induced aeronautic revenue and demand and, airport's economic rent increase but decreases with higher airlines elasticity on willingness to pay. Increase public ownership in an airport is expected to increase capacity investments owing to social welfare considerations. If the entire airport industry is governed by imperfect competitions, the total airport industry profits will be maximized when a fraction of the airports operates a budget terminal or serves as secondary airports while others are developed as hub. Under such industry structure, airports operating under spiraling cost structure that prohibits huge investment in mandatory capacity additions should position themselves as secondary airports and serve in the niche market of less time sensitive traffic with a low cost strategy.

This study has its shortcomings. Despite the availability of airport's navigations and traffic control system, congestion pricing and slot management to handle airport capacity demand as well as various other aspects that constitute to the overall airport service quality, we make the standard assumption that the quality of airport services is solely measured by the amount of delay, and delay reductions can only be brought about by investment in extra capacity. The treatment of airport strategy in this study is also restrictive. Our study explores the settings under which an airport should strive to be an exclusively super hub airport that serves major hub-and-spoke airlines or a secondary airport for low cost carriers. Since secondary airports in Asia are not as prevalent as in North America, we are aware that there are other possible strategic options such as the setting up of two-terminal airport in which one terminal serves the full service airlines and the other serves the low cost carriers, extending existing terminals to include dedicated piers to cope with the specific demands and polarized needs of the two types of airlines.

CHAPTER 5

FACTOR SUBSTITUTION AND COMPLEMENTARITY IN THE ASIA AIRPORT INDUSTRY

5. Introduction

Issues on airport efficiency have always arisen much interest from governments, regulators, airport operators and researchers alike. Governments are concerned about airport performances since airports possess considerable monopoly power that could lead to their lack of incentive to operate efficiently. The higher cost, resulting from such inefficiency, can easily be passed onto their customers while the airport managers may be enjoying some of these monopoly rents to be gained possibly in the form of slack or excessive expenditures. Particularly, for governments who are aspiring to develop their nations into air hubs and consequently as logistics hubs, it is imperative to ensure that their airports are operating at high efficiency. High operations efficiency can lead to significant cost reductions and is generally attained through increases in labor and capital productivities.

Changes in the ownership and competitive environment also invoke the attentions of regulators on airport efficiencies. Over the past decades, some airports have been privatized and others have been corporatized. Such changes in ownership and consequently the funding structure are usually accompanied by quite explicit regulation of prices. Price regulators usually set prices at the minimum consistent with the cost recovery or achievement of a specified maximum rate of return so that their airport remains competitive globally. This requires the knowledge of the baseline level of efficiency and a realistic projection of efficiency improvements so that tight price limits can be set to improve their competitive edge. Under such operational constraint, to be profitable, airport operators must elevate their level efficiency beyond the expectations of the regulators. Accordingly, Ashford (1994) and Sarkis (2000) have observed that efficiencies in airports are critical to their success as airlines choose airports that are more cost efficient, apart from higher service level to airlines and passengers. Airports that are cost effective, inexpensive and offer high service level can expect higher passenger flows and cargo traffic, and subsequently higher revenue and profitability. Recent liberalizations of the aviation industry and the increasing freedom of airlines to choose their hubs have boosted the bargaining power of the airlines vis-à-vis the airports. As a result, airport charges need to be competitively priced regardless of internal cost structure. This could only be brought about by improving efficiency and productivity.

In response to the increasing pressure for higher efficiency, the Asia Airport industry is seen to have continually increasing the level of automation in the recent years. Automation, in replacement for manual labor, speeds up procedures leading to faster and smoother processing of passengers and cargo freight. It also alleviates the pressure due to increasing internal labor cost. Whilst it is important to analyze the nature of the substitution process between capital and labor, the study in this chapter proceeds on the basis that substitutability these factors of production cannot be considered in isolation from the impact of outsourcing[1] input in the production process. As such, this study reports empirical estimates of factor substitutability in the Asia airport industry taking full account of outsourcing as a separate input.

The Airport Transport Research Society (ATRS in short) commented in their annual airport benchmarking reports that airports are more cost competitive either because they pay less for their inputs or they are able to use inputs more efficiently (generating the same level of output with a smaller amount of inputs) or both. Such observation makes the substitutability among various production factors used in airport operations important. High substitutability among factors allows for greater flexibility in an airport's operations. By flexibility, we refer to the ease by which an airport can vary its proportion of input so as to take advantages of relative price differences between factors. If high substitutability exists, airports can substitute higher priced inputs with lower priced ones to reduce their operation cost. This ideology is similar to the concept of allocative efficiency which we will deal in-depth in Chapter 6.

One possible way of assessing the inherent potential of operations flexibility or allocative efficiency present in an industry is through an explicit computation of the elasticity of substitution (ES); a measure of the degree of factor substitutability in airports' operations with high ES indicating flexible use of resources. A comparison of ES across years will then allow for the analysis of how factor substitutions have changed over the years. The ES concept originated from the field of microeconomics and was first introduced by Hicks (1932) with the main purpose of determining how factor shares of income would change as the price or quantity ratio change. Lerner

[1] The ATRS in their annual airport benchmarking project has consistently found that airports which outsource their non-core operations generally experience higher labor productivity.

(1933) later defined the elasticity substitution as the reciprocal of the degree to which the substitutability of two factors (i.e., marginal rate of substitution) varies as the ratio of the two inputs varies while the output is held constant. Hicks and Allen (1934) introduced the Hicks-Allen elasticity of substitution (HES) while introducing the concept of elasticity of complementarity. The authors denoted HES between factor *i* and *j* to be a measure the percentage change in the ratio of inputs *i* and *j* due to a one percent change in the ratio of their prices. Allen (1938) subsequently defined the Allen partial elasticity of substitution (AES) for the production function. Uzawa (1962) derived the AES for the cost function which is popularized by Berndt and Wood (1975) in a classic paper. Subsequently, AES has become a common way of classifying inputs [2] as complements or substitutes as apparent in some of the application studies in areas like energy (Westoby and McGuire, 1984)[3], construction and service (Asai, 2004) [4]and manufacturing (Khalil, 2004)[5].

Here we treat the aggregate Asia airport industry as if it were a cost-minimizing homogenous economic unit and model the cost structure of the industry

[2] It is meaningful to classify inputs into substitutes and complements because factors being good substitutes to one another may signify that operators will have the ease to replace the use of one factor with another when faced with shortages and /or price increase. On the other hand, factors being complements may imply rigidity in factors use due to the dependency of one factor on another in producing the required output.

[3] Westoby and McGuire (1984) had analysed the degree of factor substitution and complementarity in the context of the UK energy industry. Factors considered in the study were capital, labor and energy. The study was carried out to address the concern of the displacement of labor by capital and the rising cost of energy which may have undesirable consequences for the British economy.

[4] Asai (2004) examined the demand changes for information technology (IT) as factor input and explore its substitutability and complementary with labor and capital from an estimation of the total cost function in the aggregate Japan manufacturing, construction and service industry.

[5] Khalil (2005) estimated the Translog Production function of the manufacturing industry in Jordanian economy and calculate the elasticities of substitution and price elasticities for factor inputs (capital, labor and material). The purpose of his study is to test the applicability of the translog production function for a given technology structure in the Jordanian industry.

using a translog cost function[6]. Alternatively, we could specify a flexible functional form to provide a second-order approximation to the true production structure as in Christensen et al (1973) and Khalil (2005). Please see Appendix E. However, we have chosen to estimate the cost function on grounds that input prices are exogenous but input quantities are endogenous to airports. Recognizing the existence of duality between the cost and production functions, we believe that we are unlikely to lose any useful information or precision by using the cost function instead of the production function.

The model equations are estimated by means of multivariate regressions[7] using data from the selected group of representative airports over the period 1999 - 2003. From the estimated model equations, we calculate the AES between the aggregate inputs of capital, labor and outsourcing to measure the extent of substitutability among these factors. Using the same model, we determine the own-price and cross-price elasticities of factor inputs to measure the responsiveness in the change in quantities of factor use corresponding to changes in prices.

The rest of the chapter will be organized in this manner. In the next section, we present the model used in the analysis. In section 5.2, we estimate the parameters of the model using multivariate regressions and use these parameter estimates to

[6] The translog function (also known as transcendental logarithm function) is first introduced by Christensen et al (1973) as function of the logarithms of outputs and inputs for the logarithm of the production frontier (plus unity). By exploiting the duality between cost and production, the translog cost function can be easily derived. We have chosen the translog cost function because it has an advantage of being very general. First, a translog function has the ability to accommodate more than two factor inputs with linear and quadratic terms. Second, it has a flexible functional form permitting the partial elasticities of substitution between inputs to vary.

[7] Our approach is similar to Greene (1993) and Martin-Cejas (2002) who have used a regression-based approach to estimate a deterministic cost frontier by ordinary least squares. This involves shifting an estimated line such that the residual is minimum. Other methods of parameter estimation include Zellner-Efficient Iteration, Ordinary Least Squares and maximum likelihood estimations, For example, Westoby and McGuire (1984) and Khalil (2004) used the Zellner-Efficient Iteration method. Meanwhile, Asai (2004) estimated the values of parameters using maximum likelihood.

derive the various measures of elasticities. In section 5.3, we discuss the possible implications from the obtained elasticities. Finally, we point out some potential limitations before concluding the chapter in section 5.4.

5.1 The Model

Using capital (*K*), labor (*L*) and outsource (*O*) as the three inputs and number of workload units[8] (*y*) as the output, the cost function for airports is estimated in a way similar to Westoby and McGuire (1984) and Asai (2004). Assuming production is characterized by constant economies of scale[9] and using Hicks' neutral technical change[10], we write the translog unit cost function[11] as:

$$\ln C = \ln \alpha_a + \ln Y + \sum_i \alpha_i \ln P_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j \qquad i,j = K,L,O \quad (5.1)$$

where *C* refers to the total cost for an output level of *y* workload units; P_i is the factor price of input *i*; γ_{ij} represents the constant elasticities of cost share of factor input *i* to price of factor input *j*; α_a is the constant intercept term and α_i is the average cost share of factor *i*.

[8] 1 workload unit (WLU) is equivalent to 1 passenger or 100 kg of freight. This measure was taken from the airline and later adopted by airports to provide a single measure of output for passenger and freight business.

[9] Doganis (1998) found empirical evidence that economies of scale appear to be limited to airports with relatively low passenger numbers. Meanwhile, Jeong (2005) discovered that the effects of airport size levels off between 2.5 to 5 million passengers in his study of US airports.

[10] Hicks' neutral technical change requires that there is no interaction between time and capital, labor and outsourcing for any technical change affecting these variables.

[11] The cost functions are assumed to be monotonic and concave. According to Westoby and McGuire (1984), monotonicity requires that fitted shares are non-negative at all points. Concavity requires that the Hessian matrix of second derivatives of the cost function is negative semi-definite at each point. This will be true if the first n-1 estimated principal minors alternate in sign. However, the matrix is not determined if any principal minors are statistically significant, this procedure does not constitute a statistical test of concavity.

Differentiating (5.1) w. r. t. *ln* P_i, we obtain

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i} * \frac{P_i}{C} = \alpha_i + \sum_i \gamma_{ij} \ln P_i \qquad i,j = K,L,O \quad (5.2)$$

where the factor input *K*, *L* and *O* refers to capital, labor and outsource respectively. Equation (5.2) holds for $\gamma_{ij} = \gamma_{ji}$, which is the symmetry restriction imposed in Westoby and McQuire (1984), Asai (2004) and Khalil (2005).

Shephard's Lemma states that the optimal quantity of factor *i* to be used at price P_i, X_i is given by:

$$X_i = \frac{\partial C}{\partial P_i} \qquad i,j = K,L,O \ (5.3)$$

It follows from (5.2) and (5.3) that

$$X_i = \frac{\partial C}{\partial P_i} = \frac{C}{P_i}\left(\alpha_i + \sum_i \gamma_{ij} \ln P_i\right) \qquad i,j = K,L,O \quad (5.4)$$

Since the input cost share equation is $S_i = \frac{P_i X_i}{C}$ for factor *i*, we have:

$$S_i = \alpha_i + \sum_j \gamma_{ij} \ln P_j \qquad i,j = K,L,O \quad (5.5)$$

In order for the translog function to represent a well-behaved cost function[12], the following conditions must hold. First, linear homogeneity in factor input prices implies that

$$\sum_i \alpha_i = 1 \qquad i = K,L,O \ (5.6)$$

$$\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = \sum_i \sum_j \gamma_{ij} = 0 \qquad i,j = K,L,O \quad (5.7)$$

[12] For a cost function to conform to a well-behaved production structure, it has to satisfy three conditions. First, input prices have to be linearly homogenous. Second, the parameters γ_{ij} are to be symmetrical. Third, the function has to be monotonic and concave.

Second, the symmetry restrictions impose the restriction as follows:

$$\gamma_{ij} = \gamma_{ji} \qquad i,j = K,L,O \quad (5.8)$$

Since the cost shares must sum to unity, the sum of disturbances (i.e. error terms) across all equations must also be zero. As such, the disturbance covariance matrix will be singular and one of the share equations can be deleted from the system of equations. We arbitrarily choose to drop the capital (K) equation.

Substituting (5.8) into (5.6) and (5.7), we obtain the set of cross- equation equality constraints.

$$\gamma_{LK} = -(\gamma_{LL} + \gamma_{LO}) \quad (5.9)$$

$$\gamma_{OK} = -(\gamma_{LO} + \gamma_{OO}) \quad (5.10)$$

Substituting (5.9) and (5.10) into (5.5) yields the following share equations to be estimated in section 5.2.

$$S_O = \alpha_O + \gamma_{OL}(\ln P_L - \ln P_O) + \gamma_{OK}(\ln P_K - \ln P_O) \quad (5.11)$$

$$S_L = \alpha_L + \gamma_{OL}(\ln P_O - \lg P_L) + \gamma_{LK}(\ln P_K - \ln P_L) \quad (5.12)$$

$$S_K = 1 - S_O - S_L \quad (5.13)$$

To determine the elasticities between the factor inputs, we use Allen partial elasticities of substitution (proposed by Berndt and Wood, 1975)

$$\sigma_{ii} = (\gamma_{ii} + S_i^2 - S_i) / S_i^2 \qquad i,j = K,L,O \quad (5.14)$$

$$\sigma_{ij} = (\gamma_{ij} + S_i S_j) / S_i S_j \qquad i,j = K,L,O \quad (5.15)$$

If $\sigma_{ij} > 0$, factor *i* is a substitute for factor *j*. If $\sigma_{ij} < 0$, factor *i* is a complement for factor *j*. If $\sigma_{ij} = 0$, factor *i* and factor *j* are not related to each other. Higher AES entails greater flexibility in factors use since airports are able to substitute the use of one factor with another without much output sacrifices. Conversely, negative AES implies the rigidity in factors used. Airports cannot reduce the use of a particular factor without considering the impact of such reduction on the complementary factor and subsequently the output.

The own-price elasticity and cross-price elasticity of demand for factor inputs can then be found using the relationship established by Allen (1938) as

$$\eta_{ij} = \frac{\partial \ln X_i}{\partial \ln P_j} = S_j \sigma_{ij} \qquad i, j = K, L, O \quad (5.16)$$

Since the cost share S_i is always positive, η_{ij} and σ_{ij} take the same sign. If $\eta_{ij} > 0$, factor *i* is a substitute for factor *j* and the use of factor *i* will increase when the price of factor *j* increases. If $\eta_{ij} < 0$, factor *i* is a complement for factor *j* and the use of factor *i* will decrease when the price of the factor *j* increases. If $\eta_{ij} = 0$, price of factor *j* will have no effect on the use of factor *i*.

5.2 Parameters Estimation and Results

Based on data availability, the selected set of international airports examined are Bangkok (Thailand), Beijing Capital (China), Chek Lap Kok (Hong Kong), Changi (Singapore), Kuala Lumpur (Malaysia), Incheon (South Korea), Seoul Gimpo (South Korea), Osaka Kansai (Japan) and Tokyo Narita (Japan). The data used are compiled from the Airport Benchmarking Report[13] (2002, 2003 and 2005 issues) and the World Competitiveness Yearbook (2001, 2002 and 2004 issues).

Specifically, the unit prices of labor and outsourcing are obtained from the Airport Benchmarking Reports. The price of labor, denoted as P_L, is measured using the average wages of the employees (in US dollars). Outsourcing price, P_O, is

[13] Following its first publication by Air Transport Research Society (ATRS) in 2002, several papers such as Park (2003) and Yoshida (2004) have used data in this report to analyze the competitiveness and efficiency of Asia airports.

estimated by soft cost input price. Soft cost input consists of all inputs other than labor and capital (see ATRS), of which, outsourcing (also known as contracting out) is an important component. Other cost data are the shares of labor cost and outsourcing cost. The share of labor cost, S_L, is computed by dividing the labor cost per workload unit by the total cost incurred per workload unit. The share of outsourcing cost, S_O, is computed by dividing the outsourcing cost per workload unit by the same total cost. Outsourcing cost per workload unit is derived by deducting the labor cost per workload unit from the variable cost per workload unit. Total cost is calculated from the total revenue less the profit to airport. Meanwhile, cost of capital is obtained from the World Competitiveness yearbook (which has in turn gathered this data from the International Financial Statistics). Cost of capital, P_K , expressed as the average prevailing bank interest rate in a country in a particular year, represents the cost of financing capital investment through borrowing in the financial markets. Owing to the different accounting standards between countries, capital depreciation cost is omitted. Share of capital cost, S_K, is obtained by subtracting the sum of labor and outsource cost shares from unity. To reflect relative price differences in factors across airports, cost data are normalized by dividing their absolute figures by the maximum value in the sample. However, cost shares are not normalized and raw figures are used.

Cross-sectional multivariate regressions are run for each year using S_L and S_O as the dependent variable and $\left(\ln\frac{P_L}{P_K}\right)$, $\left(\ln\frac{P_K}{P_O}\right)$ and $\left(\ln\frac{P_L}{P_O}\right)$ as the independent variables to obtain parameter estimates for α_L, α_O, γ_{LK}, γ_{OK} and γ_{OL} in equations (5.11) and (5.12). For simplicity, estimation is done using ordinary least square estimates by assuming that the error terms are normally distributed with mean 0. The results obtained for the different years are tabulated in Table 5-1.

Table 5-1 Parameter Estimates for Equations (5.11) and (5.12)

	1999	**2001**	**2003**
α_K	0.770	0.524	0.673
α_L	0.126 (0.009)	0.312 (0.000)	0.154 (<0.001)
α_O	0.103 (0.954)	0.165 (0.019)	0.173 (<0.001)
$\gamma_{KL} = \gamma_{LK}$	0.117 (0.117)	0.131 (0.051)	0.318 (0.207)
$\gamma_{OK} = \gamma_{KO}$	-0.051 (0.685)	-0.077 (0.166)	0.089 (0.404)
$\gamma_{OL} = \gamma_{LO}$	0.158 (0.033)	0.196 (0.009)	0.443 (0.089)
γ_{KK}	-0.275	-0.054	-0.407
γ_{LL}	-0.066	-0.327	-0.761
γ_{OO}	-0.107	-0.119	-0.533
R-Square	0.871	0.716	0.665
Adjusted R^2	0.813	0.649	0.543

* Figures in parentheses give the p-values

Using the parameter estimates in Table 5-1 and average cost shares from the industry in the corresponding years, we calculate the Allen Partial Elasticities of Substitution (AES) and price elasticities for the capital, labor and outsource inputs in Tables 5-2 and 5-3.

Table 5-2 Average Allen Partial Elasticities of Substitution*

	Capital	Labor	Outsourcing
Capital	- 0.420 - 0.496 - 1.076	1.665 A 1.756 3.371	- 5.742 C - 3.104 2.092
Labor	-	- 8.545 - 8.772 - 28.051	69.677 B 32.205 23.391
Outsourcing	-	-	- 1166.202 - 213.209 - 52.125

*First, second and third row gives the AES for year 1999, 2001 and 2003 respectively

Table 5-2 above presents the AES obtained from equations (5.14) and (5.15) for 1999, 2001 and 2003. Positive values in cell A indicate that capital and labor are substitutes. Similarly, labor and outsourcing are also substitutes (from cell B).

Outsourcing serves as a complement to capital (i.e. cell C is negative) in 1999 and 2001. In 2003, we see that capital, labor and outsourcing become substitute to one another (i.e. cells A, B and C are all positive). While capital and outsourcing are both substitutes for labor, outsource is a better substitute between the two factors (i.e. cell B dominates cell A).

Table 5-3 Average Price Elasticities of Input Demand*

	Capital	Labor	Outsourcing
Capital	- 0.321 - 0.357 - 0.802	0.383 [A] 0.423 0.607	- 0.062 [E] - 0.081 0.230
Labor	1.274 [B] 1.263 2.511	- 1.965 - 2.114 - 5.049	0.692 [C] 0.837 2.573
Outsourcing	- 4.364 [F] - 2.232 1.558	16.026 [D] 7.761 4.210	- 11.662 - 5.543 - 5.734

*First, second and third row gives the price elasticities for year 1999, 2001 and 2003 respectively

Table 5-3 presents the own-price elasticities (diagonal values) and cross-price elasticities (off-diagonal values) for 1999, 2001 and 2003 obtained from equation (5.16). Among the three factors, outsourcing and capital represent, respectively, the most price-elastic and most price-inelastic factors. Capital and labor have gradually become more price-elastic over the years but outsourcing has moved in the opposite direction.

Unlike the AES, we note that the figures in the Table 5-3 are not symmetrical. Asymmetrical cross-elasticities between factors indicate that the responsiveness in changes in quantity usage of various factors corresponding to a relative change in price differs between the factors. Such observations are unsurprising since capital investment involves more rigidity than those of labor and outsourcing. For example, the higher value in cell B as compared to cell A implies that the *increase* in the percentage of labor use corresponding to a percentage *increase* in relative price of capital is *larger* in comparison to the *increase* in the percentage of capital use corresponding to a percentage *increase* in relative price of labor. A similar observation can be made in the case of outsourcing and labor (i.e. cell C and D). Recalling that outsource and capital are complementary inputs in 1999 and 2001, we see that the higher absolute value in corresponding cell F as compared to cell E implies that the *reduction* in the percentage of outsourcing use corresponding to a percentage *increase* in relative price of capital is *larger* compared to the *reduction* in the percentage of capital use corresponding to a percentage *increase* in relative price of outsourcing. In 2003, outsourcing has emerged as a substitute for capital. The higher value in cell F than that in cell E indicates that a one percent increase in the price of capital will bring about a greater percentage increase in the use of outsourcing than vice versa. This illustrates the relative ease to delay capital investment (and use more outsourcing instead) when capital cost increases as compared to increasing capital facilities at short notice when outsourcing cost increases. While the asymmetries of cross-price elasticity persists throughput the period, the gaps in these cross-elasticities have narrowed with time.

Last but not least, it is imperative for us to verify the model assumptions to ensure the validity of results obtained above. To do so, we check if the translog cost function is well behaved. Linear homogeneity in factor prices and symmetry are imposed as a prior. Fitted shares in equations (5.11) - (5.13) are examined for each and every observation and found to be non-negative, thus satisfying the monotonicity condition. In addition, all the own-price elasticities obtained from equation (5.16) are found to have conforming signs (i.e. negative signs). According to Westoby and

McGuire (1984), this indicates the presence of concavity. As such, the fitted translog cost function conformed to a well-behaved production structure for the observations in the study.

5.3 Discussions

Capital and labor are substitutes as automation replaces the use of manual labor in some processes. For instance, self-check in counters use automatic machines, a form of capital investment, in place of manual labor. Automation generally comes about as a result of three effects. First, there is a push for greater airport efficiency and automation is expected to bring about the required higher efficiency. Second, the airport users are now able to handle simple tasks like self check-in of baggage and issuing of boarding passes. Third, rising labor cost has prompted airport operators to seek alternative ways to reduce the demand for manual labor, especially local labor. While Japan and Singapore have attempted to decrease operating cost by hiring labor from low-income countries such as Thailand, Philippines and India, operating cost continues to increase. Consequently, widespread automation is implemented so as to reduce the need for manual labor and avoid continuing escalation of cost.

The pressure to improve airport efficiency under mounting labor cost in the late 1990s may have led airport operators to outsource part of their operations, in addition to the use automated self-service machines. Results here suggest that labor and outsourcing are substitutes to each other. Until 2001, most airports have limited their outsourced activities to non-core services such as fire fighting, rescue, security and meteorological services. While such outsourcing reduces the need to employ direct labor, airport operators continue to provide for the bulk of the physical facilities. Outsourcing has become a substitute factor for capital from 2003. It was then that more airports began allowing airlines, or some independent terminal operators, to provide for the physical facilities by leasing out operations of certain terminals[14]. This provides an alternative to capital investment for airport operators. Given the discrete and lumpy nature of capital investment, this alternative is especially valuable since there would exist a significant degree of underutilization of such investment at the early stage of implementation. Such underutilization will inevitably result in higher cost. Coupled with this, capital investment not only involves a hefty sum but is also generally long term in nature. Rapid advancement in technology, however, makes current investment obsolete quickly and airport operators are therefore unwilling to commit. In the case of privatized airports, privatization means less public funding and operators need to exercise extra caution as airports need to account to shareholders.

While capital and outsourcing are both substitutes for labor, outsource is a better substitute between the two factors. This is unsurprising noting that operations at an airport terminal still require much manual labor despite much use of complex sorting and conveying apparatus for processing cargo freight and automated baggage check-in kiosks for human passengers. Nonetheless, there appears to be a gradual improvement in the degree of substitutability between capital and labor from 1.665 in 1999 to 3.371 in 2003 respectively. This can probably be accounted for by technology advancements and proliferations in the use of automated self-service machines that promote further automations in more areas of airport operations.

It is intuitively clear to see why capital turns out to be most price inelastic, among the three factors. Considering the fact that capital investment is not only long term but also involves a great deal of indivisibilities, it will be difficult to alter the amount of physical investment planned even when price increases. On the other hand,

[14] ATRS (2005) has noted that not all airport operators are directly responsible for all of their capital investment and expenditure is a case in point.

outsourcing is the most price-elastic since it is usually based on contractual terms, covering a short period of time. When relative price changes, it will be relatively easier to award another contract (perhaps to the same current contractor or to another party who offers better terms) when the current contract expires than to lay off workers. For laying off of workers, other issues such as the morale of the remaining workers, compensations, social responsibilities, public image, etc., cannot be ignored.

Over the years, price elasticities of capital and labor as well substitutability among the three production factors (as indicated by the positive AES and narrowing of AES asymmetrical gap) are increasing. Pressures from the competition have probably forced airport to harness flexibility in their operations. We advocate that such flexibility provides the ease for airports to take advantage of the lower prices of some inputs and substitute those inputs for higher priced ones when relative prices change. Other than achieving greater cost efficiency, substitution also avoids over-dependence on a specific type of production factor. The observed increase in flexibility is made possible by two main sources. One, the increasing acceptance of outsourcing as a substitutable factor has expanded the set of options available to airport operators, enabling them to be more responsive to price changes. Two, technological advancement, which leads to higher divisibility of capital investment, has reduced the lumpiness of capital facilities.

In contrast, price-elasticity of outsourcing has been tremendously reduced over the short time period that our study has undertaken. Coupled with a growing share of outsourcing cost, it is likely that airports in Asia are exhibiting an emergent inclination towards outsourcing. The rising popularity in the use of outsourcing stems from the advantages that outsourcing could provide to airport operators. Airports, by outsourcing their peripheral services, are able to focus more attention on their core competence. Cost may also reduce as a result of outsourcing due to specialization and scale economies that can be realized as third party providers pooled the demand of various airports together. Nonetheless, the increasing reliance on outsource as a production input, which manifest itself in sharp reductions in the price elasticity of outsource, may invoke some concerns regarding the bargaining power of airports vis-à-vis outsource providers if the trend continues.

5.4 Conclusions

This chapter has lent some insights into the recent trend of factor substitutability in the Asia Airport industry. We observe that automation has replaced the use of manual labor in some processes, eliminating the complementary relationship between capital and labor. While capital and outsourcing are substitutes to labor, outsourcing represents a complementary factor to capital until 2001. It is only in the 2003 that outsourcing is regarded as a substitute factor to capital. The substitutability among the three factors of production (i.e., capital, labor and outsourcing) points to the inherent flexibility in Asia airport operations. We advocate that flexibility, as indicated by high price elasticities and positive AES, allows the airport to take advantage of the lower prices of some inputs and substitute those inputs for higher priced ones when relative prices change. In effect, such flexibility leads to allocative and cost efficiencies. Cost efficiency is important not only because of the heighten competition in this era but also ensure survival in times of financial hardship. Substitution avoids over-dependence on a specific type of production factor. Nonetheless, unrestrained increases in outsourcing expenditure and sharp decreases in price elasticity of outsourcing may undermine the bargaining strengths of airport operators and perceived benefits of outsourcing as an alternative input in airport operations.

However, this study is not without its potential limitations. First, it is noteworthy that inferences drawn from the results obtained in this analysis depend very much on the reliability of the data used and the representativeness of selected sample airports. Second, capital price differences between airports within the same country cannot be captured through the use of a single country-wide interest rate. Third, while cross-sectional data are known to yield poor fits in econometric study, we cannot sloppily cast away the possibility that the low R-square values obtained in 2003 could be due to the invalidity of our model assumptions. To recap, these assumptions include linear homogeneity of factor input prices, substitution symmetry and constant economies of scale. As outsource gain popularity in the airport industry context, third party contractors may offer preferential rates to airports which outsource larger amount of work. Such practices violate the assumption of linear homogeneity of factor input prices. New technological advancements may also alter the relative ease of substitution between factors, making substitution asymmetrical. While the earlier findings in chapter 2 illustrate the constant returns to scale in the Asia airport industry, this may not imply constant economies of scale when factor prices are taken into considerations. We have checked, however, that concavity of translog cost function holds.

While every effort is made to obtain the necessary data required for a meaningful in-depth study in this dissertation, we are not able to apply the Allen Partial Elasticity (AES) methodology to the study of seaports operations flexibility due to the unavailability of relevant price information. Indeed, Cullinane and Wang (2006) commented that it is extremely difficult to obtain confidential data such as prices. Most studies in the port literature, thus, assumed that the main objective of the port is the minimization of the use of inputs or the maximization of output, even though these objectives may not be entirely consistent with that of profit maximization or cost minimization.

CHAPTER 6

EFFICIENCY ASSESSMENTS OF ASIA PACIFIC AIRPORTS

6. Introduction

As discussed in the previous chapter, airport efficiency has been a central issue in cost control owing to reasons such as airport monopoly power, changing ownership structure, increasing competitive pressure from airlines and competing airports and government aspirations to develop their nations as an air hub and subsequently as a logistics hub. It is believed that by reducing costs and prices through an increase in labor and capital productivity, an airport will be able to achieve high airport operations efficiency thereby, improving international competitiveness. The accurate assessment of productive efficiencies has thus been one of the most pertinent issues in the unending quest towards global competitiveness within the international aviation industry. The purpose of this chapter is, hence, to identify and evaluate different sources of efficiencies relating to operations scale and input deployment, that contribute to the cost competitiveness of individual airports.

Hensher and Waters (1993) identified three broad categories of mathematical models that have been used to assess productive efficiencies. These are (i) non-parametric index number, (ii) parametric model estimations (i.e., econometric approach) and (iii) non-parametric mathematical programming (i.e., Data Envelopment Analysis or DEA in short). Several of these approaches have been applied in the aviation industry for efficiency assessment. In the non-parametric index approach, two main methods used in the airport literature are partial productive factor (PPF) and Tornquist total productive factor (TFP). For examples, Doganis et al. (1995) compared the relative performance of European airports with the average performance of 25 airports in the sample using partial ratios such as unit cost, productivity and revenue ratios in Appendix B.4.4. Hooper and Hensher (1997) summarized the most common partial ratios dealing with airport performance evaluations. While these partial indicators can provide insights that allow the productivity and efficiency of different functional areas to be assessed separately, analysis is hindered by a relatively big set of indicators. Graham (2005) also pointed out that such partial measures, by definition, presents a partial and rather disjointed diagnosis of the situation and can be misleading if only selected indicators are chosen. This is particularly the case in view that airports are complicated businesses that produce multiple outputs using multiple inputs. The productivity of an input depends not only on other inputs but also the level of the different outputs. Hence, Hooper and Hensher (1997)[1] employed the Tornquist TFP to achieve the purpose of ranking the 6 Australian airports in a sequential order according to their performances between 1989 and 1991. However, TFP requires an aggregation of all outputs into a weighted output index and all inputs into a weighted input index using pre-defined weights, which can be biased (Appendix B.4.3 outlines the methodology). In that study, the authors used prices as the weights to be applied which appears to be most logical in the absence of other more suitable ways to

[1] Hooper and Hensher (1997) used a deflated TFP revenue index as an output measure with three inputs being labor, capital, and other inputs (the residual of capital and labor).

determine weights. Other subsequent studies that evaluated airport efficiency using TFP are Nyshadham and Rao (2000)[2], Abbott and Wu (2002)[3] and Oum et al. (2003)[4].

Another alternative is to employ an econometric approach to obtain the parametric or statistical TFP through frontier analysis and production or cost functions. Some of such studies are Pels et al. (2001), Martin-Cejas (2002) and Low and Tang (2006). Pels et al. (2001) constructed a stochastic frontier and computed the efficiency scores of 34 European airports using number of passengers and aircraft movements as the outputs and terminal size, number of aircraft parking positions, number of check in desks and number of baggage claims as the inputs. Martin-Cejas (2002) used a translog cost function to estimate the productive efficiency of 40 Spanish airports with units of traffic transported as a single output variable and labor and capital as the only two inputs. Meanwhile, Low and Tang (2006)[5] also used a translog cost function to examine the potential of allocative efficiency in the Asia airport industry in a sample consisting of 11 international airports, with workload unit as a single output and labor, capital and outsource as the three inputs. The main drawback of the econometric approach is that it requires a pre-defined cost or production structure. As such, this approach works well only if the data fit nicely into the structure.

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[2] Nyshadham and Rao (2000) evaluated the efficiency performance of 24 European airports and examined the relationship between the computed TFP index and several partial measures of airport productivity. In computation of the TFP, index revenue and expenses are the output and input variables.

[3] Abbott and Wu (2002) investigated the efficiency and productivity of 12 Australian airports for the period 1990–2000 using Malmquist TFP index. The authors considered two outputs (i.e. the number of passengers and tonnage of freight cargo) and three inputs (i.e. number of staff, capital stock in constant dollar terms, and runway length).

[4] Oum et al. (2003) compared the efficiency performances for 60 airports, across Asia Pacific, Europe and North America by computing the partial productivity indexes (PPI), aggregating these PPI to obtain the gross TFP and then further analyzing the TFP using regression and removing uncontrollable factors.

[5] The contents are similar to Chapter 5 of this dissertation.

On the other hand, non-parametric mathematical programming methods, such as DEA, have been gaining popularity over the past decade. This is evidenced from many application papers in the existing airport efficiency literature, which includes Gillen and Lall (1997), Parker (1999), Sarkis (2000), Martin and Roman (2001; 2006), Abbott and Wu (2002), Fernandes and Pacheco (2002), Bazargan and Vasigh (2003), Pels et al (2003), Sarkis and Talluri (2004) and Yoshida and Fujimoto (2004). The popularity of DEA can be attributed to the fact that: (1) it allows for the assessment of multi-factor productive efficiencies through an effective integration of multiple inputs and outputs factors within a single efficiency score via the use of flexible weights or multipliers chosen through the solution of the model itself; (2) DEA does not impose a parametric structure on data, and; (3) DEA does not have heavy data requirements. Table 6-1 reveals that DEA has been extensively used in airport efficiency assessment studies over the past decade. Most of these studies dealt with regional airports though they differed in their input and output factors. Common in all these studies, authors have not taken into account the costs of input factors (with the exception of Martin and Roman (2001; 2006)) and different operating environment of airports. Hence, these airport efficiency analyses have been restricted to technical efficiency under the assumptions of identical operating and cost conditions.

Table 6-1 Literature on Airport Efficiency Using DEA

Paper	Sample	Input	Output
Gillen & Lall (1997)	21 US airports (1989 – 1993)	No. of runways, gates, employees, collection belts and parking spots; Airport and terminal areas	No. of passengers, carrier and passenger movements; Pounds of cargo
Parker (1999)	BBA airport before & after privatization	Amounts of labor, capital stock, non-labor and capital cost	No. of passengers and amount of cargo
Sarkis (2000) Sarkis & Talluri (2004)	44 US airports (1990 – 1994)	Amount of operational cost; No. of employees, gates and runways	No. of passengers and aircraft movements; Amounts of operational revenue and cargo
Martin & Roman (2001)	27 Spanish airports (1997)	Expenditure on labor, capital and materials	No. of aircraft movements and passengers; Amount of cargo
Abbott and Wu (2002)	12 Australian airports (1990 – 2000)	Number of employees; Amount of capital stock; Length of runway	No. of passengers; Amount of cargo
Fernandes & Pacheco (2002)	35 Brazilian airports (1998)	Areas of apron, departure lounges and baggage claim; No. of check-in counters and vehicle parking spaces; Length of curb frontage	No. of passengers
Bazargan & Vasigh (2003)	45 US airports (1996 – 2000)	No. of runways and gates; Amount of operating and non-operating expenses	No. of passengers and aircraft movements; Amounts of aeronautic and non-aeronautic revenues; Percentage of on time operations
Pels et al (2003)	33 European airports (1995 – 1997)	No of runways, parking positions, check-in desks and baggage claims	No. of passengers and aircraft movements
Yoshida & Fujitomo (2004)	67 Japanese airports (2000)	No. of employees; Length of runway; Terminal area and access cost	No. of passengers and aircraft movements; Amount of cargo
Martin & Roman (2006)	34 Spanish airports (1997)	Expenditures on labor, capital and materials	No. of passengers and aircraft movements; Amount of cargo

In this chapter, we incorporate external macroeconomics and price factors into the traditional DEA models to assess the extent by which international airports across the Asia Pacific region have achieved the specified objective of cost minimization given their economic conditions. According to Farrell (1957), cost efficiency stems primarily from two sources – technical efficiency and allocative efficiency. The former refers to the ability to produce the maximum quantity of output from a specific input bundle and is determined by technology while the latter refers to ability to achieve the lowest cost by selecting the input mix that is most appropriate given the input price ratio. In view of the differential factor prices between substituting factors that exist amongst the various airports (as illustrated in the preceding chapter), allocative efficiency is important in enabling airports achieve higher cost efficiency as airports are generally price takers in the input market. In this chapter, Tone (2002) DEA model is adopted for the evaluation of allocative efficiencies of the airports. Here, allocative efficiency is derived from the computation of a cost efficiency factor and an appropriate technical efficiency measure. In addition to Tone (2002) DEA model, a variety of other DEA models were developed to allow the evaluation of technical, scale, mix and allocative efficiencies of Asia Pacific airports. The proposed suite of DEA models enable more insights to be gleaned and result validation since airports also differ in their scale of operations, output demand, deployment of productive factors. The performance of each airport is compared with its performances in other periods as well as against the performances of other airports in the same period. To achieve full ranking of airports under limited sample size, we introduce a virtual super efficient airport which is able to achieve maximum output from a combination of minimum inputs. Altogether, this study represents to date, the most comprehensive assessment on the multi-dimensional efficiencies of Asian airports using the DEA methodology. In fact, to the best of our knowledge, this study is the first attempt to apply DEA analysis across international airports in Asia Pacific taking into considerations the factor price differentials and economic inequalities that exist among countries within the region.

The rest of the chapter will be organized in this manner. In the next section, we describe the DEA method in brief and introduce our proposed efficiency models and corresponding efficiency measures. Section 6.2 describes the input and output variables, airport sample and data issues. The efficiency results with and without the virtual airport are presented and discussed in section 6.3. Section 6.4 discusses the insights and section 6.5 concludes the chapter.

6.1 The Data Envelopment Analysis Method

The DEA method involves the construction of an efficient production (cost) frontier that gives the maximum possible output for a given amount of inputs, through a series of linear programming. The level of efficiency is determined using the distance to the production frontier. Any output below the optimal output is considered to be inefficient.

DEA is a popular tool owing to its main advantages over the non-parametric index number and parametric model estimation approaches. Some of these advantages have been described in the preceding section. In essence, DEA allows for the assessment of multi-factor productive efficiencies using a single efficiency score established via the use of weights or multipliers selected on sound basis. Instead of having a subjectively defined weight assigned a-priori, DEA allows each decision making unit (DMU) to choose their own most favorable weights subject to the simultaneous consideration of other DMU's efficiency scores, relevant constraints and objectives. Also, DEA does not impose a parametric structure on data and does not have heavy data requirements. Furthermore, data measured in different units can be used simultaneously within a DEA model. However, DEA is not without its shortcomings. Being an extreme point technique in which the efficiency frontier is formed by the actual performance of best performing airports, efficiency scores are highly sensitive to even small errors in measurement. Where sample size is small, it would result in a large proportion of airports having an efficiency score of 1. While these problems can be circumvented by introducing a virtual airport to act as a frontier from which the efficiencies of all airports are computed against, DEA identifies the set of efficient airports and the set of inefficient ones but it does not explain the cause of the underlying sources of efficiencies and inefficiencies. By constructing a deterministic frontier, any deviation from the frontier which is interpreted as inefficiency may in actual fact be due to random factors instead.

6.1.1 Model Forms and Efficiency scores

The efficiency models used in our assessment of Asia Pacific airports include adaptations of the CCR model (Charnes et al. 1978), the BCC model (Banker et al. 1984), a model based on the minimization of input slacks commonly known as the SBM model (Tone 2001), a cost minimization and a new technical efficiency model which considers factors costs and prices (Tone 2002). Specifically, the CCR and the BCC models evaluate the *technical* and *scale* efficiencies with and without the variable returns to scale. An alternative model based on an input oriented slack minimization objective together with the CCR model is used to evaluate the efficiency of input-output proportions (*mix efficiency*).The incorporation of price factors allows the computation of *cost efficiency*. Cost efficiency, together with technical efficiency considering factor prices (priced technical efficiency), enable the evaluation of *allocative efficiency*. In consideration of the co-existence of discretionary inputs (which are under the control of airport authorities) and non-discretionary inputs not under the control of airport authorities, existing efficiency models are extended for the evaluation of the aforementioned efficiency measures. The relationships among the

DEA model variants described in this paper and their contributions in the evaluation of different efficiency measures are summarized in Figure 6-1.

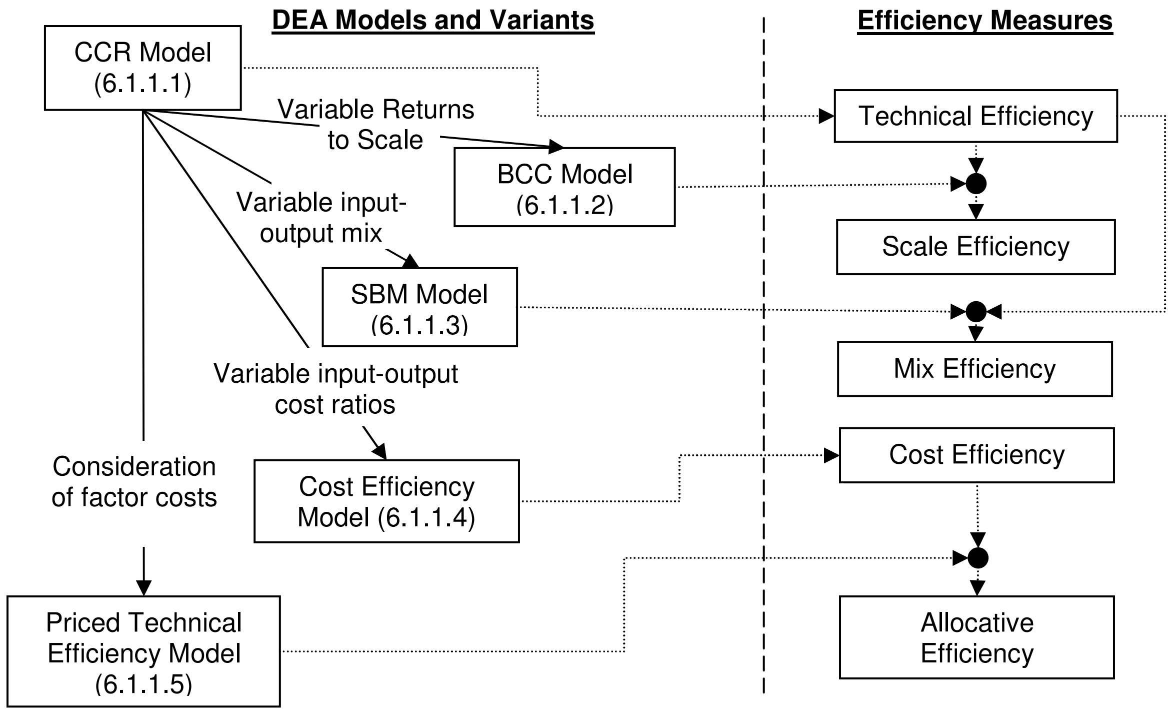


Figure 6-1. Relationship between different DEA model variants and efficiency measures (Note: figures in parentheses indicate sections where details of model are described)

6.1.1.1 Basic CCR Model

In the basic efficiency ratio model proposed by Charnes et al. (1978), the objective is to maximize the efficiency value of the airport under consideration via the selection of optimal weights associated with each input and output factor. For evaluating the efficiency value of test airport o in consideration of s outputs and m inputs, this ratio model, given a reference set of n airports, is:

$$\text{(EFF)} \quad \max_{\mathbf{v}_o, \mathbf{u}_o} \left\{ \sum_{i=1}^{s} v_{io} y_{io} \Big/ \sum_{j=1}^{m} u_{jo} x_{jo} \right\} \quad \text{s.t.} \ \left\{ \sum_{i=1}^{s} v_{io} y_{ik} \Big/ \sum_{j=1}^{m} u_{jo} x_{jk} \right\} \leq 1, \forall k \in \{1,2,...,n\} \tag{6.1}$$

where y_{io} represents the level of output factor i ($\forall i \in \{1,2,...,s\}$) and x_{jo} represents the level of input factor j ($\forall j \in \{1,2,...,m\}$). In addition, v_{io} represents the weight assigned for output factor i and u_{jo} represents the weight assigned for input factor j. $\mathbf{v_o}$ and $\mathbf{u_o}$ are s and m dimensional weight vectors representing the collection of v_{io} and u_{jo} weights. Both of these vectors are non-negative. This nonlinear program in (6.1) can be linearized via a change in coefficients. The dual of the linearized model is typically presented as the CCR model in DEA literature for the assessment of technical efficiency.

In the airport efficiency assessments, there are input factors that cannot be controlled by management. Such inputs can be considered as non-discretionary factors. In the presence of such factors, the traditional CCR model (given in dual form of linearized model EFF) can be modified as follows:

(LPC*f*) $\min_{\theta_{CCRF}, \lambda} \theta_{CCRF}$

$$
\begin{aligned}
\text{s.t.} \quad & \sum_{k=1}^{n} \lambda_k y_{ik} - y_{io} \geq 0 && ,\forall i \in \{1,2,...,s\} \\
& \sum_{k=1}^{n} \lambda_k x_{jk} - \theta_{CCRF} x_{jo} \leq 0 && ,\forall j \in D \\
& \sum_{k=1}^{n} \lambda_k x_{jk} - x_{jo} = 0 && ,\forall j \in ND \\
& \lambda_k \geq 0 && ,\forall k \in \{1,2,...,n\}
\end{aligned}
\tag{6.2}
$$

where θ_{CCRF} is the dual variable to be minimized and $\boldsymbol{\lambda}$ is a vector in $\Re^n$ comprising of the scalars λ_k ($k \in \{1,2,...,n\}$); D represents the set of discretionary input factors and ND represents the set of non-discretionary input factors in (6.2). Such a formulation enables the determination of *technical efficiency* (TE*f*[6]) under the assumption that the input-output proportions used in production remains unchanged. The constraint associated with the non-discretionary input is an equality to reflect situation where the weights generated for each airport takes into account the trade volume of the test airport, allowing for a similar virtual weighted input combination

[6] '*f*' indicates the presence of fixed or non-discretionary factors within the DEA model.

of the reference airports. Although the non-discretionary variables do not enter the objective function, they do enter the objective function in the primal of the LPC*f* model. Hence, these non-discretionary factors do affect the eventual efficiency value.

6.1.1.2 BCC Model

LPC*f* contains implicit constant returns to scale assumption. In order to relax this assumption to allow for variable returns to scale, Banker et al. (1984) added a convexity constraint and is typically defined as the BCC model. A variant of this model with non-discretionary factors is represented by (6.3):

$$
\begin{aligned}
&(\text{LPB}f) \quad \min_{\theta_{BCCF}`} \theta_{BCCF} \\
&\text{s.t.} \quad \sum_{k=1}^{n} \lambda_i y_{ik} - y_{io} \geq 0 \qquad , \forall i \in \{1,2,\ldots,s\} \\
&\qquad \sum_{k=1}^{n} \lambda_k x_{jk} - \theta_{BCCF} x_{jo} \leq 0 , \forall j \in D \\
&\qquad \sum_{k=1}^{n} \lambda_k x_{jk} - x_{jo} = 0 \qquad , \forall j \in ND \\
&\qquad \lambda_k \geq 0 \qquad , \forall k \in \{1,2,\ldots,n\} \\
&\qquad \sum_{k=1}^{n} \lambda_k = 1
\end{aligned}
\tag{6.3}
$$

Since the CCR models assumed constant returns to scale and BCC otherwise, the technical efficiencies evaluated from these models define the scale *efficiency* (SE) by $TEf / \theta_{BCCF}{}^{*}$.

6.1.1.3 SBM Model

In the previous models, efficiency values are evaluated with an underlying assumption that the input-output proportions used in production remain unchanged. This can be observed from the input constraints of the models LPC*f* and LPB*f*. This assumption can be relaxed to a certain extent by using a non-radial, slacks based measure (SBM) of efficiency based on the mean reduction rate of input relative to the test airport

(Tone 2001). The original SBM model can be extended in consideration of non-discretionary variables with an input orientation as follows:

$$
\begin{aligned}
&(\text{LPS}f) \quad \min_{s^+, s^-, \lambda} \theta_{SBMF} = \frac{1}{\|D\|} \sum_{j=1}^{\|D\|} \frac{x_{jo} - s_j^-}{x_{jo}} \\
&\text{s.t.} \quad \sum_{k=1}^{n} \lambda_i y_{ik} - s_i^+ = y_{io} \qquad , \forall i \in \{1,2,\ldots,s\} \\
&\qquad \sum_{k=1}^{n} \lambda_k x_{jk} + s_j^- = x_{jo} \qquad , \forall j \in \{1,2,\ldots,m\} \\
&\qquad \lambda_k \geq 0 \qquad , \forall k \in \{1,2,\ldots,n\} \\
&\qquad s_j^- \geq 0 \qquad , \forall j \in D \\
&\qquad s_j^- = 0 \qquad , \forall j \in ND \\
&\qquad s_i^+ \geq 0 \qquad , \forall i \in \{1,2,\ldots,s\}
\end{aligned} \tag{6.4}
$$

where, s_i^+ and s_j^- are slack variables associated with output deficits and input excesses respectively. $\mathbf{s^+}$ and $\mathbf{s^-}$ vectors comprising of s_i^+ ($\forall i \in \{1,2,\ldots,s\}$) and s_j^- ($\forall j \in \{1,2,\ldots,m\}$). The set of equations in (6.4) is essentially an input oriented SBM model that evaluates an optimal weight without constraints on fixed input-output proportions for production. Its objective function seeks to find an optimum input mix which minimizes the input excesses of the test airport. Efficiency measures based on CCR and SBM are used to define *mix efficiency* (ME) given by $\theta_{SBMF}^* / \theta_{CCRF}^*$ (Tone (2001)).

6.1.1.4 Cost Efficiency Model

In the assessment of productive efficiencies, Farrell (1957) brought input costs and output price ratios into considerations through the concept of allocative efficiencies. Another measure of productive efficiencies, frequently referred to as cost efficiency, which accounts for both technical and allocative efficiencies have also gained prominence in the literature. The overall or cost efficiency is the product of technical and allocative efficiency. LPC*f* gives the optimal technical efficiency in consideration of a particular input-output production possibility set which does not include the consideration of unit input costs (Tone 2002). In certain situations when these cost ratios are taken into consideration, the proportions of inputs may be changed while keeping this technical efficiency measure constant to achieve lower costs in production, hence, higher cost efficiencies result. DEA models for the assessment of cost efficiencies have been proposed (see Tone 2002). In consideration of non-discretionary inputs, these cost efficiencies can be evaluated using the model in (6.5):

$$\text{(LPCost}f\text{)} \qquad \min_{\bar{\mathbf{x}},\lambda} \kappa_f = \sum_{j=1}^{s} \bar{x}_{jo}$$

$$\begin{aligned} \text{s.t.} \quad & \sum_{k=1}^{n} \lambda_i y_{ik} - y_{io} \geq 0 && ,\forall i \in \{1,2,...,s\} \\ & \sum_{k=1}^{n} \lambda_k \bar{x}_{jk} - \bar{x}_{jo} \leq 0 && ,\forall j \in D \\ & \sum_{k=1}^{n} \lambda_k \bar{x}_{jk} - \bar{x}_{jo} = 0 && ,\forall j \in ND \\ & \lambda_k \geq 0 && ,\forall k \in \{1,2,...,n\} \end{aligned} \tag{6.5}$$

where, $\bar{x}_{jo}$ is the level of input factor scaled by the factor cost c_{jo} for input factor j of test airport o given by $\bar{x}_{jo} = c_{jo} x_{jo}$. $\bar{x}_{jk}$ is the level of input factor scaled by the factor cost c_{jk} for input factor j of airport k given by $\bar{x}_{jo} = c_{jo} x_{jo}$. $\bar{\mathbf{x}}$ is the vector comprising of $\bar{x}_{jo}$ ($\forall j \in \{1,2,...,s\}$). The cost efficiency with this model, CEf, is defined as κ_f^* / κ_o where κ_o represents the actual budget assessed for the test airport o given by $\kappa_o = \sum_{j=1}^{s} c_{jo} x_{jo}$.

6.1.1.5 Allocative Efficiency Model

In consideration of some shortcomings of the traditional technical efficiency measure given by θ_{CCR}^* when factor costs and prices are considered, a new technical efficiency measure is proposed in Tone (2002) for evaluating the allocative efficiency. With non-discretionary factors, this model becomes:

$$(\text{LPT}f)\quad \min_{\theta_{ZF},\lambda} \overline{\theta}_{TF}$$

$$\begin{aligned}
\text{s.t.}\quad & \sum_{k=1}^{n} \lambda_i y_{ik} - y_{io} \geq 0 && ,\forall i \in \{1,2,\ldots,s\} \\
& \sum_{k=1}^{n} \lambda_k \overline{x}_{jk} - \overline{\theta}_T \overline{x}_{jo} \leq 0 && ,\forall j \in D \\
& \sum_{k=1}^{n} \lambda_k \overline{x}_{jk} - x_{jo} = 0 && ,\forall j \in ND \\
& \lambda_k \geq 0 && ,\forall k \in \{1,2,\ldots,n\}
\end{aligned} \tag{6.6}$$

$\overline{\theta}_{TF}^{\,*}$ is defined as the "priced" technical efficiency[7] (PTE*f*) measure and the allocative efficiency, AE*f*, is defined as $CEf / PTEf$.

6.2 Data Descriptions

Our analysis uses data from a sample of 11 major international airports in Asia Pacific over the years 2001 – 2005. The airports, selected on basis of data availability, include Chek Lap Kok (Hong Kong), Changi (Singapore), Incheon (South Korea), Seoul Gimpo (South Korea), Beijing Capital (China), Osaka Kansai (Japan), Tokyo Narita (Japan), Sydney (Australia), Brisbane (Australia), Auckland (New Zealand) and Christchurch (New Zealand). Due to missing cost data, Kuala Lumpur (Malaysia), Chiang Kai-Shek (Taiwan) and Jakarta Soekarno-Hatta (Indonesia) airports are omitted.

The inputs considered falls into two broad categories, namely, the discretionary inputs and the non-discretionary inputs. The discretionary inputs are labor, capital and soft input while the non-discretionary input is trade value. O'Conner (1995) noted that operations at a terminal are labor-intensive, despite much use of complex sorting, conveying apparatus and automatic boarding pass issues and self-

[7] The original model is known as New Technical Efficiency model in Tone (2002). PTE*f* placed emphasis on the explicit considerations of factor costs and prices within a DEA model that considers both discretionary and non-discretionary inputs.

check in kiosks. It is also widely accepted that the presence of adequate physical capital is essential to ensure smooth running of airport operations and avoid costly congestions. Other than labor and capital, soft input is another major category of input. As defined by Air Transport Research Society (ATRS), soft input includes purchased services, goods and materials, of which, outsource forms a major component. Outsourcing is an important aspect of airport operations since it may significantly reduce the labor cost incurred by airports (Pels et al. 2003). Following Fernandes and Pacheco (2002) who highlighted that the evaluations of physical inputs need to be addressed in accordance to the conditions in each country, we include trade value in our set of inputs. Countries which are open, populated and affluent are characterized with high trade volume. Hence, trade represents a good surrogate for the economic conditions in each country and an indicator of the potential demand for air transport services. According to Doganis (1992), an airport's primary function is to provide an interface between aircraft and passengers or freight. From this perspective, the outputs in our efficiency evaluations are the number of aeronautic movements, passengers and tonnes of cargo.

The data required are obtained from the Airport Benchmarking Report (2002 – 2007 issues) and World Competitiveness Yearbook (2002 – 2006 issues). Among other data, the annual Airport Benchmarking Report gives the quantities of labor, capital, and soft inputs employed in an airport, prices for labor and the total cost (split into labor, variable and capital components). Specifically, labor relates to the number of employees working directly for the airport operators and the price of labor is measured using the average wages of the employees. The total soft input cost is derived from deducting the total labor cost from the total variable cost. The value of capital (or capital stock) can be obtained through divisions of net operating income by the return on capital asset (ROA). Depreciation has been unaccounted for due to the different accounting standards among countries. As there are many types of capital comprising runways, check-in counters, terminal space, gates and other peripheral equipments and facilities, it is impossible to allocate the capital cost to individual component. According to Yoshida and Fujimoto (2004), the size of the terminal determines the airport's ability to load passengers and cargo into aircrafts and hence play an important role in airport operation activity. We thus used terminal area as a proxy to the amount of physical capital[8] used in an airport. For purpose of ensuring data integrity, the labor and soft input cost incurred in an airport are checked to tally with the product of price and quantities of the respective inputs. The total cost should also equate to the aggregate summations of labor, soft input and capital cost. Meanwhile, we gather the required data on country trade value from the World Competitiveness Yearbook. This trade value is the total worth placed on the imports and exports of goods and services into and out of a country (or economy). All the monetary values are denominated in current US dollars.

6.3 Empirical Analysis

6.3.1 Efficiency Results without Virtual Airport

We present detailed DEA efficiency results during the period 2001 - 2005 in Table 6-2. Under the assumptions of constant returns to scale, Beijing Capital, Incheon, Narita and Changi are the only airports that do not report consistent and perfect technical efficiency scores of 1. With the exception of Beijing Capital in 2001 and Incheon in 2002, however, the efficiency scores are sufficiently close to 1. Hence, it may be

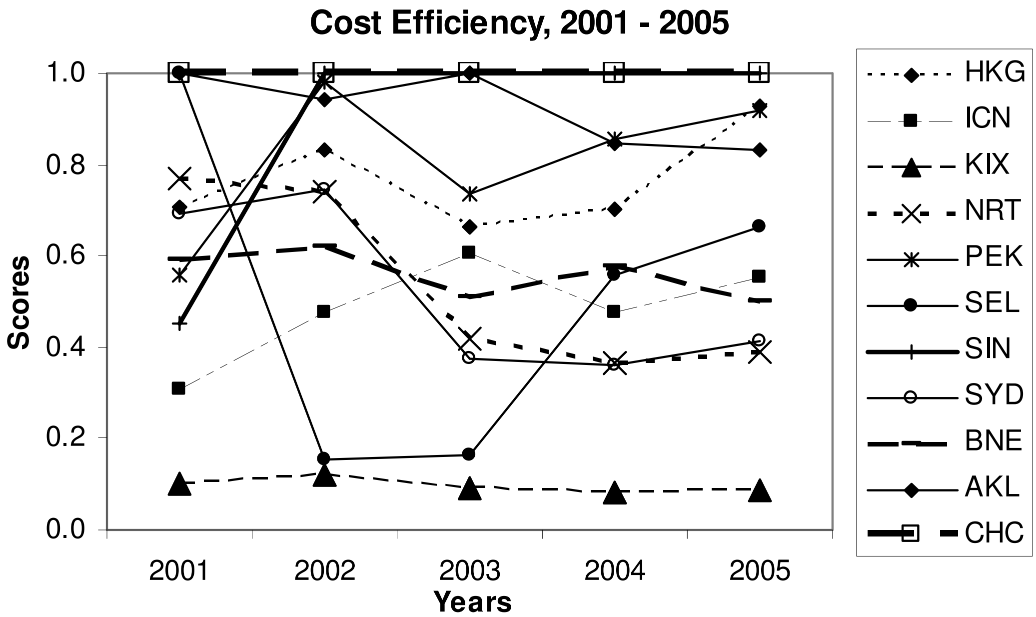
[8] Runways and terminal areas represent major airport physical capital outlays at the airside and landside respectively. Since earlier results in Chapter 2 shows that an ample provision of landside facilities is more important in driving traffic performances compared to that of airside facilities and these findings are supported by Jorge and Rus (2004), we omit the number of runways in the set of inputs under limited sample size.

possible that the minor shortfalls from full efficiency may be due to random errors rather than true inefficiency. In comparison, the BCC results show that Narita and Beijing Capital are also fully efficient throughout the study period. This is reasonable since the piecewise linear frontier that allows for variable returns to scale in BCC model envelopes the observations more tightly.

Combining the results from CCR and BCC models, we derive the scale efficiencies of the airports in the next column. Given that all airports, except Incheon and Changi, register BCC efficiency scores of 1, the scale efficiency results are rather similar to the CCR technical efficiency. In fact, those airports that score CCR technical efficiency of 1 also produce an identical scale efficiency score. In general, technical and scale efficiencies among the airports remain consistently high above 0.8. This suggests that the Asia Pacific airport industry is apt in adjusting its scale of operations with minimal impact on its corresponding production function.

We compute mix efficiency scores using the SBM model. A high mix efficiency implies that an airport is flexible in changing its input proportions. This is important because input flexibility reduces the airport's reliance on specific inputs and cushions it against unexpected shock in price changes. Beijing Capital reports an exceptionally low SBM efficiency in 2001 but it subsequently improves and maintains full SBM efficiencies through 2005. Incheon, in its initial startup, presents a relatively low mix efficiency score of 0.673 but manages to maintain mix efficiency scores higher than 0.939 thereafter. Narita's mix efficiency scores are generally acceptable, fluctuating in a narrow range between 0.89 and 1. As for Changi, the fall in its mix efficiency between the years 2002 and 2003 is due to the sharp increase employment of workers. Mix efficiency gradually recovers after 2003 as number of workers employed in the airport decreases slowly. All other airports achieve maximum mix efficiencies throughout the study period.

In terms of cost, Changi and Christchurch are shown to be the only airports that attain full cost efficiency since 2002. Following quite closely are airports like Hong Kong, Auckland and Beijing Capital which are also very cost efficient. The cost effectiveness of the New Zealand, Changi and Hong Kong airports over Beijing Capital is indeed commendable considering the lower cost for production factors in the China. With the setup of Incheon in 2001 that resulted in a transfer of traffic from Seoul Gimpo to the new airport, cost efficiency in Seoul Gimpo drops sharply from a high of 1 to 0.154 in 2002 as inputs cannot be quickly reduced at pace with the decline in traffic. Cost efficiency in Seoul Gimpo picks up with the adjustment of input quantities to the lower volume subsequently. At the same time, Incheon has also improved on its cost efficiency since it was first setup. However, the Australian airports (i.e., Sydney and Brisbane) are relatively less cost efficient especially in recent years. Owing to higher cost of production and operations factors, the Japanese airports (especially Kansai) are inferior in cost efficiency compared to their peers. While Kansai is consistently rated as the least cost efficient airport, of particular concern is Narita whose ranking in cost efficiency has fallen sharply from the fourth position in 2001 to the tenth position in 2005.



Abbreviations:
HKG: Chek Lap Kok (Hong Kong); SIN: Changi (Singapore); ICN: Incheon (South Korea); SEL: Seoul Gimpo (South Korea); PEK: Beijing Capital (China); KIX: Osaka Kansai (Japan); NRT: Tokyo Narita (Japan); SYD: Sydney (Australia); BNE: Brisbane (Australia); AKL: Auckland (New Zealand); CHC: Christchurch (New Zealand)

Figure 6-2 Overall Efficiency Trend among Major Airports in Asia Pacific

An interesting observation can be made by comparing Figure 6-2 above against Figures 6-3 and 6-4 below. Though cost efficiency is the product of allocative and new technical efficiencies, differences in cost efficiencies among airports seem to be attributed to primarily allocative efficiency. Airports that are more cost efficient are also more allocative efficient concurrently. Though there may be a need for Narita to reverse its negative trend in new technical efficiency, other airports are either fully or almost fully new technically efficient during most of the years. However, compared to new technical efficiency, there is room for improvement in allocative efficiency among many of the airports to achieve greater cost efficiency.

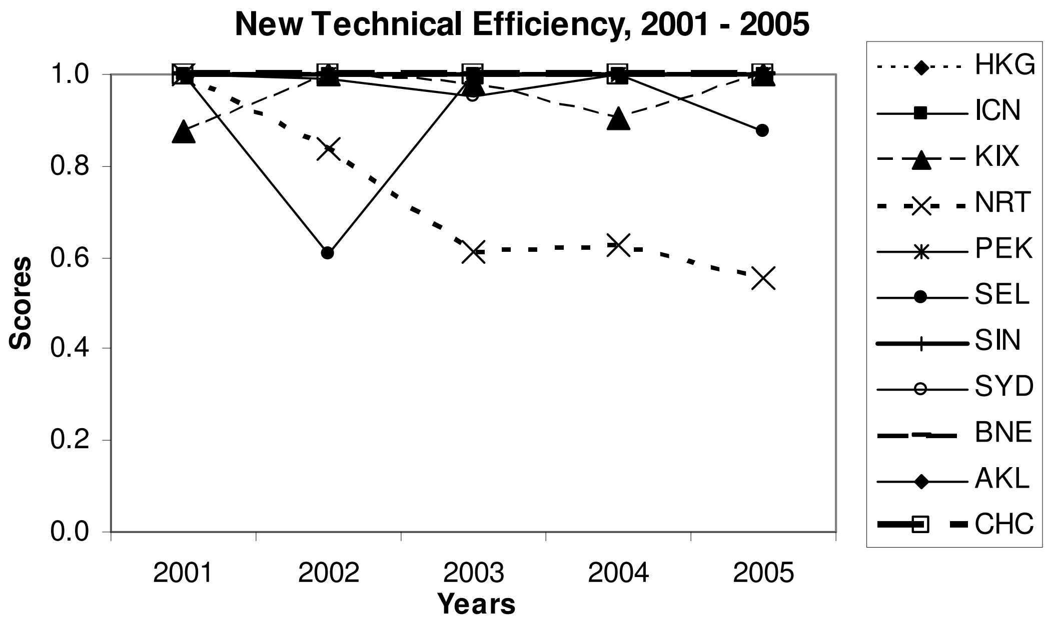


Figure 6-3 Allocative Efficiency among Major Airports in Asia Pacific

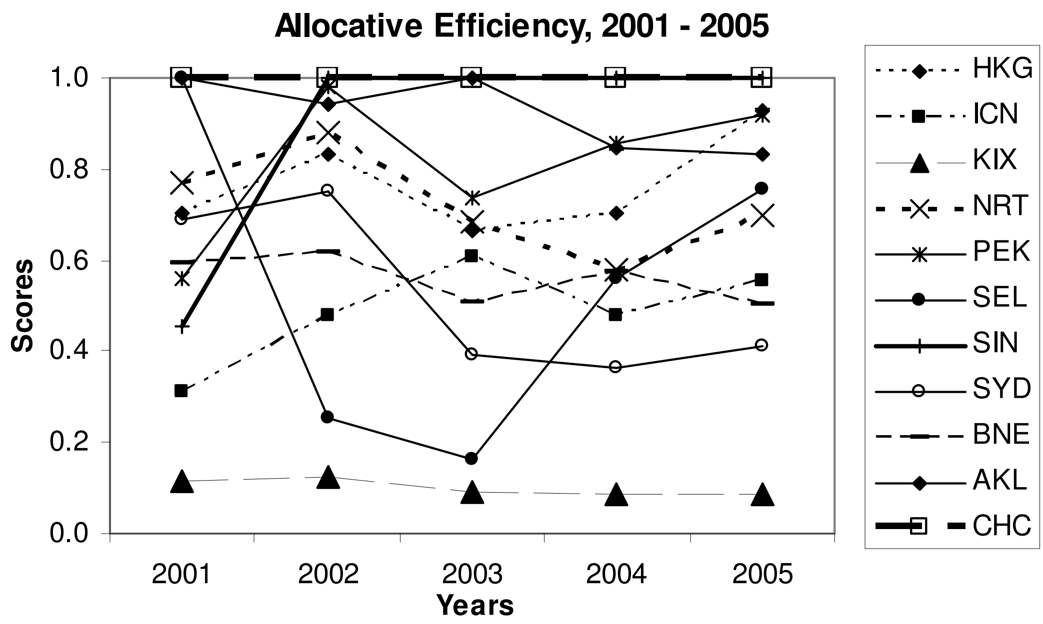


Figure 6-4 New Technical Efficiency among Major Airports in Asia Pacific

Table 6-2 Asian Airports' DEA Efficiency Results without Virtual Airport, 2001 – 2005

Year	Airport	Technical Efficiency θ_{CCR}		Scale Efficiency $\frac{\theta_{CCR}}{\theta_{BCC}}$		Mix Efficiency $\frac{\theta_{SBM}}{\theta_{CCR}}$		Cost Efficiency		New Technical Efficiency θ_T		Allocative Efficiency	
2001	Chek Lap Kok	1.000	(5)	1.000	(5)	1.000	(5)	0.705	(5)	1.000	(5.5)	0.705	(5)
	Incheon	1.000	(5)	1.000	(5)	1.000	(5)	0.310	(10)	1.000	(5.5)	0.310	(10)
	Kansai	1.000	(5)	1.000	(5)	1.000	(5)	0.100	(11)	0.874	(11)	0.114	(11)
	Narita	0.830	(11)	0.830	(11)	0.903	(10)	0.772	(4)	1.000	(5.5)	0.772	(4)
	Beijing Capital	0.903	(10)	0.903	(10)	0.546	(11)	0.559	(8)	1.000	(5.5)	0.559	(8)
	Seoul Gimpo	1.000	(5)	1.000	(5)	1.000	(5)	1.000	(2)	1.000	(5.5)	1.000	(2)
	Changi	1.000	(5)	1.000	(5)	1.000	(5)	0.454	(9)	1.000	(5.5)	0.454	(9)
	Sydney	1.000	(5)	1.000	(5)	1.000	(5)	0.691	(6)	1.000	(5.5)	0.691	(6)
	Brisbane	1.000	(5)	1.000	(5)	1.000	(5)	0.593	(7)	1.000	(5.5)	0.593	(7)
	Auckland	1.000	(5)	1.000	(5)	1.000	(5)	1.000	(2)	1.000	(5.5)	1.000	(2)
	Christchurch	1.000	(5)	1.000	(5)	1.000	(5)	1.000	(2)	1.000	(5.5)	1.000	(2)
2002	Chek Lap Kok	1.000	(5)	1.000	(5)	1.000	(5)	0.832	(5)	1.000	(4.5)	0.832	(6)
	Incheon	0.754	(11)	0.999	(10)	0.673	(11)	0.477	(9)	1.000	(4.5)	0.477	(9)
	Kansai	1.000	(5)	1.000	(5)	1.000	(5)	0.122	(11)	1.000	(4.5)	0.122	(11)
	Narita	0.900	(10)	0.900	(11)	0.991	(10)	0.741	(7)	0.839	(10)	0.882	(5)
	Beijing Capital	1.000	(5)	1.000	(5)	1.000	(5)	0.981	(3)	1.000	(4.5)	0.981	(3)
	Seoul Gimpo	1.000	(5)	1.000	(5)	1.000	(5)	0.154	(10)	0.609	(11)	0.254	(10)
	Changi	1.000	(5)	1.000	(5)	1.000	(5)	1.000	(1.5)	1.000	(4.5)	1.000	(1.5)
	Sydney	1.000	(5)	1.000	(5)	1.000	(5)	0.746	(6)	0.993	(9)	0.752	(7)
	Brisbane	1.000	(5)	1.000	(5)	1.000	(5)	0.619	(8)	1.000	(4.5)	0.619	(8)
	Auckland	1.000	(5)	1.000	(5)	1.000	(5)	0.944	(4)	1.000	(4.5)	0.944	(4)
	Christchurch	1.000	(5)	1.000	(5)	1.000	(5)	1.000	(1.5)	1.000	(4.5)	1.000	(1.5)

Table 6-2(Continued) Asian Airports' DEA Efficiency Results without Virtual Airport, 2001 – 2005

Year	Airport	Technical Efficiency θ_{CCR}		Scale Efficiency $\frac{\theta_{CCR}}{\theta_{BCC}}$		Mix Efficiency $\frac{\theta_{SBM}}{\theta_{CCR}}$		Cost Efficiency		New Technical Efficiency θ_T		Allocative Efficiency	
2003	Chek Lap Kok	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.663	(5)	1.000	(4.5)	0.663	(6)
	Incheon	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.606	(6)	1.000	(4.5)	0.606	(7)
	Kansai	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.089	(11)	0.983	(9)	0.091	(11)
	Narita	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.417	(8)	0.610	(11)	0.683	(5)
	Beijing Capital	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.736	(4)	1.000	(4.5)	0.736	(4)
	Seoul Gimpo	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.164	(10)	1.000	(4.5)	0.164	(10)
	Changi	0.933	(11)	0.933	(11)	0.749	(11)	1.000	(2)	1.000	(4.5)	1.000	(2)
	Sydney	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.374	(9)	0.951	(10)	0.393	(9)
	Brisbane	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	0.509	(7)	1.000	(4.5)	0.509	(8)
	Auckland	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	1.000	(2)	1.000	(4.5)	1.000	(2)
	Christchurch	1.000	(5.5)	1.000	(5.5)	1.000	(5.5)	1.000	(2)	1.000	(4.5)	1.000	(2)
2004	Chek Lap Kok	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	0.701	(5)	1.000	(5)	0.701	(5)
	Incheon	0.903	(11)	0.999	(9.5)	0.962	(9)	0.477	(8)	1.000	(5)	0.477	(9)
	Kansai	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	0.080	(11)	0.903	(10)	0.088	(11)
	Narita	0.944	(9)	0.944	(11)	0.893	(10)	0.363	(9)	0.625	(11)	0.581	(6)
	Beijing Capital	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	0.857	(3)	1.000	(5)	0.857	(3)
	Seoul Gimpo	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	0.558	(7)	1.000	(5)	0.558	(8)
	Changi	0.908	(10)	0.999	(9.5)	0.720	(11)	1.000	(1.5)	1.000	(5)	1.000	(1.5)
	Sydney	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	0.362	(10)	1.000	(5)	0.362	(10)
	Brisbane	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	0.576	(6)	1.000	(5)	0.576	(7)
	Auckland	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	0.848	(4)	1.000	(5)	0.848	(4)
	Christchurch	1.000	(4.5)	1.000	(4.5)	1.000	(4.5)	1.000	(1.5)	1.000	(5)	1.000	(1.5)

Table 6-2(Continued) Asian Airports' DEA Efficiency Results without Virtual Airport, 2001 – 2005

Year	***Airport***	***Technical Efficiency*** θ_{CCR}	***Scale Efficiency*** $\frac{\theta_{CCR}}{\theta_{BCC}}$	***Mix Efficiency*** $\frac{\theta_{SBM}}{\theta_{CCR}}$	***Cost Efficiency***	***New Technical Efficiency*** θ_T	***Allocative Efficiency***
2005	Chek Lap Kok	1.000 (5)	1.000 (5)	1.000 (5)	0.928 (3)	1.000 (5)	0.928 (3)
	Incheon	0.939 (11)	0.941 (11)	0.939 (10)	0.553 (7)	1.000 (5)	0.553 (8)
	Kansai	1.000 (5)	1.000 (5)	1.000 (5)	0.087 (11)	1.000 (5)	0.087 (11)
	Narita	0.973 (10)	0.973 (10)	0.898 (11)	0.390 (10)	0.557 (11)	0.700 (7)
	Beijing Capital	1.000 (5)	1.000 (5)	1.000 (5)	0.918 (4)	1.000 (5)	0.918 (4)
	Seoul Gimpo	1.000 (5)	1.000 (5)	1.000 (5)	0.662 (6)	0.875 (10)	0.757 (6)
	Changi	1.000 (5)	1.000 (5)	1.000 (5)	1.000 (1.5)	1.000 (5)	1.000 (1.5)
	Sydney	1.000 (5)	1.000 (5)	1.000 (5)	0.413 (9)	1.000 (5)	0.413 (10)
	Brisbane	1.000 (5)	1.000 (5)	1.000 (5)	0.502 (8)	1.000 (5)	0.502 (9)
	Auckland	1.000 (5)	1.000 (5)	1.000 (5)	0.831 (5)	1.000 (5)	0.831 (5)
	Christchurch	1.000 (5)	1.000 (5)	1.000 (5)	1.000 (1.5)	1.000 (5)	1.000 (1.5)

* Figures in parenthesize indicate the rank. In the event of ties, the average rank is reported

6.3.2 Efficiency Results with Virtual Airport

Owing to our small sample size[9], a significant proportion of the airports reports full efficiency in terms of technical, scale and mix efficiencies. Following Bazargan and Vasigh (2003) and Martin and Roman (2006), we introduce a virtual airport into the sample set to allow a full ranking of all airports in these efficiency dimensions. Such a virtual airport is assumed to be capable of producing the maximum output with the minimum input amongst the set of reference airports. This virtual airport, as a superior performer, will always belong to the efficient set that forms the efficient frontier for which the efficiencies of all real airports are evaluated against. Inevitably, the computed efficiency scores are underestimated with the inclusion of the virtual airport and, hence, efficiency results generated with virtual airports are typically used only for relative comparisons (or rankings) amongst the set of reference airports.

Looking across the years in Table 6-3 below, Kansai, Seoul Gimpo and Brisbane are three airports that constantly perform equally well as the virtual airport technically on assumptions of constant returns to scale. While Beijing Capital climbs from fourth position in 2001 to the first position thereafter and Sydney improves from the seventh position to the fifth in 2004, the rankings of other airports on CCR technical efficiency appear to be rather stable. Christchurch, Narita and Incheon airports are moderate performer during almost every year in the study horizon. Hong Kong, Singapore and Auckland take the last three positions.

In terms of scale efficiency, Hong Kong, Changi, Incheon and Narita are among lowest ranking owing to their large investments in capacity. When demand

[9] According to Bousoufiane et al (1991), a good rule of thumb in applying DEA is to include a minimum number of data points in the evaluation set obtained by multiplying the number of inputs with the number of outputs.

falls, the large capacity cannot be contracted at short notice and wasteful underutilization may occur. Meanwhile, Kansai, Seoul Gimpo, Brisbane and Beijing Capital are seen to be most scale efficient. This set of scale efficient airports is also identified as being mix efficient with the ability to change the proportions of their input usages easily. Hong Kong, Incheon and Narita are moderate performers but Sydney's performances are deteriorating. Nonetheless, the rankings among Changi, Christchurch and Auckland are somewhat volatile across years.

Table 6-3 Asian Airports' DEA Efficiency Results with Virtual Airport, 2001 – 2005

Year	Airport	Technical Efficiency θ_{CCR}		Scale Efficiency $\frac{\theta_{CCR}}{\theta_{BCC}}$		Mix Efficiency $\frac{\theta_{SBM}}{\theta_{CCR}}$	
2001	Chek Lap Kok	0.497	(9)	0.497	(10)	0.932	(6)
	Incheon	0.502	(8)	0.668	(6)	0.625	(10)
	Kansai	1.000	(2)	1.000	(2)	1.000	(2)
	Narita	0.593	(6)	0.593	(8)	0.993	(4)
	Beijing Capital	0.903	(4)	0.903	(4)	0.546	(11)
	Seoul Gimpo	1.000	(2)	1.000	(2)	1.000	(2)
	Changi	0.276	(11)	0.459	(11)	0.985	(5)
	Sydney	0.541	(7)	0.541	(9)	0.922	(7)
	Brisbane	1.000	(2)	1.000	(2)	1.000	(2)
	Auckland	0.402	(10)	0.711	(5)	0.848	(9)
	Christchurch	0.603	(5)	0.603	(7)	0.881	(8)
2002	Chek Lap Kok	0.466	(8)	0.466	(10)	0.909	(8)
	Incheon	0.264	(11)	0.797	(6)	0.738	(11)
	Kansai	1.000	(3)	1.000	(3)	1.000	(2.5)
	Narita	0.678	(6)	0.678	(7)	0.956	(5)
	Beijing Capital	1.000	(3)	1.000	(3)	1.000	(2.5)
	Seoul Gimpo	1.000	(3)	1.000	(3)	1.000	(2.5)
	Changi	0.269	(10)	0.440	(11)	0.897	(9)
	Sydney	0.520	(7)	0.520	(9)	0.825	(10)
	Brisbane	1.000	(3)	1.000	(3)	1.000	(2.5)
	Auckland	0.325	(9)	0.631	(8)	0.920	(7)
	Christchurch	1.000	(3)	1.000	(3)	0.939	(6)

Table 6-3(Con'd) Asian Airports' DEA Efficiency Results with Virtual Airport

Year	Airport	Technical Efficiency θ_{CCR}		Scale Efficiency $\frac{\theta_{CCR}}{\theta_{BCC}}$		Mix Efficiency $\frac{\theta_{SBM}}{\theta_{CCR}}$	
2003	Chek Lap Kok	0.423	(9)	0.423	(11)	0.937	(7)
	Incheon	0.455	(8)	0.481	(9)	0.954	(5)
	Kansai	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Narita	0.700	(6)	0.700	(7)	0.943	(6)
	Beijing Capital	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Seoul Gimpo	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Changi	0.261	(11)	0.459	(10)	0.889	(8)
	Sydney	0.540	(7)	0.540	(8)	0.766	(11)
	Brisbane	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Auckland	0.396	(10)	0.820	(5)	0.871	(9)
	Christchurch	0.721	(5)	0.721	(6)	0.823	(10)
2004	Chek Lap Kok	0.417	(10)	0.417	(11)	0.915	(5)
	Incheon	0.441	(8)	0.669	(8)	0.895	(6)
	Kansai	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Narita	0.654	(7)	0.654	(9)	0.809	(10)
	Beijing Capital	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Seoul Gimpo	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Changi	0.308	(11)	0.558	(10)	0.879	(7)
	Sydney	0.724	(5)	0.738	(6)	0.741	(11)
	Brisbane	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Auckland	0.426	(9)	0.773	(5)	0.822	(9)
	Christchurch	0.678	(6)	0.678	(7)	0.846	(8)

Table 6-3(Con'd) Asian Airports' DEA Efficiency Results with Virtual Airport

Year	***Airport***	***Technical Efficiency*** θ_{CCR}		***Scale Efficiency*** $\frac{\theta_{CCR}}{\theta_{BCC}}$		***Mix Efficiency*** $\frac{\theta_{SBM}}{\theta_{CCR}}$	
2005	Chek Lap Kok	0.442	(9)	0.442	(11)	0.958	(6)
	Incheon	0.472	(8)	0.613	(10)	0.977	(5)
	Kansai	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Narita	0.656	(7)	0.656	(8)	0.941	(7)
	Beijing Capital	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Seoul Gimpo	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Changi	0.425	(10)	0.627	(9)	0.781	(10)
	Sydney	0.738	(5)	0.745	(5)	0.721	(11)
	Brisbane	1.000	(2.5)	1.000	(2.5)	1.000	(2.5)
	Auckland	0.374	(11)	0.663	(7)	0.862	(8)
	Christchurch	0.696	(6)	0.696	(6)	0.807	(9)

6.4 Discussions

The importance of CCR technical efficiency to an airport cannot be understated owing to its implications on scale and mix efficiencies. From the DEA models presented in section 6.1, we see that scale efficiency is defined as the ratio of CCR (θ_{CCR}) and BCC (θ_{BCC}) technical efficiencies whereas mix efficiency is the ratio of SBM (θ_{SBM}) and CCR (θ_{CCR}) efficiencies. Since θ_{SBM} is always less than or equal to θ_{CCR}, an airport can only be mix efficient provided it is also CCR technical efficient. Similarly, for θ_{BCC} being at least equal to θ_{CCR}, an airport needs to be CCR technical efficient to achieve full scale efficiency. The attainment of full technical efficiency is bounded by many other considerations. First, an expansion in the physical facilities of the airport is indivisible. As it is not quite possible to fit the capacity of an airport exactly to the expected demand, airports operating under congestions may appear to be more efficient. Second, there is a time lag between the initial investments in airport infrastructure until it is ready to be put into service. Hence, airport will need to implement its expansion in advance even though the expansion causes inefficiency in the short term due to underutilization. The technical inefficiency depicted in Incheon and Changi are two examples in which investments in capacity are made in anticipation of rise in future demand. Third, different airports across the Asia Pacific region are governed by a diversity of governmental regulations such as curfew times, noise control and other environmental constraints under which airport must operate. Narita is well known as a non 24-hour airport due to government restrictions. Finally, airline inefficiency, resulting in low load factors, may cause airport inefficiency. When the number of passengers or amount of cargo per aircraft movement (i.e., the average load factor) decreases, airport terminal efficiency also decreases.

Of particular interest is the cost efficiency of an airport that determines the competitiveness of an airport to a large extent, putting service issues aside. There appears to be a country specific effect in that airports in some countries (such as Japan and Australia) are less cost efficient compared to those in other countries like New Zealand. Cost efficiency is a product of new technical efficiency and allocative efficiency. The difference between new technical efficiency and the CCR technical efficiency is the inclusion of input prices as production costs (instead of physical input quantities) in the inequality constraints and objective function. Unless airports are faced with significant price differences, both measures should not differ substantially. We observe that the majority of the airports under study are fully or near technical efficient. However, the degree of allocative efficiency among these airports differs quite considerably. It is unsurprising that technical efficiency differs little among airports as many technology and automatic equipments are bought from external vendors rather than developed in-house. Conversely, the extents of automation, outsourcing and use of manual labor have a profound impact on the airport's cost efficiency. These decisions need to be made in view of the prices the airport faces. The strong connection between cost efficiency and allocative efficiency highlights that the softer aspect such as good managerial judgment make a difference on the overall cost competitiveness of an airport.

Finally, we observe that there are some disparities between the rankings assigned to the airports with and without the virtual airport. While this approach has been used by Bazargan and Vasigh (2003) and Martin and Roman (2006) in their rankings of US and Spanish airports respectively, there are certain drawbacks that result in different ranking results obtained. This approach penalizes all other airports for not operating at the same scale efficiency or using similar input proportions, however, the degrees to which each input factor is penalized may differ, resulting in the disparity in rankings. Despite these drawbacks, the rankings based on the assumption of the existence of a super efficient virtual airport has been justified in previous studies as the same super efficient virtual airport is used for all airports within the reference set. Alternatively, we could employ super-efficiency models developed in the DEA literature to do the ranking. However, these models also possess some significant limitations for practical interpretations.

6.5 Conclusions

This chapter contributes to the existing airport efficiency literature by presenting a very comprehensive assessment of efficiencies of major airports using the DEA methodology. While the DEA application to the context of airport efficiency is not new, this study is the first attempt to apply DEA analysis across international airports in the Asia Pacific (taking into account the differing economic conditions) and discriminate against the various sources of efficiency (technical, allocative, mix and scale efficiencies) that affect overall cost efficiency of the airports. Results from our analysis reveal that international airports in the Asia Pacific region are generally technical, scale and mix efficient. However, airports in some countries may be less cost efficient due to specific country-effect such as higher cost of production factors and lower allocative efficiency. Hence, there is potential in exploiting allocative efficiency to reap cost competitiveness in the Asia Pacific airport industry.

Nonetheless, the use of the DEA as a methodology in this chapter is not fault-free. DEA identifies the set of efficient airports and the set of inefficient ones but it does not explain the cause of the underlying sources of efficiencies and inefficiencies. As DEA is an extreme point technique in which the efficiency frontier is formed by the actual performance of best performing airports, even small errors in measurement can affect efficiency scores significantly. Not only our small sample size may contribute to a large proportion of airports having an efficiency score of 1, the construction of the production frontier and henceforth the relative efficiency that is computed also depends to a large extent on the sample selected. We circumvent these problems by introducing a virtual airport to act as a frontier from which the efficiencies of all airports are computed against. By constructing a deterministic frontier, we have interpreted any deviation from the frontier as inefficiency, which may in actual fact, be due to random factors instead. Given these shortcomings, we must be cautious when interpreting the results obtained.

CHAPTER 7

ROLES OF THE AIRPORT AND LOGISTICS SERVICES ON THE ECONOMIC OUTCOMES OF AN AIR CARGO SUPPLY CHAIN: EVIDENCES FROM HONG KONG AND SINGAPORE

7. Introduction

Thus far, chapters 2 to 4 have explored the key factors influencing port competitiveness. Chapters 5 and 6 investigate how different aspects of efficiency could contribute to the overall cost efficiency in airports. As mentioned in chapter 1, the presence of a competitive and efficient airport is fundamental for a viable and profitable international air cargo service. Among others, Kasarda and Green (2005) advocated that nations with efficient air cargo services enjoy competitive trade and production advantage over those nations without such capability. This chapter aims to achieve two main objectives. The first objective is to empirically examine the internal and external influences on the growth of air cargo services. The second objective is to quantify the contributions of an airport and the associated air cargo business to the economy.

The air cargo industry has grown dramatically over the last two decades. By 2006, airfreight has accounted for approximately 35 percent of global merchandise trade by value, which is equivalent to US$4.2 trillion of the US$12 trillion value of trade (International Air Transport Association, IATA 2008). Several reasons can help to explain the phenomenal growth of air cargo. First, there is an industry trend towards the productions of high-value light-weighted goods. For these new economy products like microelectronics and pharmaceuticals, as much as eighty to ninety percent of their international movements are by air. Second, the shortening of product life cycles and adoption of Just-in-Time (JIT) manufacturing philosophy necessitate the need for speedy transportations to ensure quick market launches and deliveries. Third, more companies are recognizing that higher linehaul costs of air services can be offset by reductions of costs corresponding to inventory, warehousing and packaging. Fourth, air service cost is significantly driven down in the last twenty years partly due to the entry of large numbers of wide-body freighters and passenger (combination) aircraft and partly to the increased efficiencies that have been built into the materials handling and air cargo system. The ultimate effect is that airfreight is playing an ever-increasing role in the distribution systems of many companies (Murphy et al. 1989). More recently, Kasarda (2007) noted that not just the high-tech products and jewellery and perishables, but fashion clothing, seasonal toys, even footwear are moving around the world by air.

While economic considerations are key drivers for the growth of air service demand, air transportation itself can be a key cause and facilitator of economic growth. The aviation industry, as an important industry that creates employment and generates value add to an economy, also provides an essential input into the rapidly growing global economy. Greater connections to the global air transport network can boost the productivity and growth of an economy by providing better access to markets, enhancing links within and between businesses and attracting foreign resources and capital investments. Hence, Jarach (2001) highlighted that businesses should integrate airport infrastructure into their supply chains, rather than treating the airport as just an external medium or a mode of transfer that facilitates material contacts between spoke of the chain itself. Furthermore, air transport services provided by airports and the airfreight sector ought to be complemented with supporting services in the wider logistics industry, which comprises (but not limited to) road, rail and water transports and storage that provide essential inter-modal transfer facilities and warehousing service for a door-to-door delivery in the entire supply chain. An efficient logistics industry enables nations, regardless of location, to efficiently connect to distant markets and global supply chains in a speedy and reliable manner. Among others, Kasarda and Green (2005) advocated that nations with efficient supply chain enjoy competitive trade and production advantage over those nations without such capability.

According to the IATA, Asia Pacific is currently the biggest market for international air cargo service accounting for 45 percent of the world's demand and its relative share is expected to approach 55 percent of the world in 2011. Table 1 below shows that Asia hosts some of the world's busiest airports, including Chek Lap Kok (Hong Kong), Incheon (South Korea), Shanghai Pudong (China), Narita (Japan), Changi (Singapore), etc. Of these airports, Hong Kong Chek Lap Kok airport is an air cargo hub in North East Asia while Singapore Changi airport is an air cargo hub in South East Asia. Chek Lap Kok airport and Changi airport registered a spectacular cargo traffic volume of 3,772,673 and 1,918,159 tonnes respectively in 2006. In terms of air linkages, Chek Lap Kok airport connects companies from Hong Kong to 130 destinations on some 4000 weekly scheduled flights. Air connectivity is equally strong in Changi airport with an average of 3200 weekly flights to 149 cities in 50 countries from Singapore.

Table 7-1 Traffic volume at major airports in the world, 2006

Airport	Aeronautics Movements	Passenger Movements	Cargo Tonnes	Region
Hong Kong (HKG)	305,044	46,995,000	3,772,673	North East Asia
Incheon (ICN)	213.187	31,421,801	2,555,582	North East Asia
Shanghai Pudong (PVG)	253,494	28,929,954	2,494,808	North East Asia
Paris (CDG)	552,721	59,919,383	2,297,896	Western Europe
Tokyo Narita (NRT)	195,074	35,530,035	2,252,654	North East Asia
Frankfurt (FRA)	492,569	54,161,856	2,169,025	Central Europe
Singapore (SIN)	223,488	36,701,556	1,918,159	South East Asia
Los Angeles (LAX)	681,445	61,895,548	1,877,876	North America
Dubai (DXB)	259,952	34,348,110	1,668,506	Middle East
Amsterdam (AMS)	454,357	47,793,602	1,651,385	Western Europe
New York (JFK)	443,004	47,810,630	1,595,577	North America
Chicago (ORD)	927,834	76,159,324	1,524,419	North America
London (LHR)	481,356	68,068,554	1,395,909	Western Europe
Bangkok (BKK)	265,763	41,210,081	1,220,001	South East Asia
Beijing (PEK)	399,986	53,736,923	1,191,048	North East Asia

Source: Airports Council International, Geneva, Switzerland

The extraordinary cargo traffic performances of the Chek Lap Kok and Changi airports are believed to be partially attributed to the developments of the logistics industry, which are listed as one of the top priorities in national agendas of both Hong Kong and Singapore. Figures from the Hong Kong Census and Statistics Department reveal that the logistics service cluster comprised 34,641 establishments that employed a total of 192,983 workers and achieved aggregate operating receipts of HK $371 billion (approximately equivalent to US$48 billion) in 2006. Airfreight transport industry is one of important sectors belonging to an overall logistics industry. The airfreight sector currently employs 20.51 percent of the total number of workers in the Hong Kong logistics industry, accounting for an average 36.33 percent of the value added in the industry over the last two decades. During the same year, the Singapore Department of Statistics recorded a total of 9141 establishments, 117857 employed workers and operating receipts worth SGD$61.2 billion (approximately equivalent to US$45 billion). The airfreight sector constitutes an average of 13.81 percent and

22.24 percent of the total employment and value-add respectively in the Singapore logistics industry.

This chapter examines the internal and external influences on the growth of air cargo services and quantifies the economic benefits of the air cargo business to the Hong Kong and Singapore economies during the period from 1990 to 2006. An Air Cargo Supply Chain Operations Reference (ACSCOR) model is proposed to explore the possible performance linkages that exist among an airport, its airfreight transport and supporting logistics industries and the economy conditions under which the airport is operating. In other words, apart from internal airport attributes, the ACSCOR model relates the performance of an airport to the industrial and economic forces governing demand and supply for air transport. The economic contributions of airport investment, given the specifics of these external factors, are then estimated through the accelerator and multiplier models.

The findings obtained from the ACSCOR model will aid to evaluate if the degree of airport capitalization, service quality, logistics industry developments and general economic conditions are promoting or impeding cargo traffic at an airport. Notwithstanding the fact that sea transport competitors are luring shippers with faster ships, lower prices and innovative solutions, the evasiveness of cargo handling charges that vary with seasons and cargo types has thus far hindered researchers to study the service complementarity and substitution between the air and sea transports. The performance correlation analysis that is conducted within the logistics industry would help to reveal the underlying structure of the industry and hence provide a better understanding on the role of the seaport (which is a traditional mode for international transportation) in this modern age of air transport. To the best of our knowledge, this study presents the first attempt to assess the integrated impact of economic, industrial forces and airport operating strategies on airport performances. Such assessments are meaningful owing to the need to coordinate efforts on different levels of a supply chain to drive an economy wide agenda for the provision of competitive cargo service (Mangan et al. 2008). Furthermore, the estimations of economic contributions of the air cargo service business will be useful in shedding lights on the investment returns of airport development.

The remainder of this chapter is organized as follows. Section 7.1 reviews the literature on the economic impact of a competitive airport. Sections 7.2 and 7.3 outline the research design and methodology. Section 7.4 applies the proposed models to the Hong Kong and Singapore air cargo supply chains. Specifically, the ACSCOR model compares performance linkages in the multi-level air cargo supply chains of the two economies. The accelerator and multiplier models, in conjunction with a value added approach, quantify the aggregate economic contributions of airport development and air cargo service to an economy. Section 7.5 highlights the limitations of the study and concludes the chapter.

7.1 Literature Review

The counterfactual approach is one of the widely adopted methods that measure the net economic benefits brought about by airports. Benell and Prentice (1993) estimated the relationship between airport revenue (and airport employment) and the economic activities of airports in a regression model using various readily available economic and airport data. They showed that passenger traffic, the region's economic condition, and the presence of a maintenance base are positively related to employment size and the revenue of Canadian airports. Raguraman (1997) investigated into the annual benefits of additional weekly flights to Thailand by considering inbound and outbound tourist spending and airline marginal expenditure on airport service. He found that the additional service can bring in US$3.3 million in tourist spending, which in turn, has positive effects on output, GDP, and employment through the multiplier effect. With the help of an input-output table, Ishikura et al. (2003) applied the computable general equilibrium model to study the impact of an airport development on different sectors in Japan. Under the assumption that some percentage improvements in productivity of the air transport industry brought about by airport development will result in a proportional reduction of travel time by air, most of the sectors studied enjoy a cost decrease coupled with a rise in output and final demand. The authors, therefore, confirmed the importance of proper airport developments to the Japanese economy. York Aviation (2004) conducted a survey for Airports Council International Europe measuring the economic impact of airports in Europe. The council estimated that there are 950 on-site employments for every one million workload units in year 2001, and 2,100 indirect or induced national employments for every 1,000 on-site jobs in European airports, and thereby substantiating the benefits of the presence of air transport services to the economies. Using Pearson correlation analysis and multiple regression, Karasda and Green (2005) examined the role that air cargo plays in economic development by presenting basic empirical relationships between air cargo and trade and gross domestic product per capita. The authors then discussed and assessed the importance of air service liberalization, customs quality improvement and corruption reduction in enhancing air cargo's positive impact (i.e., effects of these three factors on per capita net inward foreign investment and gross domestic product per capita) using empirical data from 63 countries.

While the counterfactual approach gives a clearer picture of the additional economic contribution of the aviation sector, Fung et al. (2006) highlighted that no one knows exactly how economic development would have differed if air transport services had been absent. Since the comparison of change in tourism income and airline expenditure may not fully reflect the actual economic impact of air transport services, many other factors have to be taken into account. These include the businesses that developed around the airport given the existence of the airport, and other industries also have flourished as a result. In order to obtain a more holistic quantification, Fung et al. proposed the use of a value-added approach. However, the accelerator effect of air cargo traffic on the demand for airport infrastructure that in turn leads to the multiplier effect of subsequent infrastructure investments on income has not been studied.

7.2 Research Aims and Hypotheses Development

Despite the examples given above, there is still a need for comprehensive study to assess the type of linkages and coherence between various level of the supply chain integration and the internal airport operations and their effect on the viability of the air cargo business. According to Caplice and Shefi (1995) and Cagliano et al. (2006), any valid performance model within the logistics and supply chain context should integrate different measures of internal activities and link them to measurement activities of other entities in the supply chain. With the exception of Bichou and Gray (2004) who examined the relationships between key performance measures in the seaport and various levels of sea cargo supply chain, there has been no study that seeks to relate important performance indicators of different stages in the air cargo supply chain.

This chapter will address this issue, in the context of the Hong Kong and Singapore air cargo supply chains. The overall proposition is that supply chain strategies and airport operations strategies should be linked and coherently selected. On this basis, specific hypotheses are formulated and will be tested:

H1: The cargo traffic in an airport is related to cost control and other management aspects of airport operations

Page (2003) advocated that successful airports look at how the airline looks at the market and who their customers are. In the extant airport economics literature, a variety of factors has been identified as important user-perceived qualities for an attractive airport. These include adequate capacities provision (Meredith 1995; Hufbauer et al. 1995; Dempsy and O'Conner 1997; Buyck 2002), quick customs (Zhang and Zhang 2002; Ohashi et al 2005; O'Conner 1995), low airport charges (Berechman and De Wit 1996), reasonable local labor costs (Adler and Berechman 2001; O'Conner 1995) and so on.

H2: The viability of the air cargo service at an airport is positively related to the scale and profitability of the airfreight sector.

According to Schwartz (2002), the main customers of airlines/ freighter operators at airports are the airfreight forwarders who are traditionally based at the main airports and do not want to fragment their flow of freight and go to new places. To this end, Gardiner et al. (2005) recognized the increasingly influence of airfreight forwarders on airlines/freighter operators airport choice. Hence, the presence of a sizable airfreight industry is a pull factor and driver for freighter operators and air cargo traffic at the airport, considering that the demand for air cargo services at an airport is a derived demand from the airfreight industry.

H3a: The scale and profitability of the airfreight sector are positively related to the scale and profitability of the aggregate logistics industry.

Under one bill of lading for a door-to-door delivery, the attractiveness of air cargo services offered in the airfreight sector depends not on the basis of its performances, reputations, or cost of services, but on the availability of greater inter-modal coordination which will result in a lower total cost. Wan et al. (1998) emphasized that freight forwarders in the logistics industry play a central role in airfreight transportation as middleman for managing information flow and coordinating the movements of physical goods among airlines, air-cargo terminals and customers. With the ability to consolidate shipments from different customers, freight forwarders benefit from the economies of scale. Hence, the viability of the airfreight sector may be determined by the viability of the overall logistic industry (and vice versa) to a large extent.

H3b: The airfreight and sea freight sectors within the Hong Kong and Singapore logistics industry complement each other.

Alternative transportation modes compete with one another in terms of cost and time. For example, air transport is more reliable and speedier but cost much more than sea transport. Coyle et al. (2003) noted that as shippers of value-added goods regularly identify reliability and transit time as attributes equal to the importance of affordable freight rates in modal choice decisions, the best attributes of each mode of transport is often combined in a system such that the lowest cost of transportation for the supply chain can be achieved. The tradeoffs between cost, speed and reliability, hence, give rise to opportunities for different modes of transportation to complement one another in a competitive logistics hub.

H4: The scale and profitability of the aggregate logistics industry are related to the economic conditions in its operating environment.

The increasing global sourcing of parts, global production, global marketing and global logistics alliances that replaced the traditional method of local sourcing of parts, local production, local marketing and independent transportation and services has contributed to growth in trade volumes. Alongside, Persson and Virum (2001) have observed that users are also buying logistics services at an increasing international scale. In doing so, users not only take advantages of price differences but act as an invisible hand in market by channeling resources to their most profitable use and increasing the income that can be fetched by these resources. As such, we could expect a positive relationship between size and the amount of value-add of the logistics industry and trade volume of an economy.

7.3 Research Methodology

Section 7.3.1 will introduce the Air Cargo Supply Chain Operations Reference Model (ACSCOR). The ACSCOR depicted key performance measures for different levels of the air cargo supply chain, and degrees of inter-relationship between the levels are examined by means of Pearson Correlation. Section 7.3.2 outlines the principles of the accelerator and multiplier models that are used, in conjunction with the value added approach, to investigate extent to which air cargo is an engine to economic growth. Section 7.3.3 describes data sources for the identified performance measures in the preceding sub-sections.

7.3.1 Air Cargo Supply Chain Operations Reference (ACSCOR) Model and Performance Measures

The Supply Chain Operations Reference Model (SCOR) has been developed and endorsed by the Supply Chain Council as the cross-industry standard diagnostic tool for supply chain management. The SCOR model, consisting of four levels, spans across all customer interactions (from order entry through paid invoice), product (physical material and service), transactions (from upstream to downstream) and market interactions (from understanding of aggregate demand to the fulfillment of each order). Nonetheless, the SCOR model has been primarily applied to evaluate the supply chains of the manufacturing industries thus far. Some examples of these applications are described in Hwang et al. (2008).

In this section, an ACSCOR model is proposed based on the SCOR model. Similar to the SCOR model, the **first** level of ACSCOR Process is defined to span across 5 activities: Plan, Source, Make, Deliver and Return. *Planning* (also typically referred to as demand management) refers to the processes that balance aggregate demand and supply to develop a course of action which best meets sourcing, production and delivery requirements. An airport needs to be adequately equipped with sufficient manpower and physical (landside and airside) facilities to handle the expected cargo volume. *Sourcing* refers to the processes that procure goods and services to meet planned or actual demand. For example, tenders need to be called for to hire the right contractors to build physical facilities and provide services for outsourced activities. Well-trained workforces need to be sought so as to ensure smooth operations and reduce the likelihood of misdirecting or damaging of cargo. *Making* refers to the processes that transform product to a finished state to meet planned or actual demand. These processes include the sorting of cargo according to destinations and carriers, loading cargo from source, unloading cargo at destination etc. *Delivering* refers to the processes that provide finished products and services to meet planned or actual demand. The right cargo must be sent to the right destinations at the right time. Complex custom service needs to be simplified to avoid unnecessary time-consuming procedures slowing down the cargo delivering process. *Returning* refers to the processes associated with the returning or receiving of returned products such as misdirected cargo, damaged cargo, etc. Though being non-value adding, these are essential processes that place additional demands on the manual labor and physical facility capacity of the airport. The "traffic volume" in an airport is used to measure how well the airport has performed these functions in the first level of the ACSCOR model.

In the **second** level, each ACSCOR process can be further described by Process Type activities that facilitate the fulfillment of cargo traffic at the airport. These Process Type activities often encompass Planning, Execution and Enable carried out by the airlines in the downstream airfreight transport industry. Airlines will plan the service frequencies and supply capacities, designate the appropriate flights and aircrew to serve the demands of various origin-destinations in consideration of important issues such as utilizations and rotations of flights, profitability of service routes, etc. Since the demand for an airport cargo services is a derived demand from the airfreight industry, the ability of the airfreight industry to conduct these activities effectively will not only impact on the operational efficiency of the airfreight industry but also on the viability of air cargo service offered by the airport. Therefore, "amount of value added" and "number of employments" in the airfreight industry are applied as proxies to measure the success of the airfreight industry in carrying out the Process Type activities given the services provided by the airport.

The **third** level of the ACSCOR model presents detailed process element information for each second level process category. The airport cargo services and airfreight industry are integral components in the overall logistics industry, which plays a supporting (but critical) function in bringing the cargoes from the airport to the recipients at different destinations (or from sources of productions to the airport) and providing the necessary storage and inter-modal transfer in process. The scale and profitability of logistics industry are assessed using the “number of establishments” and “number of employments” and “amount of value added”.

Finally, the **fourth** level of the ACSCOR model defines the specific practices that companies implement to achieve competitive advantage and adapt to changing business conditions. These specific practices also include supply chain management practices, for example, shippers will only move from the use of sea transport to air transport on condition that there will be greater demand for higher value and more rapidly launched new products. Therefore, alike other types of service and manufacturing industries, the air transport and logistics industry cannot operate in isolation from economic and environmental influences. In relation to these influences, Chin (1997) advocated that a strong domestic market can command a certain level of air services while Zhang and Zhang (2002) indicated that air cargo volume is strongly linked to trade volume. Here, “GDP per capital” is used to estimate the domestic market strength and “total value of imports and exports” measures the trade volume. Figure 7-1 gives a diagrammatic representation of the ACSCOR model.

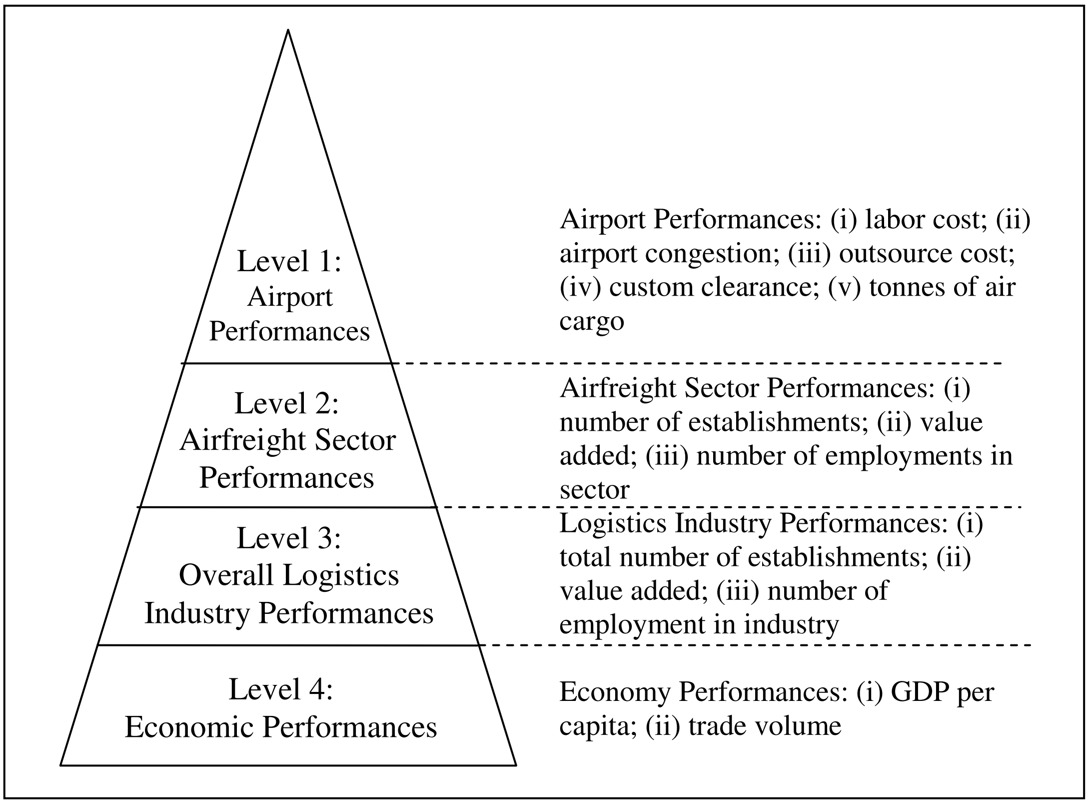


Figure 7-1 Air Cargo Supply Chain Operations Reference (ACSCOR) Model

Correlation analysis is applied to examine the performance linkages between the various levels of the ACSCOR model depicted in Figure 7-1. In the correlation analysis, a common measure for the relationship between two random variables is the covariance from which the Pearson correlation coefficient ρ between the random variables can be computed. ρ gives the strength and direction of the relationship between the two variables, for example, -1 indicates perfect negative linear correlation while +1 indicates perfect positive linear correlation. However, it does not postulate a cause-and-effect relationship. Rather, the relationships depicted within the ACSCOR model are generally bilateral as one level is dependent on the other for inputs and jointly achieves the outputs (i.e., results).

7.3.2 Principles of the Accelerator and Multiplier

An airport serving higher air cargo traffic requires a larger stock of capital (or capacity), ceteris paribus. The accelerator model specifies the desired capital stock K_t^d as a multiple of air cargo volume Y_t at period t:

$$K_t^d = \alpha Y_t \tag{7.1}$$

where α is the desired capital-air traffic ratio.

Assuming that there is no depreciation, the net capital investment, denoted by I_t^n, is the difference between the desired capital stock and the stock of capital inherited from the preceding period K_{t-1}. That is,

$$I_t^n = K_t^d - K_{t-1} \tag{7.2}$$

The stock of capital inherited from the last period will be the desired capital stock based on income in the last period:

$$K_{t-1} = K_{t-1}^d = \alpha Y_{t-1} \tag{7.3}$$

Substituting (7.1) and (7.3) into (7.2),

$$I_t^n = K_t^d - K_{t-1} = \alpha Y_t - \alpha Y_{t-1} \tag{7.4}$$

Thus, the level of net investment spending in period t depends on the rate of change in air cargo traffic from period $t-1$ to t.

However, it may be optimal for an airport to adjust its actual capital stock to the desired capital stock slowly over time since capacity adjustment costs may rise significantly as the rate of investment increases rapidly (Foyer 1993). Let λ denote the partial adjustment lag that gives the fraction of the gap between the desired and actual capital stock filled each period by the investment. To reflect this adjustment lag, the model in (7.2) is re-expressed as:

$$I_t^n = \lambda\left(K_t^d - K_{t-1}\right) \qquad 0 < \lambda \leq 1 \qquad (7.5)$$

In (7.5), λ is a choice variable, which is influenced by the airport operator's decision on the speed of investments to be undertaken to fill the gap between the desired and actual capital stock. For example, if the speeding up of airport development or expansion projects entail high labor overtime and other facilities constructions-related cost, the airport may choose to delay (or spread out) its investment to future periods.

Substituting (7.1) into (7.5), we obtain

$$I_t^n = \lambda\left(\alpha Y_t - K_{t-1}\right) \qquad (7.6)$$

It is also important to note that different levels of traffic can be handled using the same level of physical capacity by varying the labor and outsourcing inputs and therefore the desired α may change. Generally, the optimal choice of capital-labor-outsource mix depends on the ratio of the cost factors. Since the outsourcing cost is often pegged to real wage, the ratio of cost factors is essentially the ratio of capital cost c_K to actual wage c_L. Hence, expressing α as a function of capital cost and actual wage, it follows that

$$I_t^n = \lambda\left(\alpha\left(c_K, c_L\right)Y_t - K_{t-1}\right) \qquad (7.7)$$

Using the multiplier principle, the change in the income of the economy ΔGDP is

$$\Delta GDP = MI_t^n = M\lambda\left(\alpha\left(c_K, c_L\right)Y_t - K_{t-1}\right) \qquad (7.8)$$

where M is the multiplier effect that gives the change in income for a unit of investment.

7.3.3 Data Descriptions

The required data are sourced from the Airport Benchmarking Reports, World Competitiveness Yearbooks, Hong Kong Census and Statistics Department and Singapore Department of Statistics.

The Airport Benchmarking Report [1] (2002 – 2007 issues) gives the data pertaining to airport traffic, capacity and cost between 1998 and 2006. Since the focus of this study is on the air cargo supply chain, airport traffic will be measured in terms of airfreight tonnes that go through the airport. Airport capacity is classified into two types of capacities, physical (fixed) capacity and human (variable) capacity. The physical capacity is further subdivided into airside and landside capacities. Following Pels et al. (2003) and others, the number of runways and size of terminal area are used as proxies to the airside and landside capacity respectively. The adequacies in the provision of airside and landside capacities are measured by their degrees of utilizations [2] (or congestions). According to the Air Transport Research Society (ATRS), labor provides another measure of airport capacity. The size of labor force is generally measured by the number of full time workers (and the equivalents) directly employed in the airport. The total labor cost in an airport is computed by multiplying the number of airport workers by their average compensations. Also, Low and Tang (2006) demonstrated a prominent trend towards increasing outsource over the years. As documented by the ATRS in the annual Airport Benchmarking Reports, the outsourcing of peripheral services and facilities to outside contractors has enabled

[1] The first issue of the Airport Benchmarking Reports compiled airport data for the year 1998. Also it is from 1998 that new Chek Lap Kok airport is opened for commercial operations, replacing the old Kai Tak airport. Hence, the statistical analysis relating to airports will cover the period between 1998 and 2006.

[2] The number of aeronautics movements is divided by the number of runways to estimate the level utilization of airside capacity. Likewise, the volume of air cargo is divided by the terminal area to estimate the landside capacity utilization.

airports to focus on their core businesses and thus increase the productivity of their labor force. The total outsourcing cost is derived through a deduction of the total labor cost from the total variable cost incurred by the airport.

Other required data are supplemented by the Containerization International Yearbooks (1992 – 2008 issues), World Competitiveness Reports (1991 – 1995 issues) and Yearbooks (1996 – 2007 issues). The Containerization International Yearbooks give the container traffic at the seaports. The World Competitiveness Reports and Yearbooks report economic data such as GDP, trade volume, degree of cumbersomeness in custom administration, etc. between 1990 and 2006. GDP and trade volume, whose interpretations are self-explanatory, indicate the levels of affluences and economic developments of a country. Custom service complexity is given as a rating of the perceived cumbersomeness in custom clearance by businesses.

Finally, the respective statistical departments provide the information on the logistics industry in their economies. This includes annual figures on the number of establishments, size of employment and amount of value added (defined as the annual turnover minus annual purchases) in the land, water, air and storage sectors that made up the logistics industry. The data covers the period between 1990 and 2006.

7.4 Results and Discussions

7.4.1 Hypotheses Testing

In the following hypothesis testing, relationships between key performance measures in various levels of the ACSCOR are tested at both the 99 percent and 95 percent significance levels. If the Pearson coefficient is significant at 99 percent significance level, we conclude that there is a very strong or significant relationship between the two constructs. If the Pearson coefficient is significant at 95 percent significance level but not at 99 percent significance level, we conclude that there is a significant relationship between the two constructs. Else, the relationships are interpreted as statistically non-significant.

H1: The cargo traffic in an airport is related to cost control and other management aspects of airport operations. In general, accept.

The utilization of airside capacity exhibits a very strong relationship with the level of air cargo traffic in the Hong Kong's Chek Lap Kok airport (ρ = 0.864). This relationship is also significant in the Singapore's Changi airport, with ρ equal to 0.739. On the assumption that cargo loadings and average size of flights are unchanged, such positive relationships are logical considering that higher runway utilizations imply larger number of flights that brings along a greater volume of cargo. Further simplifications of custom service in these highly efficient airports have negligible effect in stimulating higher air cargo traffic, exhibiting with ρ values of -0.208 and -0.267 in the two airports.

On the other hand, increased landside capacity utilization at the Changi airport has a very significant positive impact on air cargo volume (ρ = 0.864) but increased utilization of landside capacity creates congestions that result in an almost equally strong opposite effect[3] in Chek Lap Kok airport (ρ = -0.839). High labor cost has a negative impact on air cargo volume in Chek Lap Kok airport (ρ = -0.729) but a negligible impact in Changi airport (ρ = 0.262). It could be inferred that Hong Kong's labor cost (adjusted for its productivity) may be higher in comparison to that of Singapore, resulting in higher operating costs that adversely impact air cargo traffic. Since outsourcing cost is pegged against labor cost in an economy, outsourcing cost

[3] A cause-and-effect relationship is inferred in this case, as lower cargo traffic cannot lead to higher utilization of a given landside capacity.

also shows a significant negative impact on the air cargo traffic in Chep Lap Kok airport (ρ = -0.759) but not in Changi airport (ρ = -0.201). Following the observation in Low and Tang (2006) that labor and outsource inputs are substitute to capital input, an alternative interpretation for the insignificant effect of outsourcing and labor cost is that Changi airport is more capital intensive.

Together, the above may indicate a need for Hong Kong to curb high variable operating cost to maintain international competitiveness. The importance of cost is not unfounded given that Chek Lap Kok airport is one of the most expensive airports in the world (Zhang 2003). In addition, the airport operator of Chek Lap Kok could seek to improve the workflow by adding more landside facilities to ease congestion at the landside, while the operator at Changi airport could seek to reduce the airport's outlay on fixed cost and enhance capacity utilization.

H2: The viability of the air cargo service at an airport is positively related to the scale and profitability of the airfreight sector. Accept

Between levels 1 and 2 of the ACSCOR model, the cargo traffic at the airports is positively related with amount of value add in the domestic airfreight sector. This statistically significant relationship appears to be stronger in the Hong Kong than Singapore, with ρ values of 0.887 and 0.768 in Hong Kong and Singapore respectively. Meanwhile, the correlation between the employment level in the airfreight industry and the air cargo traffic is significant (or on the verge of attaining statistical significance) at Chek Lap Kok (or Changi) airport with a ρ value of 0.897 (0.694). A two-way interpretation is reasonable: (i) higher volume of airfreight will stimulate the need for more workers or (ii) more workers engaged in the airfreight industry enable faster processing service and attract bigger volume.

H3a: The scale and profitability of the airfreight sector are positively related to the scale and profitability of the aggregate logistics industry. Accept

Although there is no clear relationship between the number of establishments[4] in the airfreight sector and that of other logistical sectors, it is evident that very strong correlations between amounts of value-added in the airfreight sector and logistics industry exist in Hong Kong (ρ = 0.985) and Singapore (ρ = 0.881). In terms of employment, the relationship between the airfreight sector and the aggregate logistics is very strong in Hong Kong and significant in Singapore (i.e., ρ = 0.881 in Hong Kong and ρ = 0.679 in Singapore). From these observations, we may infer that the airfreight sector is dependent on other sectors in the aggregate logistics industry in terms of value added and employment generated.

H3b: The airfreight and sea freight sectors within the Hong Kong and Singapore logistics industry complement each other. Accept

Within level 3 of the ACSCOR model, statistics from Hong Kong shows a very strong positive relationship between the value add in ocean water transport sector and that in the airfreight sector as depicted by a high ρ value of 0.970. This relationship is also statistically significant in Singapore with ρ equal to 0.785. Additional correlation test between the cargo volume at the seaport and the value add in the ocean transport sector reveals that the traffic volume at Hong Kong's (Singapore's) seaport is significantly related to the value added in the Hong Kong (Singapore) ocean water transport industry with a ρ value of 0.847 (0.827). Thus, it can be further inferred that both Hong Kong and Singapore are able to benefit from the complementary

[4] Apart from the number of establishments, the average size of each establishment is another factor influencing the aggregate output in the industry.

relationship between their excellent seaports and airports to realize their vision of a regional/ global logistics hub.

H4: The scale and profitability of the aggregate logistics industry are related to the economic conditions in its operating environment. In general, accept.

Testing the relationship between levels 3 and 4 of the ACSCOR model, it is found that there is a very strong association between value added in the logistics industry and national GDP per capita. The ρ values stood at 0.958 and 0.820 for Hong Kong and Singapore, respectively. Similarly, very strong relationship are displayed between the value added in the logistics industry and the trade volume in Hong Kong (ρ = 0.890) and Singapore (ρ = 0.849). In other words, logistics industries in both economies appeared to be related to their economic environments such that an increase in trade volume or income helps to increase the value added of the industry and vice versa.

However, both income and trade have negligible effects on the employment levels in the Hong Kong and Singapore logistics industry. These observations arise possibly because employment numbers are affected by many other factors such as skills and productivity of employees, degree of automatic and mechanization, etc.

7.4.2 Quantifying the Accelerator and Multiplier Effects

Tables 7-2 and 7-3 below give the airport cargo traffic and capital investments[5], as well, as the amounts of value added and the percentages of GDP contributions of their associated airfreight industry from 2001 through 2006.

[5] Airport capital includes a variety of facilities such as runways, check-in counters, terminal space, gates and other peripheral equipments. The annual value of capital (or capital stock) is obtained by dividing net operating income by the return on capital asset (ROA) given in the Airport Benchmarking reports. The ensuing analysis does not account for depreciation owing to the different accounting standards between Hong Kong and Singapore.

Table 7-2 Selected indicators on the importance of the Hong Kong air cargo industry

Year	(1) Cargo Traffic (Tonnes)	(2) Capital Outlay (US$)	(3) Value Add (US$)	(4) Proportion of GDP (Percentage %)
2001	2,312,391	3,492,063,492	2,676,520,000	1.579
2002	2,546,000	6,111,111,111	3,380,050,000	1.958
2003	2,738,000	6,931,818,182	2,907,230,000	1.632
2004	3,100,000	6,076,923,077	3,614,340,000	1.868
2005	3,402,000	5,568,181,818	3,957,650,000	2.235
2006	3,609,780	Not available	3,750,000,000	1.983
Average:	2,951,362	5,636,019,536	3,380,965,000	1.876

*based on the exchange rate of 1 HKD = 0.1281 USD

Table 7-3 Selected indicators on the importance of the Singapore air cargo industry

Year	(1) Cargo Traffic (Tonnes)	(2) Capital Outlay (US$)	(3) Value Add (US$)	(4) Proportion of GDP (Percentage %)
2001	1,507,062	3,861,538,462	1,779,358,720	1.581
2002	1,637,797	3,205,172,414	1,771,288,429	1.527
2003	1,611,407	4,160,000,000	1,998,938,293	1.679
2004	1,775,092	2,142,857,143	2,709,283,879	2.001
2005	1,833,721	2,551,724,138	2,689,859,857	1.839
2006	1,931,881	Not available	2,979,097,512	1.871
Average:	1,716,160	3,184,258,431	2,321,304,448	1.750

*based on the exchange rate of 1 SGD = 0.7337 USD

Assuming that there is no lag effect in capacity investment (i.e., λ=1), the accelerator can be computed using equation (7.7). This assumption is not unreasonable owing to the intense competition in the Asia airport industry that makes prolonged under-capacity a detrimental factor to the competitiveness of an airport. As shown in Figure 7-2, the accelerator effect reaches its peak in 2003 for both Hong Kong and Singapore. The desired capital-air traffic ratio α lies between 1500 and 2600 for Hong Kong whereas this range is between 1200 and 2600 for Singapore, averaging about 1989 and 1940 in Hong Kong and Singapore respectively. These results are congruent to the earlier findings from the ACSCOR model, which advocate the need for Chek Lap Kok airport to increase its physical capacity and control its labor cost (perhaps by adopting more capital-intensive cargo processing methods).

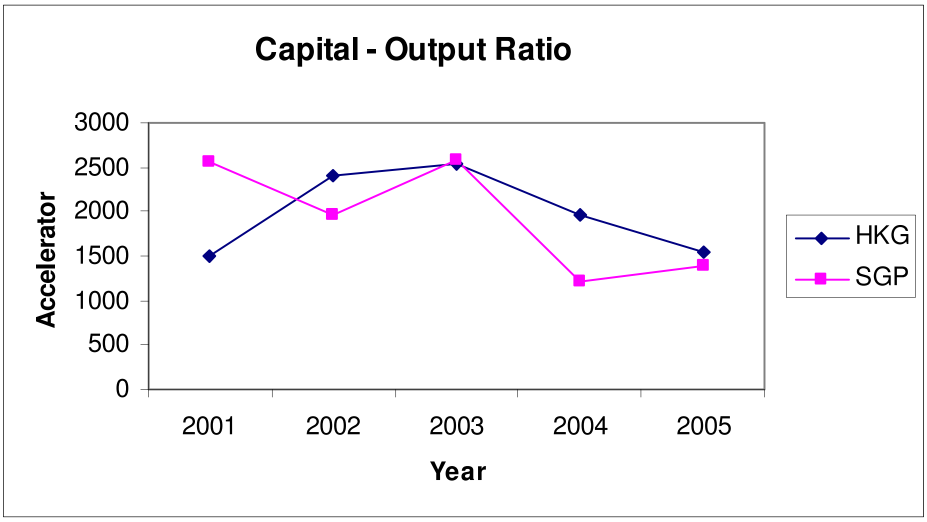


Figure 7-2 Accelerator effect of airport traffic in Hong Kong and Singapore

The multiplier in equation (7.8) is obtained by dividing the data in column (3) by column (2) of Tables 7-2 and 7-3. The average multiplier effect, as shown in Figure 3, is 0.609 and 0.762 in Hong Kong and Singapore respectively. Larger airport capacity enables higher cargo traffic to be handled at an airport, which in turn, increases the amount of value-added and number of employments in the airfreight sector as suggested by the ACSCOR model. The airfreight sector, being a key component of the logistics industry, contributes to the total employments in the aggregate logistics industry. Since number of employments in the logistics industry is more closely correlated with the average income in Singapore, a higher multiplier effect in Singapore is expected.

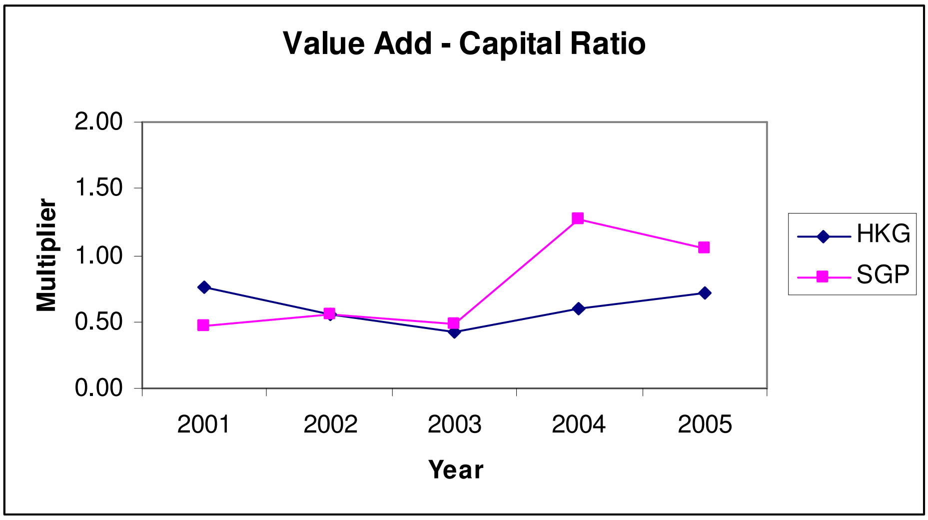


Figure 7-3 Multiplier effect of airport capacity investment in Hong Kong and Singapore

Using the value add approach suggested by Fung et al. (2006), the net effect on the contribution of the airfreight industry to GDP is an overall increase somewhere around 0.3 and 0.4 percentage points as displayed in column (4) of Tables 7-2 and 7-3. Similar to the conclusion derived from the ACSCOR model, this implies that value added in the logistics industry (which includes the airfreight sector) has a somewhat greater impact on the income of Hong Kong (1.876% of GDP) compared to that of Singapore (1.754 % of GDP).

7.5 Conclusions

Many governments in the Asia have been actively pursuing economic policies that would help to develop designated regions in their respective countries into global or regional air transport and logistics hub. Ohashi et al. (2004) advocated the ability of the airports in these designated regions to attract carriers and air cargo traffic is crucial to the establishment of a transport and logistics hub. On recognition that this 'airport ability' is dependent upon many internal operating and external factors, this chapter proposes an Air Cargo Supply Chain Operations Reference (ACSCOR) model to examine the performance linkages between different levels of the air cargo supply chain. The derived inter-level relationships in the air cargo supply chains are verified to be supported by the findings obtained from the traditional macroeconomic accelerator and multiplier models, from which the economic contributions are also quantified. Together, the integrated results can help the airport users, airport operators, logistics providers and governments to evaluate and improve the effectiveness of the air cargo supply chain and bring about greater benefits to participants in all levels of the supply chain.

In the light of statistics from Hong Kong and Singapore, the ACSCOR model demonstrates that economic progress, logistics industry development, efficiency of an airport and the competitiveness of its air cargo service are closely intertwined. Specifically, trade volume and income of an economy are shown to be positively associated with the amount of value added achieved in its logistics industry. While these economic indicators have no significant impact on the employment figures in the logistics industry, both the amount of value added and employment levels of the logistics industry are positively correlated with those in the airfreight sector. Furthermore, the integration of the airfreight sector with other supporting sectors in the logistics industry is necessary for a competitive air cargo supply chain that may involve more than one mode of transport to facilitate a seamless flow of cargo from its origin to destination. It is also observed that higher amount of value added and number of employments in the domestic airfreight industry generate higher air cargo volume for the airport (or vice versa). At the airport level, the importance of cost control in Chek Lap Kok airport can be inferred from the negative relationship between the variable costs and air cargo traffic. Nonetheless, it is cautioned that the pursuit for lower cost needs to be balanced against the adverse impact of longer waiting time inflicted by landside facility congestion. Conversely, the higher utilization of physical facilities at the airside and/or landside is beneficial to Changi airport. Further simplifications of custom clearance procedures, however, do not exert significant influences on the cargo volume handled at both the Chap Lap Kok and Changi airports. These observations lead to the inferences that an airport operator's effort to develop its airport into a regional/ global airfreight hub must go hand-in-hand with government's effort to push the logistics industry and the overall economy to greater heights.

Admittedly, this study is not without its limitations. First, by using the covariance to measure the directions and strengths of the relationships between performances of the various levels of the supply chain, an implicit assumption on the existence of a linear relation between these performance variables is imposed. However, the covariance might be less sensitive if the relationship is nonlinear. Second, the actual multiplier effect experienced in each economy is dependent upon the marginal propensity to consume and the marginal propensity to import but these marginal propensities are not considered in the computations of the multiplier effect.

CHAPTER 8

CONCLUSIONS

8. Summary

In this dissertation, we have examined some recent advances in the Asian port systems and their implications on port competitiveness and economic contributions. Preliminary in **Chapter 2**, our analysis reveals that the impact of capital intensity on cargo traffic has been rising while those of labor (quantity and quality) have been decreasing over the study horizon. Overall, the degrees of scale economies have fallen considerably. However, improvements in the economic conditions stimulate air traffic but have insignificant effects on seaport traffic. One possible reason could be the differing nature between airborne and seaborne cargoes (i.e., time sensitivity and value). From another angle, the insignificant economic influences on sea cargo traffic can be explained by the fact that improvements in economic conditions of advanced and developing nations affect sea cargo traffic differently and thereby producing an offsetting effect. Through the application of a cluster analysis, it is observed that the traffic diversion from higher-cost seaports to lower-cost seaports displays the "flying geese paradigm" as the latter catches up technically and economically. As for the airport industry, an ample provision and good utilizations of physical facilities for landside operations are found to be a more important driving force for cargo traffic performances compared to that for airside operations in the recent years.

According to Haralambides et al (2002), the increasing importance of capital input uncovered in analysis in chapter 2 could be an indication of intensifying competition. To survive the competition and protect market share, port authorities would need devise an appropriate set of development and positioning strategies for their ports. **Chapter 3** proposes a novel network-based hub port assessment (NHPA) model from an explicit formulation of connectivity and cooperation indexes. The former index is integrated with the considerations of some important observational port attributes such as port charges, turnaround time, inter-modal facilities availability etc. classified into three broad dimensions via factor analysis to fulfill the purpose of hub port assessment and uncover the key influential factors affecting liners' port choice. Through the service networks of large liner companies, the global hub seaports are found to be Singapore, Hong Kong, Shanghai, Pusan and Kaohsiung, of which, Singapore and Hong Kong ports are the more sustainable ones due to the cooperative relationships that these seaports engaged with other major Asian seaports. Jawaharlal Nehru, Laem Chabang and Tanjung Priok are the regional hub seaports. Results from this chapter further conclude that port efficiency and scale economies are two of the more important determinants for seaports to qualify as hub seaports. Despite exhibited general trend towards more competitive relationships among ports, engaging in inter-port cooperation is empirically verified to increase port traffic.

In the context of airports, **Chapter 4** examines the effect of hub development on airport's pricing and capacity decisions and proposes directions for strategic developments of airports. The analysis in this chapter takes into account three important aspects. First, airports are imperfect competitors to one another and compete for airline users and hub status through airlines' route decisions. Second, aeronautic pricing and capacity decisions may not be independent. Third, mixed ownership is another alternative to pure private or public ownership. Findings from this chapter confirm that airports which offer higher service value to airlines are able to command higher aeronautic prices. Other factors that leads to higher aeronautic prices are increase marginal variable cost of aeronautic operations, increase public ownership or decrease concessionary profits. In contrast to Zhang and Zhang (2003) and Oum et al. (2004), the inter-dependency between prices and capacity investment decisions causes increments in airport's economic rent and capacity-induced aeronautic revenue and demand, and decrements in airlines' willingness to pay elasticity to increase the optimal capacity investment in an airport. Airports with higher degrees of public ownership also tend to invest more into capacity for the purpose of social welfare maximization. Since excessive capacity increments at either the airport or aggregate industry level may possibly suppress aeronautic prices and the re-emergent of low-cost carriers opens opportunities for airport to compete on price, it will be more profitable for airports to pursue price strategy in the niche market of less time-sensitive traffic under circumstances where spiraling cost structure prohibits investment in huge mandatory additions to capacity.

Efficiency is one of the key mandatory elements contributing to an airport's success. As flexible operations enhance operations efficiency, **Chapter 5** measures and analyzes how the degree of flexibility of factor use (i.e., capital, labor and outsourcing) in Asia airport industry has changed over the years. Through estimations of the aggregate industry cost functions, Allen partial elasticities of substitution (AES) and price elasticities for the factor inputs are computed. The empirical results from this chapter demonstrate that while labor and capital are substitutes, outsourcing has emerged from a substitute for labor and a complement for capital in the late 1990s to a substitute for both labor and capital inputs in the more recent years. At the same time, increases in price elasticities of labor and capital indicate that airport operators in Asia have responded to the pressure for increased cost efficiency by improving their ability to react to price changes. However, there is an operating concern for the rapid increase in reliance on outsourcing that manifested in sharp reductions in the price elasticity of outsourcing inputs over the short study period.

Chapter 6 proceeds to present a comprehensive assessment of productive efficiencies across major airports in the Asia Pacific region. Several Data Envelopment Analysis (DEA) models, which simultaneously account for external macroeconomics and price factors in the computation of efficiency scores, are proposed. The integration of these models allows technical, scale, mix, cost and allocative efficiencies to be evaluated from a reference set of eleven Asia Pacific airports. To achieve a full ranking on the efficiency performances of the airports, a virtual airport is introduced into our reference sample as a superior performer. Results in this chapter show that the technical, scale and mix efficiencies among the major Asia Pacific airports are high. However, there are significant disparities in cost efficiency among airports that can be attributed to the presence of country-specific effect and differences in allocative efficiencies.

More recently, academicians and industrial practitioners have placed increasing emphasis on the veracity that the overall competitiveness of a supply chain plays an influential role on the attractiveness of a port and its success as a hub port. While ports form a vital link in supply chains, the competitiveness of a supply chain is dependent on each of the parts (i.e., the port and other supporting entities) working together to provide an effective reliable system that in turn promotes even higher economic growths. **Chapter 7** explores the inter-relationships among performances of an airport, its operating characteristics, logistics industry and economic regulatory environment by introducing and testing the validity of Air Cargo Supply Chain Operations Reference (ACSCOR) model in the light of Singapore and Hong Kong statistics. The empirical results show that the cargo traffic at an airport is significantly influenced by its operating characteristics, the performances of its airfreight and supporting logistics industry, and the economic environment that it is functioning within. Through the traditional economic models, it is found that on average Hong Kong experiences a higher accelerator effect but lower multiplier effect in airport investment compared to Singapore. While the multiplier effect may signify that Singapore can benefit from higher returns in terms of the spillover effect to the overall air cargo supply chain, the higher accelerator effect in Hong Kong corresponds to the empirical results from the ACSCOR model that advocate Chek Lap Kok airport to increase its physical inputs relative to human inputs.

8.1 Suggestions for Further Research

Similar to the existing studies on port literature, Chapter 2 has suggested that the availability inter-modal transport facilities will enhance port attractiveness and advance its development prospects as hub ports. However, while land transport such as railway and roads will complement and improve the competitiveness of seaports and airports, the investments in these alternative infrastructures are competing with one another for the pool of limited funds. A dollar invest in one area will mean a dollar less in another and allocation of available funds among these competing public development projects is a challenge. For socially optimal investment decisions, it will be useful to construct a model or framework that can measure the individual and combined economic spin-offs of these supporting transportation infrastructures.

A natural extension of chapter 3 is to collect service network information from a wider selection of liner companies. First, the inclusion of additional liner companies will enable more accurate assessments on port current standings and the evolutions of port competitiveness. Second, comparisons among liner companies' networks will allow a better understanding of port selection behavior of liner companies of different sizes. Along the same line of thought, other influential variables such as container mix, hinterland trade structure and port service reliability can be included into the port connectivity logit function to improve the evaluation of the relative contributions of various port dimensions on port competitiveness. Both container mix and hinterland trade structure are factors affecting the efficiency and hence connectivity of the port. Larger ports tends to handle a larger proportion of 40ft containers than their smaller counterparts but it takes approximately the same amount of time to handle containers regardless of sizes. The hinterland trade structure (other than trade volume) determines the need for space and other inputs. If there is a pronounced imbalance between the arrival and departure of cargo in the hinterland, there will be a need for large flows of empty containers that, in turn, affect the productivity and efficiency of the port. Reliable port service is highly valued by liners as it minimizes disruptions to their schedules and ensures timely service to shippers.

The model in Chapter 4 assumes that airlines are atomistic and symmetrically sized. In practice, hub airports typically have one or two dominant airlines accounting for almost half of the departure traffic. An investigation on how the dominant airline interacts with the atomistic airlines and the associated impacts on airport capacity (and congestion) would make the analysis and policy implications more realistic under the scenarios of hub airports. Since some of the atomistic airlines at the airport are the dominant airlines at other airports, such consideration may further lead to a full analysis of the pricing and capacity investment problem for a network of airports. Other than the pure strategy of hub or secondary airport development, we can explore other possible strategic options such as the setting up of two-terminal airport in which one terminal serves the full service carriers and the other serves the no-frill carriers, or extending existing terminal to include dedicated piers to cope with the specific demands and polarized needs of the two types of airlines.

Chapter 5 uses WLU as a single combined output measure for cargo and passenger traffic volume. Similar analysis using separate types of output such as number of passengers, aeronautics movement and volume of cargo etc will be interesting to see if there is any significant difference in the factor usages among these categories of output. Chapter 6 can be extended in two broad directions, namely, methodological and empirical. In terms of future methodological developments, it will be meaningful to enhance the capabilities of existing DEA models to measure long-run efficiency that takes into account the time lag of capital investment and include observations with fuzzy and missing data. Empirically, we may construct a stochastic frontier and compare the results obtained with those of a deterministic frontier. In this stochastic frontier, we could include a composite error as a sum of a one-sided disturbance term representing shortfalls of the produced output from the frontier due to inefficiency and a two-sided disturbance term representing upward or downward shifts in the frontier itself due to random factors. When airport charges for aircraft movements are too low, airlines may fly more frequent flights with lower loadings. The resulting airline inefficiency is passed on as airport inefficiency since airport's output consists of aircraft movements, human and cargo traffic. To isolate airline inefficiency from airport inefficiency, we can include aircraft movements (and their prices) into the DEA models as inputs rather than outputs.

Last but not least, the Air Cargo Supply Chain Operations Reference (ACSCOR) model is proposed in Chapter 7 as a framework for examining the performance linkages between different levels of the air cargo supply chain. According to Heaver (2006), port authorities can affect the competitiveness and structure of logistics services through their policies and involvement in services. Hence, more policy and regulation related research could be carried out to see how logistics and other industrial developments in hub ports are spurred on through policy and regulations. For example, the setting up of distribution centers within the ports is one of the many aspects that will contribute to the overall cost efficiency of a distribution system and the attractiveness of a port. The basic function of a distribution centre is to act as a platform to arrange for distribution and (de-) consolidate cargo in time and space. The presence of a distribution centre increases the flow of cargo through a port. While the concept of the setting up of a distribution centre is not new, more research could be also conducted in single- or multi-dimensions and/ or factors such as spatial factors, provisions of value-added services (for example, bunkering, pilotage, warehousing and cold storage etc.), info-structure or distribution centers in order to find out how and to what extent they contribute to port performances.

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APPENDIX A

COUNTRY'S LOGISTICS INFRASTRUCTURE and PORT DESCRIPTIONS

This appendix presents a brief overview on the logistics and economic environment of various countries in East Asia and provides some descriptions of their major seaports and airports. The SWOT analysis highlights strengths and weaknesses of major ports as well as opportunities and threats faced by the respective countries. The internet links to the official port websites, which give the latest information regarding current and future development of ports, are provided.

China

Table A1- SWOT Analysis for China

Environmental Analysis	
Opportunities	1. *Growth in the Logistics Industry* The **China**'s logistics industry is enjoying a high market growth rate of Chinese logistics that is expected to be over 8.5% annually. The growth of the Chinese logistics market is closely related to the growth of the Chinese economy and the country has maintained its high economic growth rate at 7%-8% over recent years and. 2. *Foreign Trade and Investment* Chinese import and export trade is expected to increase and growth of foreign capital investment in China is expected to continue at a relatively high rate with China's access to the World Trade Organization (WTO). 3. *Globalization* The trends toward globalization and development of high technology, e-commerce, and supply chain management ideologies have also led many corporations to integrate their supply chains and adopt Just-In-Time operations. China is one of the prime locations given her inherent advantages pertaining to her abundant labor force and huge market potential. 4. *Government Support* Strong state and regional government supports are seen from the inclusion of the logistics industry as a strategic industry into the 10th five-year development plan. This development plan devises policies that encourage the development of logistics and create an appropriate environment for modern logistics development which includes strengthening, planning and construction of the logistics infrastructure, promoting information technology and new technological invention, broadening the opening of the logistics market, and stepping up training of logistics personnel etc.

Threats	Large gaps exist between Chinese logistics development and international logistics standards. 1. *Lack of Integration* Suppliers of raw materials, manufacturers, wholesalers, retailers, logistics operators and end users still not linked together. 2. *Cost Differential* In China, approximately 20% of a products price is accounted for by logistics costs and relative logistics costs can reach up to 50% higher than the US. 3. *Backward Infrastructure Development* While there has been good progress in developing rail, road, water, pipeline and air transport lines, freight stations, transport vehicles and equipment, packing, and shipping facilities, the densities are still very low. Also even though digital transmission artery networks have been developed for the exchange, management, and control of logistics information in the telecommunications area, these communications networks are concentrated mainly in the coastal regions. Hence, much more development is needed in terms of internal river channels, ports, berths, railways, airports, transport and communication equipment. 4. *Outdated Management Techniques* China lacks modern facilities such as Information technology, centralized administrative enterprise management for logistics operations. Transportation cost and cargo damage are high. Inventory period for Chinese manufacturing enterprises is long and timely distribution is low compared to those of the developed countries. 5. *Cumbersome Custom Administration* Custom clearance is complex in comparison, although much effort has been put in to streamline and simplify the process.
Ports Analysis	
Strengths **Seaports** Shanghai Internet Website: www.portshanghai.com.cn	• Located at the mouth of Changjiang (Yangtze) on the apex of a vast hinterland of inter-modal waterways, rail and road links running inland to central China, the port of Shanghai is the leading port among China container port. • Containerization is high, reaching above 55 percent. • The port is attracting an increasing number of direct, deep-sea vessel calls. However, these are limited in the size and volume of cargo they can ship due to draught restriction. • In an attempt to attract transshipment traffic, the port of shanghai has simplified custom procedures and implemented computer linkage between the port, customs and other related agencies. • The bulk of Shanghai's cargo originates in or travels to the conurbation and neighboring provinces of Jiangsu and Zhejiang. A costal and inland container hub is being developed at Longwugang in Shanghai Harbor to extend the port's hinterland. • The sustained investment in new terminals, together with the introduction of world-class port management, has driven rapid ascend of the port on the world rankings.

Shenzhen Internet Website: http://www.szport.com/	• Shenzhen Port is located in south China's Guangdong province. • More international shipping companies are choosing the port for transshipment due to its merits:- 1. The port's loading and unloading charges are low, nearly half of those at ports in neighboring Hong Kong. 2. The two terminals, Chiwan and Shekou international container terminals, have constantly improved the efficiency of custom procedures. → By offering shorter time and lower cost of transport (including handling charges) between Hong Kong and the rest of China, the port of Shenzhen port has now become the largest port on the Chinese mainland in terms of handling international transshipment goods.
Yantian Internet Website: www.ytport.com	• Sited in the sheltered waters on Dapeng Bay just 20 nautical miles north of Hong Kong, the port of Yantian is opened in July 1994 as an alternative access point to Southern China. • This deep-water container port has lifted its throughput to over 1 million TEU in just 4 years since its opening, making it the largest container ports in Southern China. • The main bulk of Yantian's cargoes originated largely from Shenzhen, Dongguan, Guangzhou, Huizhou and other Pearl River locations. • The port is equipped with advanced port facilities and is served by a sophisticated rail and road network. • Among other factors, the simplified customs procedures as well as its lower cost have encouraged its development.
Airports	
Beijing Capital Internet Website: http://www.bcia.com.cn/ch/	• Established in 1958, Beijing Capital International Airport is located 28 km from the capital city of Republic China. • The 24-hour curfew free airport is the only Chinese airport with 2 runways. • As China's busiest airport, a second terminal is opened in 1999. It is currently served by 51 airlines (39 foreign and 22 domestic airlines) offering 107 non-stop destinations, of which the majority is destined in Asia.
Shanghai Internet Website: http://www.shairport.com/en/	• Shanghai airports are made up of the Shanghai Pudong International Airport and Shanghai Hongqiao airport. The former is opened in 1999 to provide relief for the severe capacity shortage at the latter airport. • Shanghai Pudong International airport is located 30 km from the city centre and 40 km away from Shanghai Hongqiao airport, which is 13 km west from Shanghai city centre. • Currently, Shanghai Pudong International Airport is served by 25 international airlines offering 56 non-stops destinations throughout the world. • As part of the China government's plan to promote Pudong Airport as an aviation hub in the Asia-Pacific region, all international flights from Hong Kong and Macau can only take off and land at Pudong International Airport.

	• Despite being operating mainly as an airport for domestic flights from late 2002, Shanghai Hongqiao remains as one of the three biggest airports in China registering continual but more gradual growth. The airport has 23 air carriers, offering 51 non-stop destinations in major Asia cities.
Weakness **Seaports** 1. Shanghai 2. Shenzhen 3. Yantian **Airports** 1. Beijing Capital International 2. Shanghai	• Ports in China are labour-intensive and relatively backward in terms of technological adoption and management techniques. • Even if rail connections are provided at some ports, these rail capacities are limited and services are undeveloped. • While much effort has been put into simplifying the complex custom administration procedures, it still takes generally longer for ships and aircrafts to be processed in China as compared to their counterparts in Hong Kong. • In the case of the Shanghai seaport, its limited depth restricts access to the port. Even with dredging, there may be difficult in accommodating 6000 TEU ships.

China- Special Administrative Regions (SAR)

Table A2- SWOT Analysis for China (Hong Kong)

Environmental Analysis	
Opportunities	*1. Geographical Location* **Hong Kong** is located right next to the world's largest manufacturing centre of Pearl River Delta. *2. Historical Background* Traditionally a transport hub, her logistics sector represents one of the most important industries in generating employment and wealth for the country. *3. Conducive Environment* Other supporting factors such as knowledgeable workforce, favourable economic policies (like low taxes rates and free trade) and efficient transportation system with high densities of road and rail make Hong Kong a prime location for businesses. *4. Efficiency* Hong Kong maintains her British governing system and continues to enjoy autonomy as a SAR after returning to China in 1997**.** Thus, Hong Kong position's as a superior logistics hub is not affected by the general image of China as a bureaucratic and less efficient country.
Threats	*1. Cost* Hong Kong suffers high land and labor cost. Hence, business operations cost at the country are high due to high rental and wages paid out. *2. Regional Competition* The port of Hong Kong is also facing increased competition from cheaper ports, especially those in the southern China.

	3. *Direct Trade between China and Taiwan* The current status of Hong Kong as the gateway to the China mainland may not be permanent. The demand for the Hong Kong port's services is likely to decrease with the resumption of direct trade between China and Taiwan.
Ports Analysis	
Strengths Port of Hong Kong (Internet Website: www.mardep.gov.hk)	• Located on the north shore of the South China Sea at the mouth of the Pearl River Delta, the port of Hong Kong is the leading container port for the mainland of China and a major hub port for intra-Asia trade. Being at the centre of the Asia – Pacific Basin and strategically placed on the Far East trade routes, the port has also been a key factor in the development of the area • The port possesses one of the most perfect natural harbours in the world. • Operating in a business-friendly environment with world-class infrastructure, Hong Kong is the busiest and most efficient international container port in the world. • The port, handling about 22 million twenty-foot equivalent units (TEUs) of containers in 2004, is served by some 80 international shipping lines providing over 450 container liner services per week connecting to over 500 destinations worldwide.
Chek Lap Kok International Airport (Internet Website: http://www.hongkongairport.com/eng/index.html)	• Chek Lap Kok airport is located on a man-made island, 25km west of Hong Kong Island. • Commenced in 1998 to succeed the old Kai Tak airport, Chek Lap Kok airport is used by more than 70 airlines which operate 4,000 flights weekly to more than 130 destinations around the world. • The airport is one of the very few airports with its own internal underground rail network. Its automatic people mover is able to transport passengers from the furthermost gates in less than 1.5 minutes. • In 2004, the airport experience cargo growth of 20% due to the flow of manufactured goods from the fast-growing Pearl River Delta region. • The airport has been voted among the top three best airports worldwide in the IATA passengers' satisfaction year after year.
Weakness	• High operating cost, arising higher wages and land prices, is the primary weakness in Hong Kong ports.

Table A3- SWOT Analysis for China (Macau)

Environmental Analysis	
Opportunities	1. *Location* **Macau** is on the Southwest of Guangdong Province along the Pearl River Delta and shares a border with Zhuhai. 2. *Government Support* The regional government is starting to develop the county's logistics in the recent years. Particularly, Macau SAR is planning to build a logistics center to cope with the future development of Macau's transportation industry.
Threats	*1. Underdevelopment of the Logistics Sector* Macau returns to embrace of the Chinese motherland as a Special Administrative Region of China in 1999 and is most famous for tourism, gaming and the garment industry. Until recently, the logistics industry has been neglected and hence relatively underdeveloped.
Ports Analysis	
Strengths Macau International Airport (MFM) (Internet Website: http://www.macau-airport.gov.mo/en/index.php)	• Macau International Airport is a 24 hour airport, governed by an open sky policy which creates supportive conditions to the competitiveness of the airport. • Since it begins operations in 1995, Macau International airport has rapidly established itself as a vital link between the Pearl River Delta and the rest of the world. • With ample capacity and well-established and efficient direct sea links to neighboring regions, the airport is ideally positioned as a hub for freight and express cargo in the Asia-Pacific. • The establishment of a logistic park by the Macau SAR Government may help to stimulate the movement of air cargo and other related business.
Weakness	• Less than 9% of the 10,300,000 to Macau are by air. • Macau airport has always relied heavily on passenger source from Taiwan and as much as 65% of its passenger traffic is from Taiwan routes. • However, the number of passengers in Macau airport is gradually decreasing as Taiwan passengers are channeled through Hong Kong and mainland China.

Taiwan

Table A4- SWOT Analysis for Taiwan

Environmental Analysis	
Opportunities	1. *Geographical Location* **Taiwan** is situated in the hub of the Asia-Pacific region and is said to offer one of the shortest and the fastest average shipping and flight time at reasonable cost. Benefiting from its geographical, cultural and language advantages with the Mainland China, Taiwan serves as the main entrance to this major market for foreign businessmen.

	2. Conducive Environment Besides its strategic geographical location, Taiwan's competitiveness in logistics operations has been highly strengthened through the substantial improvements in the infrastructure environment, enhanced efficiency by reducing customs clearance time, considerable reduction of telecommunication fees, accumulated well-experienced professionals in logistics, and advanced information application techniques for the logistics industry. → For examples, the country has cut down on the need for long and tedious paper works to simplify the trading, custom clearance and shipping procedures and kept customs clearance time within 24 hours, with no time limit on the storage of goods. Meanwhile, distribution efficiency has been enhanced by simplifying the standing operation procedures. There are also over 60 industrial zones that can be easily transformed into private warehouses. The "Taipei Harbor Expansion Plan" by BOT and "Kaohsiung Sea/Air Joint Transportation Plan" are drawn up to strengthen the harbor-related infrastructure. Taiwan Association of Logistics Management (TALM) is also set up to provide training services to its members and information aids to foreign players. *3. Government Support* The Taiwanese government is supportive of the logistics industry as seen from the numerous incentives and assistance to logistics providers, shopping malls, retailers and wholesalers such as land use priorities, low-interest loans, exemption from business income taxes etc. Taiwan businesspeople are encouraged to establish strategic alliances with international logistics providers. In order to mitigate tax exposure and develop Taiwan as a regional logistics center for multinationals, Taiwan-based logistics centers which engage in and derived revenues from storage, processing and delivering goods to local customers are exempted from Taiwan corporate income tax.
Threats	*1. Slow Growth* Over the years, the main port of Taiwan (i.e. Port of Kaohsiung) as one of the primary supporting pillars of the logistics industry has increased its cargo volume at a rate slower than that of Singapore and Hong Kong. Since the year 2000, ports such as Pusan, Shanghai and Shenzhen have been fast overtaking Kaohsiung and the trend appears to continue.
Ports Analysis	
Strengths **Seaports** Port of Kaohsiung Internet Website: http://www.khb.gov.tw/English/	• Situated in the South-Western part of Taiwan at the nexus of main Asia Pacific trade routes, the naturally deep-water port of Kaohsiung with low tidal variance is the fifth largest port in the world • With more than 40% of its volume derived from transhipment, direct sailings between the Port of Kaohsiung and Ports of Xiamen and Fuzhou since 1997 have helped the port to secure more transhipment cargos from North America and China. • The port also has ample space for expansion and provides one of the world's largest ship scrapping facilities

Port of Keelung Internet Website: www.klhb.gov.tw	• The port of Keelung lies on the northern part of Taiwan, 40 km away from the capital city of Taipei. • The port has shipping routes linking globally with all the other major container ports. • For purpose of promoting the international friendship and strengthening the exchange of technology and experience on port developments, the port has affiliated as sister ports respectively with the ports of Oakland, Los Angeles, Bellingham and San Francisco in the United States and the Port of Southampton in the United Kingdom.
Port of Taichung Internet Website: www.tchb.gov.tw	• Located on the west coast of Taiwan, Taichung is the closest to mainland China among the three main container ports of Taiwan. While container traffic is on a much smaller scale, it has increased most rapidly. • The port of Taichung is potentially the main contender for direct trading links between Taiwan and mainland China.
Airports Chiang Kai-Shek Int (TPE) Internet Website: www.cksairport.gov.tw/CKSchi/	• CKS International Airport is located in Taoyuan County approximately 40 kilometers, or about 50 minutes by car or bus from downtown Taipei. • Since the airport begins its operations in 1979, Chiang Kai-Shek International Airport has become not only the most important gateway for travellers to and from Taiwan but also one of the most important air transport centres in Asia. • To cope with increasing passengers and cargo traffic, the second terminal is opened in 2000. • The airport is currently served by 29 airlines, providing direct routes to 42 destinations around the world.
Weakness	
Seaports Port of Kaohsiung Port of Keelung Port of Taichung **Airports** Chiang Kai-Shek Int (TPE)	• While setting off from the same footing as the ports in Hong Kong and Singapore, the Taiwanese ports expand at a slower pace. This results in the widening performance gaps between the ports. In terms of rankings, Kaohsiung was the world's third largest port on TEUs volume until 2000 when it slipped into the 4th position after overtaken by Pusan. Kaohsiung further fell to the 5th and 6th positions in 2002 and 2003 with the growth of Shanghai and Shenzhen ports. Haynes et al (1997) attributed this phenomenon to customers' dissatisfactions with service such as cumbersome custom clearances, costs and corrupt management. • While volume has been steadily increasing until the mid 1990s, the growth of the Port of Keelung is severely hindered by its capacity limits. Throughput in this port starts to fall in the late 1990s as carriers have abandoned the port due to increasing congestion, declining productivity and poor labour relations.

India

Table A5- SWOT Analysis for India

Environmental Analysis	
Opportunities	*1. Huge market* **India** has a large population representing an attractive potential market. *2. Cost* The abundance of labour in the workforce translates into low labour cost, which helps to keep production cost low, especially for labour intensive industry. *3. External assistance* External assistance is being obtained for the improvement of National Highways through international agencies such as the World Bank, Asian Development Bank and Overseas Economic Cooperation of Japan. As the increased output of basic industries would necessitate facilities for bulk transport, the Government of India who has activated the National Highways Authority is entrusted with the Asian Development Bank Project.
Threats	*1. Custom Administration* Despite the fact that the government of India has put in tremendous effort to reduce bureaucracy interface, red tapism and import regulation in the last five years, the country is still behind that of neighboring countries such as China, Taiwan, Singapore and Malaysia. *2. Restrictive Regulations* Also commercial vehicles in India are able to run only 250 kilometers on average per day as compared to 600 kilometers in developed countries. *3. Cost* The import through port cost for containers in India is much higher compared to the cost in neighboring ports (in Colombo, Singapore and Bangkok) due to costly the terminal charges (shore handling, storage, delivery and transport in ports), custom agent charges and the speed money incurred. This is hinders the achievement of the desired goal of globalization of the Indian economy. *4. Inter-modal Link* India has one of the largest road networks in the world (over 2.9 million km at present) but only 20% of the surfaced roads are estimated to be in good condition. This compares unfavorably with other countries (Indonesia and Brazil 30%, Korea 70%, Japan and USA more than 85%). Within the road networks, National Highways (NHs) which are the main arterial roads connecting ports, state capitals, industrial and tourist centers, and neighboring countries constitutes less than 2% of the total road network, but carries nearly 40% of the total road traffic. The majority of these NHs are only single lane. The deficiencies in the road network are causing huge economic losses due to slow transportation and also contributing to a high rate of road accidents. The delay on the roads and ports also results in high inventory costs for the industry, thus affecting its global competitiveness. In terms of railway, the Indian railway consists of extensive network spread over 62,915 kilometers covering 7068 stations and is considered as the second largest in the world. Despite the government's recommendations to give railways the lead role in the transport sector

	because of their greater energy efficiency, eco-friendliness and relative safety, road transport has assumed a pivotal role in the predominantly agrarian economy in India with heavy rural concentration due to the inadequacy of an inter-linked, exhaustive and all penetrating railway network or inland/coastal waterways or airways. *5. Limited Funding* While roads are the lifelines of an economy and India has attempted to evolve a cohesive transport policy as early as in the mid-60s, the Rakesh Mohan Committee on Infrastructure has highlighted the public sector outlay for road development and highways went down. Instead investments go heavily into production of vehicles, resulting in the present limited road space coupled with an unbalanced high growth of vehicles. Beginning early last decade, the Indian Ministry of Surface Transport (MOST) offers incentives and tax holidays to encourage private sector participation in the construction of road infrastructure under the build, operate and transfer (BOT) concept. However, infrastructure investments having long gestation periods are unattractive to private investors. *6. Congestions* Outdated transport technology, congestion at the ports and the insufficiently developed air services negatively affect foreign investment decisions in industries, which place a great premium on the infrastructure. Future investment needs are projected to be much higher because of demands created by rapid urbanization, and the need to make up for past inadequate investment and the country's high export growth rate. *7. Imbalanced Development* Since much of the network of rail, roads, ports and airports is geared to the needs of the urban economy, the vast rural hinterland is very poorly served by communications which will still be the responsibility of the government.
Ports Analysis	
Strengths **Seaports** Jawaharlal Nehru Internet Website: www.jnport.com	• Commissioned in 1989, Jawaharlal Nehru is the biggest and most environmental friendly port in India and handles 55% to 60% of the nation's total containerized cargo. The port operates 24 hours per day, possesses modern handling facilities and adopts up-to-date customs EDI and vessel traffic management system. • The Port is connected to the national extensive network of Railways. Projects to improve its rail and road connectivity and expand ports facilities are underway.
Chennai Internet Website: http://www.chennaiport.gov.in	• Situated in the Coromandel Coast in South-East India, the Chennai Port (previously known as Madras) seeks to achieve greater heights through a series of continuous modernization, efficiency services at minimum cost, simple and intergraded procedures, and user-friendly approach.

Airports Chennai International (MAA) Internet Website: http://www.airportsindia.org.in /aai/chennai-airport/)	• Chennai International Airport is situated in Meenambakkam, 7 Km south of Chennai. • The airport is the third most important international gateway into India after Mumbai and Delhi, and the main air terminus for south India. • It is also an important cargo terminus for India, second only to Mumbai. It has two terminals with the Kamaraj Terminal handling domestic flights connecting 20 destinations across the country with Chennai.
Indira Gandhi International (DEL) Internet Website: http://www.airportsindia.org.in/aai/igi/index.htm	• Indira Gandhi International Airport is a major gateway to India. • Located in the national capital, Delhi, it is a vital link between India and rest of the globe. The International Terminal (Terminal II) has 35 airlines flying to major cities across the world. Meanwhile, the Domestic Airport has three terminals. • The airport is equipped with state-of-the-art category - IIIA landing system making it operational even during dense foggy weather. • The airport currently handles an average of 13100 domestic and 9500 international passengers daily. Indira Gandhi International Airport is to be privatized through the route of Joint Venture, as part of Government's plan to privatize the four metro airports for providing world class terminals and other facilities to the passengers.
Weakness	• Ports in India are generally characterized by high level of congestions. Berths are often occupied 100% leaving no time for maintenance. Ships have to wait long in the channel for berthing and productivity in loading and unloading is low. These translate into long national average turnaround time of vessels. • Ports are labor intensive and mechanization process is non-existent or slow. Equipments used are outdated and obsolete. • Night navigation is not available. Restrictions in navigation channels do not allow bigger vessels to be berthed. Handling vessels and feeder vessels in container berths is time-consuming. • Road links to ports are insufficient and badly maintained. • Lack of coordination between ports and the custom authorities delay dispensation of documentation and goods.

Indonesia

Table A6- SWOT Analysis for Indonesia

Environmental Analysis	
Opportunities	1. *Resource Abundance* Being a resource-rich country, **Indonesia** provides huge opportunity for logistics companies. Logistics companies can play a significant role in enhancing the country's economic growth and benefiting from the growth of other industries at the same time. 2. *Growth in Logistics Industry* The logistics industry has seen stable growth over the past several years, at between 5% and 10% per year. As Indonesia’s economy

	improves and exports and foreign direct investment (FDI) rise, the country expects better growth in the logistics business. In order to target at greater growth, it has pledged more reforms to lure investors. 3. *Ports Attractiveness* To attract more users for their ports, the port authorities have given ship owners greater freedom to choose routes and schedules which may benefit to traders and businessmen at the end.
Threats	1. *Slow Development* As an island nation, well-maintained waterways and inter-island shipping are vital to Indonesia's economy. Until the mid-1960s Indonesia's transportation system was very poor. Rebuilding and development progressed slowly until early 1980s, when several of the main ports (i.e., Jakarta, Surabaya, Semarang and Medan) for international trade were modernized and inter-island transport services were improved. Other aspects such as telecommunications and roads/highways that support the activities of logistics businesses need further improvements. 2. *Political Instability and Natural Disaster* The country is affected by her political instability and natural disasters such as the tsunami. 3. *Monopoly power* The monopoly power of PT Pos Indonesia on delivering letters in envelopes should also be re-looked into since many businesses need documents, which are certainly not letters, to be delivered in a timely manner.
Ports Analysis	
Strengths **Seaports** Tanjung Priok Internet Website: http://www.priokport.co.id/	• Located in western Java 13 km from the city centre of Jarkarta, Tanjung Priok (also known as Jakarta's port) is the one of the two principal ports of Indonesia. • The port is constructed after the independence of the Indonesia Republic with the main purpose of ships' loading/unloading among the islands on recognition that the existing Sunda Kelapa Port was unable to be further developed to accommodate increasing trade ships brought about by the opening of Suez Canal. • The Tanjung Priok port is well protected by breakwaters, with facilities for all types of cargoes • Currently, about 45 percent of total freight handled by Tanjung Priok Port is containerized. • Tanjung Priok is the main port for the major manufacturing region around Jarkarta and west Java. It deals with both coastal and international trade
Tanjung Perak Internet Website: http://tgperak.pp3.co.id/	• The Port of Tanjung Perak (also known as the port of Surabaya City) is located on the northern coast of the island of Eastern Java, opposite Madura. • The port serves as one of the main gateway ports to Indonesia.

	It is also the principal port in East Java, functioning as a main cargo collection and distribution center for both the Province of East Java, and the whole eastern archipelago of Indonesia. • Since its construction in 1910, the Port of Tanjung Perak as a maritime transportation hub of Indonesia has contributed greatly to the economic development of the Eastern Indonesian region by promoting the growth of trade and development in East Java. • The Port of Tanjung Perak, equipped to accommodate tankers, general cargo vessels and container vessels, has undergone continual physical development with modification of existing berths, and provision of additional berths specifically designed for container handling operations. • The Port Authority, in its efforts to encourage development of the associated port industries and construction of the passenger terminal, continues to upgrade and improve both port facilities and services to meet demand.
Airport Jakarta Soekarno-Hatta International Airport (CGK) Internet Website: http://www.angkasapura2.co.id/cabang/cgk/	• Jakarta Soekarno-Hatta International Airport, whose architecture is said to well represent the best of Indonesia, is located 20 km northwest of central Jarkarta. • The airport is served by 36 airlines which offer passengers 36 non-stop destinations, of which 31 of them are major cities. • There are two terminals at The Soekarno-Hatta Airport. Terminal I serves the domestic flights. Terminal II serves international and domestic flights. The airport has the capacity to handle 74 aircrafts per hour and 9,000,000 passengers per year. • Efforts in improving the quality of service have paid off with the airport being one of the fastest growing airports in passenger volume.
Weakness	• The Indonesian seaports generally suffer from slow turnaround, which preclude them from attracting more users even though the charges are low.

Malaysia

Table A7- SWOT Analysis for Malaysia

Environmental Analysis	
Opportunities	1. *Government support* Along with the intention of the **Malaysia**n government to transform the nation into a logistics hub, special focus has been given to seaports and airports in the Ninth Malaysia Plan (9MP). 2. *Improved port competitiveness* Over the last decade, port productivity, efficiency and performances have improved as they strive to compete with other international ports in the stiff competition from regional port leaders like the Port of Singapore and other emerging hubs like Thailand's Laem Chabang and Indonesia's Tanjung Perak. Particularly, the ports have

	demonstrated success with China Shipping relocating its operations from Singapore to Port Klang and Danish liner Masek diverting the bulk of its transhipment from the port of Singapore to that of Tanjung Pelapse. *3. Conducive environment* Malaysia is politically stable with an expansive hinterland. English speaking workforce and good facilities and infrastructure are added advantages.
Threats	*1. Corruption* The corruption perception index of the country slipped from the 39th position in 2005 to 44th position in 2006. Comparing to her neighbor Singapore who is ranked 5th, corruption appears to be quite a problem in Malaysia. Corruption is undesirable as it stifles investment interests and hinders developments in its industries (including logistics industry)
Ports Analysis	
Strengths **Seaports** Port Klang Internet Website: www.pka.gov.my	• Situated on the west coast of Peninsular Malaysia, 40 km from the capital Kuala Lumpur，Port Klang's proximity to the greater Klang Valley (the commercial and industrial hub of the country as well as the country's most populous region) makes it a premier port in Malaysia. • Port Klang is the one of the most established ports in Malaysia. Started in 1963, the port is well sheltered by surrounding islands which form a natural enclosure. • The port has trade connections with over 120 countries and dealings with more than 500 ports around the world. It serves as the nation's load centre and regional transshipment centre (i.e.hub port). • Port efficiency is improved through modern infrastructure facilities, hi-tech state-of-the-art cargo handling equipment, computer information systems (including EDI), pre-clearance and advanced pre-clearance on Customs, Health and Immigration formalities.
Tanjung Pelepas Internet Website: www.ptp.com.my	• Located at the confluence of major shipping routes at the southern tip of Johor West in Malaysia, Tanjung Pelepas Port starts operations in October 1999 and aspires to be the region's premier transhipment hub. • Being only 45 minutes from the confluence of the world's busiest shipping lanes, the port has steadily attracted the worlds leading main shipping lines which include Maersk Sealand in 2000 and Evergreen Marine Corporation in 2002. • Factors that have contributed to rapid port growth are its excellent port facilities and infrastructure, supported by a state of the art integrated information technology systems and highly trained staff, which enabled high efficiency and productivity to be achieved. The 15 meters naturally sheltered deep water port also boosts of its excellent connectivity via road, rail, air or sea.

Airports Kuala Lumpur International Internet Website: http://www.klia.com.my/	• Situated 60 km south of the capital city of Malaysia, Kuala Lumpur airport is used by more than 40 airlines operating flights to more than 82 destinations around the world. • As one of the world's largest airport, Kuala Lumpur International Airport aspires to be one of the three international hub airports of Asia. • The airport boosts itself with the latest technology and state-of-the-art facilities to provide for maximum passengers' safety and comfort. Accordingly, the IATA Global Airport Monitor 2003 and 2004 has ranked Kuala Lumpur airport among the top five airports in the world in terms of overall passenger satisfaction.
Penang International (PEN) Internet Website: http://www.tourismpenang.gov.my/page.cfm?name=ap02b	• Penang International Airport is located 16 km from Georgetown in northern Malaysia. • The airport is served by 8 air carriers, which operate flights to 9 non-stop destinations such as Bangkok, Singapore and Taipei • It has the ability to handle 5,000,000 passengers annually. With Penang being a popular tourist spot, the airport is used by many tourists.
Weakness	• The seaports offer short working hours which may represent inconvenience to liner companies, in comparison to their nearby counterpart in Singapore which offers round-the-clock service. • While new berths are constructed and cranes are added, space expansion in the port Klang is still very limited. • The Penang airport's traffic, consisting of mainly tourists, is much affected by the conditions in the global economic environment.

Philippines

Table A8- SWOT Analysis for Philippines

Environmental Analysis	
Opportunities	1. *Government Support* The **Philippines** government has launched a Sustainable Logistics Development Program (SLDP) as a priority project aimed at realizing improvements and modernizations in infrastructure, particularly in transport, storage and handling of agricultural commodities. The proposed SLDP consists of three main components: (1) the Roll-On, Roll-Off Terminal System that will establish a nautical highway where a network of terminals and ferryboats facilitate efficient sea transport links; (2) the Food and Grains Highway that will incorporate bulk processing and handling centers, trucking, terminal facilities with grain silos as well as bulk carriers and bulk grain handling; and (3) the Cold Chain component that will provide for improved cold storage logistics for perishable items like fruits and vegetables. 2. *Cheap Loans* The Development Bank of the Philippines (DBP) is also offering development loans to local government units (LGUs) and other interested parties who wish to participate in the logistics development program.

	3. Airports Constructions New airports are being developed in Negros Occidental (Silay City), Iloilo (Sta. Barbara/Cabatuan), and Bohol (Panglao) while the existing Diosdado Macapagal International Airport in Pampanga and Busuanga Airport in Palawan are being upgraded to serve as gateways to tourism destinations. *4. Technological Progress* The Philippine CyberServices Corridor, an ICT belt stretching 600 miles from Baguio City to Zamboanga which is envisioned to provide a variety of cyber-services at par with global standards, is launched to upgrade the country's digital infrastructure. To fuel growth and enhance the access to information and communications technology, internet connectivity cost was sharply reduced.
Threats	*1. Agricultural-based economy* Philippines is largely an agricultural-based country and the government of Philippines has only started to focus attention on the country's logistics aspects recently. *2. Logistics cost* The logistics in Philippines is characterized by prevailing high transport, handling, storage and distribution costs and significant waste and spoilage of harvested produce leading to huge losses for farmers and high commodity prices for consumers. *3. Inadequacy* Lack of adequate infrastructure, inefficient use of production and processing technologies and poor marketing practices have also contributed to low agricultural productivity.
Ports Analysis	
Strengths	
Seaports Davao Internet Website: www.ppa.gov.ph	• The Davao port is situated on the southeastern coast of Mindanao Island. • The port is bounded in the east by the natural islands of Samal and Talikod along Pakiputan Strait of Davao Gulf. It is relatively protected by land masses on all sides except at the South.
Manila Internet Website: www.ppa.gov.ph	• Situated at the East end of Manila Bay, the Manila port is the most significant port in Philippines, handling over 90% of the nation's international cargoes. • The port of Manila has a shoreline of 2km and is protected by 3050m of rock barriers, enclosing approximately 600 hectares of anchorage.
Airport Ninoy Aquino International (MNL)	• Originally known as Manila airport, Ninoy Aquino International Airport is reconstructed on a site 10 to 15 km from Metro Manila's business centre, Makati in 1982. • There are 26 airlines serving the airport, making it the main international gateway to Philippines. It handles about 13,000,000 passengers a year, of which, 7 millions are international passengers.
Weakness	• Road traffic congestion, work stoppages and a draught of only 6.5 m in the harbour of Manila port represent some of the main problems to shippers.

Singapore

Table A9- SWOT Analysis for Singapore

Environmental Analysis	
Opportunities	1. *Geographical advantage* **Singapore**, being located at the crossing of major trade routes, gives her an incentive to develop her logistics sector to further enhance trade and port performances 2. *International Relations* The country maintains liberal open sky policies, seeks cooperation opportunities with regional and international partners and encourages local and foreign investments. 3. *Supporting Facilities (software and hardware)* Singapore engages in continual improvements to related areas such as road networks, warehousing, and training programs for logistics professionals of all levels.
Threats	1. *Rising cost* Increasing labor cost and land cost as the economy progresses is eroding the nation's cost competitiveness if productivity increase fails to keep pace.
Ports Analysis Recognising that ports constitute one of the major pillars of a successful logistics hub, substantial efforts have been channelled to develop her seaport and airport.	
Strengths **Seaport** Port of S'pore Internet Website: www.mpa.gov.sg	• Located at the crossroads of international trading in sea routes in the Asia-Pacific, the naturally deep harbour port of Singapore is strategically positioned to participate in as a transhipment hub for South East Asia and contribute to its growth process. • Singapore is also an active feeder shipping spot in Asia, with a network service ranging from short to long routes. • Other than being highly efficient, the port offer full range of service, including fuel, pilotage and towage, cargo, vessel repairs, warehousing, banking, insurance, communications, entertainment, training and education in port operation and management, logistics and distribution management and other transport studies.
Airport Changi International (SIN) Internet Website: http://www.changiairport.com.sg	• Located 20 km from the city centre, Changi International Airport is served by more than 70 carriers offering 170 non-stop destinations all over the world. • The airport is one of the 10 busiest international airports in the world and is best known for its high standard of service, safety, efficiency and comfort for all travelers. • With 3 terminals serving full service carriers and a terminal for budget carriers and their passengers, Changi airport is well regarded as a major air hub in the Asia Pacific Region. • The airport is also recognized as a premier cargo airport, inline with the visions of the Singapore government to develop the country into a logistics hub.

Weakness	• Cost is relatively high compared to other neighbouring low-cost countries • The Port of Singapore is said to be somewhere 30% more costly than Malaysian ports. For reasons partially due to cost, one of the port's major Danish customer Marsek has moved its operations to Port of Tanjung Pelapse, Malaysia.

Thailand

Table A10- SWOT Analysis for Thailand

Environmental Analysis	
Opportunities	1. *Logistics Facilities & Technology Infrastructure Upgrades* A number of projects are underway, including the construction of a new Suvarnabhumi international airport, the expansion of **Thailand**'s premier deep-sea port, improvements in multi-modal linkages, the proliferation of e-logistics and a move toward paperless customs procedures using radio frequency identification (RFID) electronic container and seal system. These logistics advances aim at increasing Thailand's freight handling capacity and assure faster, more efficient cargo movement so as to boost the competitiveness of manufacturing-based operations that utilize imported materials to produce goods both for domestic and export markets. 2. *Setting Up of Logistics-Related Organizations* For examples, i. Federation of Thai Industries (FTI) addresses issues relating to supply chain management and ii. Thai Logistics and Production Society (TLAPS) educates and supports professionals in Thailand who work in fields related to logistics and production.
Threats	*1. Inferior physical and human infrastructure* Compared to other countries in the Asia Pacific region, Thailand is relatively backward in terms of infrastructure and labor skills. *2. Underdevelopment of the logistics industry* Attention to the development of its logistics industry is also quite recent. 3. Supporting roads The severe traffic congestion problem in Bangkok adversely affects port – related services such as banking and insurances.
Ports Analysis	
Strengths **Seaports** Bangkok Internet Website: http://www.bkp.port.co.th/bkp/home.asp	• Bangkok Port (also known as Krung Thep and Klong Toey) is located on the left side of the Chao Phraya River between +26.5 and +28.5 km from Klongtoey District, Bangkok. • It is well connected with road and rail systems, which enable fast and economical transport of cargoes between the port and its hinterland. • The Port has a capacity of approximately 1.3 million TEU. Its bonded warehouse offers several value-added services such as

	online inventory account reporting, more equipment for lifting and moving goods, and expansion of storage areas.
Laem Chabang Internet Website: www.ich.pat.or.th	• Laem Chabang port is located on eastern Thailand in the Sriracha district, about 130km south of Bangkok and Thailand's industrial heartland. • The deep water harbours of the Laem Chabang port is opened in 1999 with TEU capacity of 3.04 million to compensate for the water depth restriction at port of Klong Toey. • Improvement to transport links has increased the accessibility of the port and the port has witnessed steadily rising traffic volume since its opening. • The port provides a comprehensive range of services to exporters and importers, operating 24 hours a day, 7 days a week.
Airports	
Bangkok International (BKK) Internet Website: http://www.airportthai.co.th/	• Located in the capital city of Thailand 24 km from the city centre, Bangkok International Airport is the biggest and 24 hour curfew-free airport in the country. • The airport is served by 80 airlines. It has two international terminals and one domestic terminal, with sufficient capacity to handle 36,500,000 passengers and 1,273,000 tons of cargo annually. • Suvarnabhumi Airport starts operation in 2006 to aid further traffic increases. The Suvarnabhumi Airport's proximity to Bangkok as well as its multi-modal sea, rail and road transport linkages for efficient cargo movement is expected to help to control logistics costs.
Chiang Mai International (CNX) Internet Website: http://www.airportthai.co.th/	• Chiang Mai International Airport is situated in the centre of the upper Northern part of Thailand where there is large number of commercial transactions. • Chiang Mai International Airport can handle 24 flights per hour, and accommodate an annual traffic of 4,246,000 passengers and 30,000 tons of air cargo. • The airport has 9 airlines that offer 16 non-stop destinations in Asia. Owing to its comparatively high number of passengers and existing networks to international destinations such as Singapore and Taipei, the airport is a gateway to its neighbouring countries and Mae Khong River Basin. In addition, this airport is a major gateway to the scenic beauty and rich culture of northern Thailand, helping to promote travel and tourism throughout the northern region.
Hat Yai International (HDY) Internet Website: http://www.airportthai.co.th/	• Hat Yai International Airport is located in the Songkhla province. • The airport can handle around 30 flights per hour and accommodate an annual traffic of 1,900,000 passengers and 16,000 tons of air cargo. • There are 3 airlines operating in the airport, offering 3 direct routes to Bangkok, Phuket and Singapore. • Being in the Business zone, this airport is the gateway to the Southern Thailand for business and leisure, in addition to the

Phuket International (HKT) Internet Website: http://www.airportthai.co.th/	Muslims on their pilgrimage to Mecca each year. • Phuket International Airport, as the second busiest and 24-hour curfew free airport in Thailand, can handle around 10 flights per hour and accommodate an annual traffic of 5,100,000 passengers and 24,000 tons of air cargo. • Alike Hat Yai International airport, Phuket airport also serves as another gateway to the Southern Thailand especially Phuket island for leisure travel. • Human traffic in the airport is fast recovering after a drastic hit by the tsunami in 2003.
Weakness	• The Bangkok port cannot accommodate big vessels due to the draught of the Chao Phraya River. • Both Chiang Mai International and Hat Yai International are not 24-hour airports. Chiang Mai operates daily from 0600 to 2330. Hat Yai International operates between 0600 and 2400 daily

South Korea

Table A11- SWOT Analysis for Korea

Environmental Analysis	
Opportunities	1. *Geographical Location* **Korea** is ideally located at the center of the world's trunk routes (including the North American route, the Southeast Asian route and the European route), giving Korean ports very favorable conditions in handling transshipment cargo originating from China, Russia and Northwestern Japan. 2. *Government Support* With the motivation of developing Korea into a logistics hub for Northeast, the Korean government plans to improve the national logistics system through a series of huge investment in railways and ports as well as tax incentives. For examples, (i) Existing railway lines will be gradually converted into freight lines, and more artery railways linking major ports and industrial areas in the western, southern and eastern regions will be built. Particularly, a 199 km double electric railway is constructed on Cholla Line between Iksan and Yosu and the two major ports in Korea, Pusan and Gwangyang will be linked via railways by 2008. Bullet trains will run through major cities in Cholla and Kyongsang provinces, catering to more than three million residents by 2011. (ii) Pusan and Gwangyang ports will be transformed into super-size container ports to serve the Pacific Rim. Other developments include the setting up of distriparks at these ports, which are now attractive sites for investment. (iii) The new Incheon airport is constructed and continually expanded to alleviate the capacity constraint of Seoul Gimpo. 3. *Tax Incentives* To narrow the gap in logistics outsourcing ratios between Korea and advanced countries and to reduce business logistics and annual inventory-related costs, various tax incentives are given to logistics

	businesses and those who outsource more than 70% of their logistics. Foreign workers in the logistics industry are also exempted from income taxes, and expand tax credit for the overtime payment of field workers in logistics industry.
Threats	1. *Inadequate Seaport Facilities* Present port facilities are capable of handling only 84% of the expected total cargo traffic volume, and container handling facilities are only 80% sufficient. There is a need to further expand these port facilities if the trend for potential growth continues. 2. *Cost Disadvantage* While South Korea may have a cost advantage over Japan which helps her to attract transhipment cargo from N.E. Asia to the rest of the world, this cost advantage is gradually being eroded by China ports (especially Shanghai) which are experience tremendous improvement in their service offering and offer even lower cost. 3. *Supporting roads* Roads are highly congested in Korea and long traffic jams are a frequent sight. 4. *Workforce* The majority of the workforce does not speak English.
Ports Analysis	
Strengths **Seaports** Pusan Internet Website: www.pba.or.kr	• Located close to Japan on the Korea's south eastern coast, Pusan is a natural deep water harbour. • The Pusan port is by far the most important container port in South Korea, accounting for more than 90% of the nation's container throughput. The port ranked third in the world after Hong Kong and Singapore. • Transhipment cargo accounts for some 20% of container throughput and is expected to increase. • Pusan is an attractive relay centre for minor Japanese ports on the sea of Japan because it undercuts transport via major Japanese ports (by a reported 30-40% in the late 1990s). Thus, an increasing number of shippers have been sending their cargos through Pusan for transhipment to/ from regional Japanese ports.
Incheon Internet Website: www.portincheon.go.kr	• Located on the mid-western coast of the Korean Peninsula near the capital city Seoul, the Port of Incheon has contributed greatly to the development of the economy and industries as a gateway to Seoul. • As an artificial port with the world's largest and most advanced lock gate (wet dock) facilities that overcome a tidal difference of 10 meters and permit vessels up to 50,000DWT to berth directly in the inner closed harbor basin, the port is also equipped with various modernized harbor facilities for trade promotion with the main ports of the world.
Gwangyang Internet Website:	• Port of Gwangyang, situated on the south coast of South Korea

www.yosu.momaf.go.kr	above the Gwangyang Ha River of Yosu, is the fastest expanding port in Korea. • The port is connected to land through four eastern and western container driveways. The port is also connected directly to a 2.5 km railroad with an annual conveyance capacity of more than 240 thousand TEU. • Near the port, Yeosu Airport is current under expansion. Together railroad, highway and other private airports, a systematical network that enables fast commuting in every direction is formed. • The port is scheduled to be developed into a 33-berth super-scale container port by 2011.
Airports Seoul Gimpo (SEL) Internet Website: http://gimpo.airport.co.kr/	• Gimpo airport is located in the west of Seoul, the capital of the Republic of Korea. • Since its full-scale upgrade into an international airport in 1971, Gimpo International Airport has been the gateway to Seoul. • After the commencement of operations of Incheon Airport in 2001, Seoul Gimpo International Airport became a delicate domestic airport and traffic in the airport declines. • Nonetheless, multiplex theatre theme park, golf driving range developments projects which seek to transform the airport to an integrated city offering air transportation, shopping and entertainment facilities are underway.
Incheon International (ICN) http://www.airport.or.kr/eng/airport/	• Incheon International Airport, located 52km west of Seoul and 15 km west of Incheon, is constructed in 2001 with the primary aim of alleviating the pressure of rising number of passengers and air cargo volumes on Seoul Gimpo since the late 1980s. • The 24 hour curfew free Incheon Airport is served by 70 international airlines. The airport is deliberately constructed with largo capacities for handling more than 240,000 flights and accommodating 30,000,000 million passengers and 2.7 million tons of cargo annually. Current expansion is expected to increase the annual capacity of the airport to 100,000,000 passengers, 7,000,000 tons of air cargo and 530,000 flight movements in the next 20 years. • This airport is endowed with state-of-the-art facilities and constitutes a major part of the ambitious South Korea's government plan to develop the country into regional logistics hub.
Weakness	• The main port of Korea, Pusan, has been consistently losing out to her competitors Shanghai and Shenzhen in terms of TEUs volume since 2003. Not only can these nearby China ports present lower cost due to cheaper labor, the geographical location is such that for a voyage originating from Singapore heading towards that Yokohama, Hong Kong and Shanghai present lower marginal stopover cost as compared to Pusan. • Topographic of location is another concern. It has been observed that the coastline of Incheon port becomes a mud bank at low tide and vessels need to exercise due caution when approaching the port.

Japan

Table A12- SWOT Analysis for Japan

Environmental Analysis	
Opportunities	• **Japan** is an advanced and efficient country with excellent inter-modal links and high technological facilities. Her workforce is well educated and diligent.
Threats	1. *High cost* Japan is characterised as the country having highest cost in the entire Asian region. 2. *Absence of a Strong Port* Without a preferred port, it becomes hard for the logistics sector of the country to take off. 3. *Lack of Government Support* In comparison to other countries in the Asia Pacific region, the Japan government has placed relatively less emphasis in the country's logistics development owing to their competency in generating wealth from other areas especially advanced electronics.
Ports Analysis The four main seaports are Ports of Kobe, Osaka, Tokyo and Yokohama and the two main international airports are Narita and Osaka. Interestingly, while the seaports are experiencing excessive facilities, the airports are facing congestion problems.	
Strengths **Seaports** Kobe Internet Website: http://www.city.kobe.jp/cityoffice/39/port/index_e.htm	• The Port of Kobe is located in the central part of the Japanese Archipelago, with a hinterland that covers the whole of western Japan. It also lies on the main routes of world marine-transportation networks. • Favorable natural conditions include no seasonal winds and rivers flow into the Port which makes dredging unnecessary. • Kobe port is accessible from various directions as it stretches from east to west and ideal for mooring since it has little variation in tides. • The Port also has many regular service lines, including North American, European, Southeast Asian, and Chinese lines that linked the Port with 500 ports in 130 countries. • The Port's transportation efficiency is secured by expressway networks, domestic feeder services, and ferry services. • Kobe improves various services for user convenience and friendliness by reducing port facility charges, simplifying various port procedures, computerizing operations using EDI (electronic data interchange) system for submitting various application. Domestic container feeders are also permitted to use overseas berths. • The Port of Kobe is the principal foreign trade port of Japan.

Osaka Internet Websites: www.optc.or.jp and www.oppa.or.jp	• The port of Osaka is located in the western part of the city of Osaka. • The port is directly connected to the main area of the country through an advanced network of expressways and other main roads as well as a feeder network. • It is also directly linked up with Kansai International airport. • The port is constantly improving its services in an attempt to make the port more user-friendly.
Tokyo Internet Website: www.kouwan.metro.tokyo.jp	• The Port of Tokyo is located on the west coast of Honshu in area between the estuaries of the Arakawa and Tamagawa Rivers. • The port takes on the responsibility of distributing essential commodities such as sundry goods, foodstuffs, paper products, building materials and so forth throughout the Tokyo Metropolitan area (Shinetsu and southern Tohoku) for its industrial activities and 40 million citizens. • The port has taken early actions to enhance the accessibility and functionality of its terminals for container, ferry and specialized cargo use. Warehouses and distribution centers, which complement terminal functions, have been set up in the reclamation areas behind each terminal and arterial routes and other roadways are developed to facilitate distribution activities. The port also is connected to the JR rail network.
Yokohama Internet Website: http://www.city.yokohama.jp/me/port/ en/index.html	• The Port of Yokohama is located on the northwestern edge of Tokyo Bay, 30 km from Tokyo. • It is a naturally blessed port with a spacious water area on the eastern side and undulated hills on the northern, western and southern sides. It also has an ample water depth. • In addition to its natural assets, the port operates 24 hours daily and has been equipped with various facilities such as inner and outer breakwaters to protect the port from the effects of winds and tides. • The Japanese government aspires to develop the Port of Yokohama into a major container hub port, with separate facilities for intercontinental and Asian container traffic.
Airports Kansai International (KIX) Internet Website: http://www.kiac.co.jp/english/default.htm	• Located 50 km from the city centre of the second biggest province Osaka in Japan, Kansai is an offshore airport designed to preserve the natural environment. • Kansai is served by 42 airlines which offer direct routes to 63 destinations. • Unlike many airports in Japan, Kansai is a 24 hour airport. • Capacity shortages are a recognised problem in Kansai and expansions to the airport in the form of an additional runway are on the way.

Narita International (NRT) Internet Website: http://www.narita-airport.jp/en/access/haneda/index.html	• Located 66km away from the capital city of Japan, Tokyo Narita airport is the biggest and busiest airport in Japan with 61 airlines offering 80 non-stop destinations throughout the world. • Being 2 driving hours away from the city centre, a railway which is under construction is expected to link the airport with central Tokyo in less than 40 minutes. • A second runway is opened in 2002 to ease the runway congestion, increasing the annual number of slots from 135,000 to 200,000. The airport also seeks to increase efficiency through an allocation of the 49 operating air carriers in the two terminals, rather than a physical land expansion. • The capacity in Narita airport is well utilized. Coupled with the high efficiency, cost at the airport is maintained at acceptable levels.
Weakness	• All the above seaports are not 24-hour ports • Congestions are a main problem in both airports • By international standards, Narita airport is far away from the city and hence time and monetary cost of getting to and fro the airport are high. • Operating costs are high • Natural disasters especially earthquakes have known to disrupt the operations of the seaports and airports

APPENDIX B

REVIEW of METHODOLOGIES EMPLOYED in PAST STUDIES

B.1 Port Traffic Forecasting

B.1.1 Log-linear (translog) Regression Models

Using $Y_i\ (t)$ and $X_i\ (t)$ to denote port i's output and the corresponding inputs at time t, Tongzon (1995)[1] and Cullinane and Song (2006)[2] formulated log-linear regression model by expressing a seaport's cargo traffic function as:

$$Y_i(t) = e^{b_0} X_{i,1}(t)^{\alpha_1} X_{i,2}(t)^{\alpha_2} \ldots X_{i,n}(t)^{\alpha_n} \quad 0 < \alpha_i < 1 \ \forall i = 1,2,\ldots,n$$

A linearised model can be obtained by taking natural logarithms, which yields

$$\ln Y_i(t) = b_0 + \alpha_1 \ln X_{i,1}(t) + \alpha_2 \ln X_{i,2}(t) + \ldots + \alpha_n \ln X_{i,n}(t)$$

Similar log-linear model has been developed in the airport industry to measure the economic contributions of airports by Benell and Prentice (1993)[3].

B.1.2 Fuzzy Regression Models

Profillidis (2000)[4] used fuzzy regression analysis to estimate traffic for an airport. The model is given as:

[1] Tongzon, J.L. (1995). Determinants of port performance and efficiency. Transportation Research Part A 29, 245 – 252.

[2] Cullinane, K. and Song, D. (2006). Estimating the relative efficiency of European container ports. In Research in Transportation Economics - Port Economics edited by Cullinane and Talley, Elsevier

[3] Benell, D.W. and Prentice, B.E. (1993). A regression model for predicting the economic impacts of Canadian airports. Logistics and Transportation Review 29 (2), 139 – 158

$$Y_i = (r_0 + r_1 D_i + r_2 X_i) \pm (c_0 + c_1 D_i + c_2 X_i)$$

where Y_i is the traffic, D is the exchange rate of currency of country in which airport i operates compared to the currencies of origin countries of traffic, X_i is the dummy variable for years

B.1.3 Vector Error Correction Model (VECM)

Fung (2001)[5] made use of '**Structural Vector Error Correction Model'** to forecast traffic volume in a seaport (Hong Kong) in view of the competition from its closest competitor (Singapore). Yap and Lam (2006)[6] employed a similar model on a selected set of seaports in East Asia. The reduced formed for the VECM takes the following specification:

For $Y_t = (y_{1t,} y_{2t}, ..., y_{kt})'$ as the set of variables of interest and each of the elements in Y_t has a unit root (i.e $I(1)$), There are exactly h cointegration relations if there exists an $h \times k$ matrix $A = (a_{1,} a_2, ..., a_h)'$ such that $A'Y \sim I(1)$

And there is no matrix C that is linearly independent of A such that $C'Y_t \sim I(1)$, (i.e., $C'Y_t$ is stationary). That is, A forms the basis for the space of co-integration vectors. Suppose that Y_t follows a vector of autoregressive process of order p. i.e $Y_t \sim Var(p)$. and there are exactly h cointegration relations. The VAR model can be written as

$$Y_t = \alpha + \Phi_1 y_{t-1} + \Phi_2 Y_{t-2} + ... + \Phi_p Y_{t-p} + \xi X_t + \varepsilon_t \qquad \varepsilon_t \sim i.i.d(0, \Omega_\varepsilon)$$

where X_t is a matrix of stationary exogenous variables.

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[4] Profillidis, V.A. (2000). Econometric and fuzzy models for the forecast of demand in the airports of Rhodes. Journal of Air Transport Management 6, 95 – 100

[5] Fung, K.F. (2001). Competition between the ports of Hong Kong and Singapore: A structural vector error correction model to forecast the demand for container handling service. Maritime Policy and Management 28 (1), 3 – 22

[6] Yap, W.Y and Lam, J.S.L. (2006). Competition dynamics between container ports in East Asia. Transportation Research part A 40, 35 – 41

For $\rho = \sum_{i=1}^{P} \Phi_i$ and $\xi_i = -\sum_{j=i+1}^{P} \Phi_j$, the above can be rewritten as

$$Y_t = \alpha + \rho_1 y_{t-1} + \xi_1 Y_{t-1} + \xi_2 Y_{t-2} + ... + \xi_{p-1} Y_{t-p+1} + \xi X_t + \varepsilon_t$$

Subtracting Y_{t-1} from both sides, the error correction representation is

$$\Delta Y_t = \alpha + \xi_0 y_{t-1} + \xi_1 Y_{t-1} + \xi_2 Y_{t-2} + ... + \xi_{p-1} Y_{t-p+1} + \xi X_t + \varepsilon_t$$

where $\xi_0 = \rho - I = -\Phi(1) = -BA'$, A is the co-integration matrix and B is any $n \times h$ constant. The term, $\alpha + \xi_0 y_{t-1}$, on the right hand side is the 'error correction term'.

The Johansen's procedure is then adopted as a test for cointegration. This procedure involves auxiliary regressions of

$$\Delta Y_t = \pi_0 + \pi_1 \Delta y_{t-1} + \pi_2 \Delta Y_{t-2} + ... + \pi_{p-1} \Delta Y_{t-p+1} + \alpha X_t + u_t$$

$$Y_{t-1} = \Theta_0 + \Theta_1 \Delta y_{t-1} + \Theta_2 \Delta Y_{t-2} + ... + \Theta_{p-1} \Delta Y_{t-p+1} + \alpha X_t + v_t$$

The corresponding sample variance-covariance matrices for the residual are:

$$\sum_{vv} = \frac{1}{T} \hat{v}.\hat{v}' \qquad \sum_{uu} = \frac{1}{T} \hat{u}..\hat{u}' \qquad sum_{uv} = \frac{1}{T} \hat{u}.\hat{v}' \qquad \sum_{vu} = \sum_{uv}'$$

where

$$\hat{v} = \begin{bmatrix} \hat{v}_{11} & . & . & . & \hat{v}_{1t} \\ . & . & & & . \\ . & & . & & . \\ . & & & . & . \\ \hat{v}_{k1} & . & . & . & \hat{v}_{kt} \end{bmatrix} \quad \text{and} \quad \hat{u} = \begin{bmatrix} \hat{u}_{11} & . & . & . & \hat{u}_{1t} \\ . & . & & & . \\ . & & . & & . \\ . & & & . & . \\ \hat{u}_{k1} & . & . & . & \hat{u}_{kt} \end{bmatrix}$$

The max-lamda test statistics and trace test statistics are two types of likelihood ratio test statistics that can be derived from the procedure. Specifically, the max-lamda test statistics is $2(L_A^* - L_o^*) = -T \sum_{h+1}^{k} \log(1-\lambda)$ and the trace test statistics is $2(L_A^* - L_o^*) = -T \log(1 - \lambda_{h+1})$

B.2 Inter-Port Relationship

B.2.1 Marginal Rate of Substitution (MRS)

Using microeconomics fundamentals, Yap and Lam (2004) [7] considered the relationship between 2 ports in the form of **'cross price elasticity'**. For a port user facing a choice of consuming services offered by port i and port j, the port user chooses a level of consumption in the two ports to be denoted by TEU_i and TEU_j for port i and j respectively. Supposed that the port user has allocated a budget of 'B' dollars to be spent on such services and the respective generalized cost of using the services of port i and j can be expressed as C_i and C_j. The budget constraint is assumed to take the linear form of $B = C_i TEU_i + C_i TEU_j$

The port user's level of utility is represented by the function: $U = f(TEU_i, TEU_j)$. Assuming that preferences are complete, reflexive and transitive, the marginal rate of substitution is represented by:

$$MRS_{ij} = -\frac{\partial TEU_j}{\partial TEU_i}\bigg|_{U=constant}$$

Hence, the port user aims to minimize expenditure: $B = C_i TEU_i + C_i TEU_j$ such that: $U \geq f(TEU_i, TEU_j)$ The expenditure minimization condition is given by:

$$-\frac{C_i}{C_j} = -\frac{\partial TEU_j}{\partial TEU_i}\bigg|_{U=constant}$$

and the condition of diminishing marginal rate of substitution will provide the necessary and sufficient condition for expenditure minimization.

For the case of n ports, the port user's objective is thus to minimize: $B = \sum_{i=1}^{n} C_i TEU_i$

[7] Yap, W.Y and Lam, J.S.L. (2004) An interpretation of inter-container port relationships from the demand perspective. Maritime Policy and Management 31(4), 337 – 355.

such that $U \geq f(TEU_i)$ where *i =1, . . . , n*. The expenditure minimizing solution can be obtained by solving for the Lagrangian expression:

$$L = \sum_{i=1}^{n} C_i TEU_i + \lambda [U - f(TEU_i)], \qquad \text{where } i = 1, \ldots, n$$

However, the port user can also choose to maximize utility for a given level of expenditure and the objective will be to maximize: $U = f(TEU_i)$ such that: $B \leq \sum_{i=1}^{n} C_i TEU_i$ and the utility maximizing solution can be obtained by solving for the Lagrangian expression:

$$L = f(TEU_i) + \lambda \left[B - \sum_{i=1}^{n} C_i TEU_i \right], \qquad \text{where } i = 1, \ldots, n$$

Returning to the two-port scenario, container throughput handled by ports i and j are complementary in demand when an increase in the generalized cost of handling one TEU in one port lowers the amount of containers handled at the other port. In mathematical terms, the notion can be expressed as

$$\frac{\partial TEU_i}{\partial C_j} < 0 \qquad \text{and/ or} \qquad \frac{\partial TEU_j}{\partial C_i} < 0$$

Conversely, two ports are considered to be substitutes, i.e. in competition with one another, if an increase in the generalized cost of handling one TEU in one port results in higher throughput handled in the other port. That is,

$$\frac{\partial TEU_i}{\partial C_j} > 0 \qquad \text{and/ or} \qquad \frac{\partial TEU_j}{\partial C_i} > 0$$

However, it is important to note that the relationship need not be symmetric as it is possible for containers handled at port *i* to be a substitute for those handled at port *j* while, at the same time, for containers handled at port *j* to be a complement to those handled at port *i*.

The overall change in demand can be decomposed into income and substitution effects where substitution effect is measured by the change in the relative price ratio of handling one TEU at the two ports while income effect is measured by the change in demand attributed to the change in purchasing power. It is also assumed that port services are normal (i.e. non-inferior) goods.

B.2.2 Gravitational Models

Verleger Jr (1972)[8] and Matsumoto (2007)[9] employed the '**Gravity Model**' to analyze traffic flows between two airports. In his model, the traffic flow between port i and port j takes the following form

$$T_{ij} = \frac{A\left(G_i G_j\right)\left(P_i P_j\right)e^{sD_1} e^{\varepsilon D_2} e^{\varsigma D_3} \ldots e^{\phi D_{17}} e^{\chi D_{18}} e^{\psi D_{19}}}{(R_{ij})^{\gamma}}$$

where T_{ij} is the net volume of international air passengers over ten thousand or net volume of international air cargoes over one hundred tons between $city_i$ and $city_j$, G_i is the Real GDP per capita of the country in which $city_i$ is located, expressed in US dollars at the base year exchange rate and prices, G_j is the real GDP per capita of the country in which $city_j$ is located, expressed in US dollars at the base year exchange rate and prices, P_i is the population (in thousands) of $city_i$, P_j is the population (in thousands) of $city_j$, R_{ij} is the distance between $city_i$ and $city_j$ in kilometers, D is the city-dummy variables, and A is the constant.

After transforming the proposed model into log form as follows,

[8] Verleger Jr, P.K (1972). Models of the demand for air travel. The Bell Journal of Economics and Management Science 3 (2), 437 – 457

[9] Matsumoto, H. (2007). International air network structures and air traffic density of world cities. Transportation Research Part E 43, 269 – 282

$$\ln T_{ij} = \ln A + \alpha \ln(GG) + \beta \ln(PP) + sD_1 + \varepsilon D_2 + \varsigma D_3 ... \phi D_{17} + \chi D_{18} + \psi D_{19} - \gamma \ln R_{ij}$$

ordinary least-squares (OLS) regression analysis was used.

B.3 Port Choice

B.3.1. Analytical Hierarchy Process (AHP)

AHP is a popular and common tool used in the study of seaports and airport choice. Among many, Lirn et al (2004)[10] and Song and Yeo (2004)[11] adopt the AHP to examine how shippers and liner companies choose their ports.

The AHP is introduced by T.L Saaty in 1980. This model assumes a value function given as $v(y) = \sum_{i=1}^{q} w_i y_i$. For all $w_i > 0$, define the weight ratio as $w_{ij} = \frac{w_i}{w_j}$. For any i, j, k indexes, $w_{ij} = w_{ji}^{-1}$ and $w_{ij} = w_{ik} w_{kj}$. Define the matrix of weight ratios as

$$W = \begin{bmatrix} \frac{w_1}{w_1} & . & . & . & \frac{w_1}{w_q} \\ . & . & & & . \\ . & & . & & . \\ . & & & . & . \\ \frac{w_q}{w_1} & . & . & . & \frac{w_q}{w_q} \end{bmatrix}$$

The above matrix W is consistent if its components satisfy the equalities $w_{ij} = w_{ji}^{-1}$ and $w_{ij} = w_{ik} w_{kj}$ for any i, j and k. Since each row of W is a multiple of the first row, the rank of W is 1 and there is only one nonzero eigenvalue q. This is attributed to the

[10] Lirn, T.C., Thanopoulou H.A, Beynon, M.J, and Beresford, A.K.C (2004) An application of AHP on transshipment port selection: A global perspective. Maritime Economics and Logistics 6, 70 – 91

[11] Song, D.W and Yeo, K.T (2004) A competitive analysis of Chinese container ports using the Analytical Hierarchy Process, Maritime Economics and Logistics 6, 34 – 52

fact that $w_{ii} = 1$ and the sum of all eigenvalues is equal to the trace of W (i.e. $\sum_{i=1}^{q} w_{ii} = q$)

The weight ratio w_{ij} is elicited by a_{ij} such that for $a_{ij} = a_{ji}^{-1}$, a_{ij} values are assigned in accordance to Saaty's scale of relative importance as below

Intensity of Relative Importance	Definition
1	Equal importance
3	Weak importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values between

Letting matrix $A = \lfloor a_{ij} \rfloor_{q \times q}$, $\lambda_{\max}$ is found by solving $\det[A - \lambda I = 0]$. $\vec{w}$ is then the normalized eigenvector corresponding to $\lambda_{\max}$ of A. Hence $\vec{w}_i > 0$ for all $1 \le i \le q$

B.3.2 Discrete Choice Analysis

Tiwari et al. (2003)[12], Nir et al. (2003)[13], Veldman and Buckmann (2003)[14] and Malchow and Kanafani (2004)[15] examined how shippers and liner companies select their seaports to use by means of '**Discrete Choice Analysis**'. Ohashi et al (2005)[16] applied this analysis to airports. For a specified utility function, the simplest and most

[12] Tiwari, P., Itoh, H. and Doi, M. (2003). Shipper's port and carrier selection behavior in China: a discrete choice. Maritime Economics and Logistics 5 (1), 23 – 29

[13] Nir, A.S, Lin, K. and Liang, G.S. (2003). Port choice behavior: from the perspective of the shipper. Maritime Policy and Management 30 (2), 165 – 173

[14] Veldman, S. and Buckmann, E. (2003). A model on container port competition: an application for the West European container hub-ports. Maritime Economics and Logistics 5 (1), 3 – 11

[15] Malchow, M.B. and Kanafani, A. (2004). A disaggregate analysis of port selection. Transportation Research Part E 40, 317 – 337

[16] Ohashi, H. Kim, T.S, and Oum, T. H. and Yu, C. (2005). Choice of air cargo transshipment airport: an application to air cargo traffic to/ from Northeast Asia. Journal of Air Transport Management 11, 149 – 159

convenient functional form for a discrete choice probability of alternative i is the standard MNL form (McFadden 1981), which is expressed as

$$P(i/N, Z, \beta) = \frac{\exp(Z_i \beta)}{\sum_{N=1,\dots,n} \exp(Z_N \beta)}$$

where

$N = \{1,..., n\}$ denotes the set of n discrete port-shipping line choices,

Z_i = a vector of K attributes specific to choice i, and

β = a vector of corresponding cost parameters.

However, this simple MNL model is constrained by the Independence of Irrelevant Alternatives (IIA), which implies that the cross-elasticities of the probability shares must be equal.

Following McFadden, Tiwari et al. (2003) formulates the nested multinomial logit (NMNL) model, which is generalized by McFadden (1981), consisting shipping lines and ports at different levels of hierarchy. The choice within a cluster and the choices among the clusters within each nest are described by a conditional logit choice probability and conform to the IIA assumption. Mathematically, the probability of choosing alternative ij in the NMNL model is

$$P(ij) = P(i) * P(j/i)$$

where i = number of subsets and each subset has some or all of j = shipping lines-port combinations (some or all of the total of 10), $P(i)$ = the marginal choice probability of subset i, and $P(j|i)$ = the conditional probability of choosing alternative j from the alternatives included in subset i.

The conditional probabilities of choosing alternative j in subset i have the form of MNL choice probabilities

$$P(j/i) = \frac{\exp\{I(i) * s(i)\}}{\sum_{j^i=1,\dots,i} \exp\{I(j^i) * s(j^i)\}}$$

The marginal choice probability is represented as

$$P(i) = \frac{\exp(Z\beta / s(i))}{\exp(I(i))}$$

where the "inclusive values" $I(i)$ is defined by

$$I(i) = \log \sum_{j=1}^{k-1} \exp(-Z\beta) / s(i)$$

are weighted by "similarity coefficients" $s(i)$. These similarity coefficients refer to their respective subsets and characterize the degree of substitutability among the alternatives in the subset. Values of similarity coefficients between zero and one are a measure of the importance of similarities and dissimilarities among choices. If, however, these values are equal to one, the trees reduce to simple MNL.

Malchow and Kanafani (2004) used an alternative form of the discrete choice model which is generally known as the Chamberlain model. The Chamberlain's method, rather than maximizing the probability that the carrier selects the chosen port for each shipment, maximizes the probability that the carrier selects the observed distribution from the set of feasible distributions. The log-likelihood for all observations is then

$$L = \sum \ln\left[\exp\left(\beta' \sum_{n,j} x_{inj} w_{inj}\right) / \sum_{d \in D} \exp\left(\beta' \sum_{n,j} x_{inj} d_{inj}\right)\right]$$

where

x_{inj} is the vector of attributes that influence the choice by carrier i of port j for a particular shipment n

$w_{inj} = 1$:if carrier i actually sends shipment n through port j, and 0 otherwise,

$s_{ij} = 1$ if the number of shipments moved by carrier i through port j ($\sum_n w_{inj}$)

$d_{inj} = 1$ for each feasible distribution, and 0 for all others.

D represents all feasible distributions of the shipments.

B.4 Port Efficiency

B.4.1 Data Envelopment Analysis (DEA)

By far, DEA is one of the most extensively used methods for measurement of technical efficiency. Roll and Hayuth (1993)[17] , Cullinane and Wang (2006)[18], Park and De (2004)[19] are some of these papers in the seaport literature, while Gillan and Lall (1997)[20], Martin and Roman (2001)[21], Vasigh and Hamzaee (2000)[22] , Parker (1999)[23] and Sarkis (2000)[24] are those in the airport literature. Other than the scale

[17] Roll, Y. and Hayuth, Y. (1993). Port performance comparison applying Envelopment Analysis. Maritime Policy and Management 20(2), 153 – 161

[18] Cullinane, K. and Wang, T., (2006) The efficiency of European container ports: a cross-sectional Data Envelopment Analysis. International Journal of Logistics – Research and Applications 9, 19 – 31

[19] Park, R. K and De, P. (2004). An alternative approach to efficiency measurement of seaports. Maritime Economics and Logistics 6, 53 – 69

[20] Gillen, D. and Lall, A. (1997). Developing measures of airport productivity and performance: an application of Data Envelopment Analysis. Transportation Research E 33(4), 261 – 273

[21] Martin, J.C. and Roman, C. (2001). An application of DEA to measure the efficiency of Spanish airports prior to privatization. Journal of Air Transport Management 7, 149 – 157

[22] Vasigh, B., and Hamzaee, R.G, (2000). Airport efficiency: an empirical analysis of the US commercial airports. Paper presented at the Fourth Annual Conference of the Air Transport Research Group, Amsterdam.

[23] Parker, D. (1999). The performance of BAA before and after privatization. Journal of Transport Economics and Policy 33, 133 – 145

economies (BBC, CCR and VRS) which arise through different assumptions of the scalar λ, the DEA model is a standard one and these papers mainly differ in terms of their samples, inputs and output variables.

For an output-oriented measure of technical efficiency,

$$\max_{\phi,\lambda,s^+,s^-} Z_i = \phi + \varepsilon I s^+ + \varepsilon I s^-$$

subjected to

$$Y\lambda - s^+ = \phi Y_i$$
$$X\lambda + s^- = X_i$$
$$I\lambda = I$$
$$\lambda, s^+, s^- \geq 0$$

X and Y are the input and output matrices respectively, X_i and Y_i are the input and output vectors of the unit i, respectively, ϕ and λ are parameters calculated in the model, and represent the maximum proportional output that can be attained and the linear convex combination that dominates the i^{th} unit, respectively,ε and s^+, s^- are the Archimedian constant and the slack variables.

B.4.2 Stochastic Frontier Analysis (SFA)

The level of efficiency, in SFA, is determined as the distance to the production frontier plus the stochastic deviation (that has an expected value of 0). The use of SFA allows for stochastic deviations, necessities the specification of the production functional form and assumptions of production technology. Pels et al (2001)[25] considered the stochastic production frontier of airports with the following form

$$y_{j,t} = x'_{j,t}\beta + E_{j,t}$$

[24] Sarkis, J. (2000). An analysis of the operational efficiency of major airports in the United States. Journal of Operations Management 18, 335 – 351

[25] Pels, E., Nijkamp, P. and Rietveld, P. (2001). Relative efficiency of European airports. Transport Policy 8, 183 – 192

$$E_{j,t} = V_{j,t} - U_j$$

where $y_{j,t}$ is the output of airport j at time t, $x_{j,t}$ is the corresponding inputs. $V_{j,t} \sim N(0, \sigma_V^2)$ and i.i.d and independent of U_j. U_j is distributed according to half normal distribution with variance σ_U^2. For $U_j > 0$, airport is not fully efficient.

The technical efficiency of an airport is given by

$$h_j^f = \frac{E(y_{j,t} / U_j, x_{j,t})}{E(y_{j,t} / U_j = 0, x_{j,t})}$$

where f denotes the efficient coefficient obtained from the production frontier

Quite similarly, Martin-Ceja (2002)[26] used a production frontier represented as

$$y_j = f(x_j, \beta) + E_j$$

$$E_j = e_j + \min(e_j)$$

where Y_j is the maximum output that can be obtained for an input vector X_j; and β is a vector of unknown parameters to be determined and E_j is the random measure which aggregates technical and allocative inefficiencies.

Cullinane and Song (2006)[27] adopted similar SFA on seaports. The cross-sectional logarithmic stochastic production frontier specified for the container terminal operating sector is defined as:

$$\ln(y_{it}) = \ln f(x_{1it}, x_{2it}, x_{3it}; \beta) + v_{it} - u_{it} \qquad \forall i = 1,2,...,n; \quad t = 1,2,...,T$$

where y_{it} represents the output of the i^{th} container terminal operator at time t, x_{it} denote the respective input variables and β is a vector of input coefficients associated with the independent variables in the model and is the object of estimation. The

[26] Martin Cejas, R.R. (2002). An approximation to the productive efficiency of Spanish airports network through a deterministic cost frontier. Journal of Air Transport Management 8, 233 – 238

[27] Cullinane, K. and Song, D. W. (2006). Estimating the relative efficiency of European container ports: a stochastic analysis. In Research in Transportation Economics 16 - Port Economics, 85 – 115

disturbance term v_{ij} represents the symmetric (statistical noise) component. u_{it} (>=0) is the one-sided inefficiency component.

B.4.3 Total Factor Productivity (TFP)

Oum et al (2003)[28] derived the TFP from the production transformation function. Define x_i and y_i as standardized input and output such that:

$$x_i \equiv \exp\left(\frac{\ln X_i - \ln \overline{X}_i}{\sigma_{\ln X_i}}\right)$$

$$y_j \equiv \exp\left(\frac{\ln Y_j - \ln \overline{Y}_j}{\sigma_{\ln Y_j}}\right)$$

where the upper bar indicates the geometric mean, $\sigma_{\ln X_i}$ and $\sigma_{\ln Y_i}$ are the standard deviation of $\ln X_i$ and $\ln Y_j$.

The production function is then defined as:

$$f(x_1,...,x_{m,}, y_1,...., y_n) = 0$$

Assuming separability in production function,

$$f(g(x_1,...,x_{m,}), y_1,...., y_n) = 0$$

This means that there exist isoquants such that at any point along each isoquant, the corresponding production possibility frontier is identical. Assume the production function can be specified in the constant economies of scale function form as below:

$$\left(\frac{1}{n}\sum_{j=1}^{n} y_j^{\gamma}\right)^{1/\gamma} = A\left(\frac{1}{m}\sum_{i=1}^{m} x_i^{\rho}\right)^{\delta/\rho}$$

[28] Oum, T. H., Yu, C. and Fu, X. (2003) A comparative analysis of productivity performance of the world's major airports: summary report of the ATRS global benchmarking research report 2002. Journal of Air Transport Management 9, 285 – 297

For $\frac{\left(\frac{1}{n}\sum_{j=1}^{n} y_j^{\gamma}\right)^{1/\gamma}}{A\left(\frac{1}{m}\sum_{i}^{m} x_i^{\rho}\right)^{\delta/\rho}} \sim LN\left(0,\sigma^2\right)$, we estimate the parameters by minimizing the sum of squares as follows:

$$\min_{A,\gamma,\delta,\rho} \sum \left[\frac{1}{\gamma}\ln\left(\frac{1}{n}\sum_{j=1}^{n} y_j^{\gamma}\right) - \ln A - \frac{\delta}{\rho}\ln\left(\frac{1}{m}\sum_{i=1}^{m} x_i^{\rho}\right)\right]^2$$

The productivity index is then constructed as

$$TFP = \frac{\left(\frac{1}{n}\sum_{j=1}^{n} y_j^{\hat{\rho}}\right)^{1/\hat{\gamma}}}{\hat{A}\left(\frac{1}{m}\sum_{i}^{m} x_i^{\hat{\rho}}\right)^{\hat{\delta}/\hat{\rho}}}$$

where (^) denotes estimated parameters

From the DEA production frontier, Abbott and Wu (2002)[29] wrote the Malmquist TFP index between period *t* (i.e., the base period) and period *s* as

$$M_0\left(y^s,x^s,y^t,x^t\right)=\left[\frac{D_o^t\left(y^s,x^s\right)}{D_o^t\left(y^t,x^t\right)}\times\frac{D_o^s\left(y^s,x^s\right)}{D_o^s\left(y^t,x^t\right)}\right]$$

where M_0 is the output-oriented TFP index, $D_o^s\left(y^t,x^t\right)$ is the distance function showing a maximal proportional expansion of the observed period t output under the period's technology. The technology represents output vector y, which can be produced using the input vector x.

Hooper and Hensher (1997)[30] used the multilateral TFP index, to account for the effects if economies of scale and scope, expressed as

[29] Abbott, M. and Wu, S. (2002). Total factor productivity and the efficiency of Australian airports. The Australian Economic Review 35 (3), 244 – 260

$$\ln\left(\frac{TFP_k}{TFP_b}\right) = \frac{1}{2}\sum\left(R_{ki}+\overline{R}_i\right)\left(\ln Y_{ki}-\ln\overline{Y}_i\right) - \frac{1}{2}\sum\left(R_{bi}+\overline{R}_i\right)\left(\ln Y_{bi}-\ln\overline{Y}_i\right)$$

$$-\frac{1}{2}\sum\left(W_{kn}+\overline{W}_n\right)\left(\ln X_{kn}-\ln\overline{X}_n\right) + \frac{1}{2}\sum\left(W_{bn}+\overline{W}_n\right)\left(\ln X_{bn}-\ln\overline{X}_n\right)$$

where k :each individual observation, k = 1, …., K
b :base observations
i :output, i = 1,…, I
n :inputs, n = 1,…, N
R_i :weights for each output
W_n :weights for each input
$ln\ Y_i$:unit measure of output
$ln\ X_n$:Unit measure of input

B.4.4 Ratio Analysis

Ratio analysis can generally be classified into two broad categories of that measures operational and financial efficiency. Vasigh and Haririan (2003)[31] examined various operational efficiency ratios such as

(i) Number of annual enplaned passengers/ airport gates

(ii) Number of annual enplaned passengers/ runway capacity

(iii) Movements/ gate

(iv) Movements/ runway

and common financial efficiency ratios such as

(i) Revenue/ gate

(ii) Revenue/ runway

(iii) Cost/ gate

(iv) Cost/ runway

[30] Hooper, P. G and Hensher, D. A (1997). Measuring total factor productivity of airports: an index number approach. Transportation Research E 33 (4), 249 – 259

[31] Vasigh, B. and Haririan, M. (2003). An empirical investigation of financial and operational efficiency of private versus public airports. Journal of Air Transportation 8(1), 91 – 107

APPENDIX C

MULTI-COLLINEARITY DIAGNOSTICS for PORT PERFORMANCE REGRESSION MODELS

C.1 Seaports

Table C-1 Tolerance, VIF, Condition Index and Variance Proportions (1994-2006)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	ln(Ki/Li)	ln(Hi/Li)	ln(Xi)
1994	1	3.392	1.000	0.01	0.01	0.00	0.01
	2	0.513	2.571	0.07	0.08	0.01	0.01
	3	0.068	7.082	0.13	0.04	0.29	0.61
	4	0.027	11.204	0.80	0.88	0.70	0.38
				Tolerance:	0.119	0.148	0.455
				VIF:	8.430	6.763	2.198
1997	1	3.339	1.000	0.01	0.01	0.00	0.01
	2	0.556	2.450	0.06	0.06	0.01	0.01
	3	0.080	6.477	0.09	0.04	0.27	0.51
	4	0.025	11.559	0.84	0.90	0.72	0.48
				Tolerance:	0.104	0.140	0.424
				VIF:	9.599	7.127	2.361
2000	1	3.438	1.000	0.01	0.01	0.00	0.01
	2	0.447	2.773	0.10	0.09	0.01	0.02
	3	0.085	6.353	0.20	0.00	0.13	0.81
	4	0.029	10.837	0.70	0.90	0.86	0.17
				Tolerance:	0.137	0.159	6.298
				VIF:	7.296	0.555	1.801
2003	1	3.465	1.000	0.01	0.01	0.00	0.01
	2	0.420	2.873	0.13	0.08	0.01	0.03
	3	0.082	6.509	0.38	0.01	0.11	0.85
	4	0.033	10.229	0.49	0.91	0.87	0.12
				Tolerance:	0.146	0.160	0.634
				VIF:	6.845	6.252	1.578
2006	1	3.352	1.000	0.01	0.01	0.01	0.01
	2	0.504	2.578	0.08	0.12	0.01	0.04
	3	0.101	5.765	0.34	0.03	0.11	0.84
	4	0.043	8.833	0.57	0.85	0.87	0.11
				Tolerance:	0.193	0.203	4.934
				VIF:	5.171	0.798	1.253

C.2 Airports

Table C-2 Tolerance, VIF, Condition Index and Variance Proportions (1999-2005)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	ln(Ki/Li)	ln(Hi/Li)	ln(Xi)
1999	1	3.072	1.000	0.00	0.01	0.01	0.00
	2	0.824	1.931	0.02	0.00	0.16	0.00
	3	0.084	6.051	0.07	0.84	0.59	0.01
	4	0.021	12.113	0.90	0.14	0.24	0.98
				Tolerance:	0.225	0.239	0.243
				VIF:	4.448	4.189	4.107
2001	1	3.093	1.000	0.01	0.01	0.01	0.01
	2	0.807	1.958	0.02	0.00	0.16	0.01
	3	0.069	6.708	0.01	0.93	0.48	0.15
	4	0.032	9.877	0.96	0.06	0.35	0.84
				Tolerance:	0.239	0.223	0.544
				VIF:	4.188	4.483	1.840
2003	1	3.579	1.000	0.01	0.01	0.01	0.01
	2	0.243	3.836	0.16	0.13	0.13	0.04
	3	0.142	5.023	0.06	0.50	0.24	0.09
	4	0.036	9.926	0.78	0.36	0.62	0.87
				Tolerance:	0.509	0.319	0.534
				VIF:	1.963	3.131	1.873
2005	1	3.647	1.000	0.01	0.00	0.00	0.00
	2	0.285	3.578	0.17	0.02	0.04	0.03
	3	0.052	8.405	0.72	0.00	0.07	0.76
	4	0.017	14.641	0.10	0.97	0.89	0.21
				Tolerance:	0.147	0.133	0.557
				VIF:	6.814	7.497	1.796

APPENDIX D

STANDARD CAPITAL PRODUCTIVITY and ECONOMIC VOLUME PLOTS

D.1 Seaports

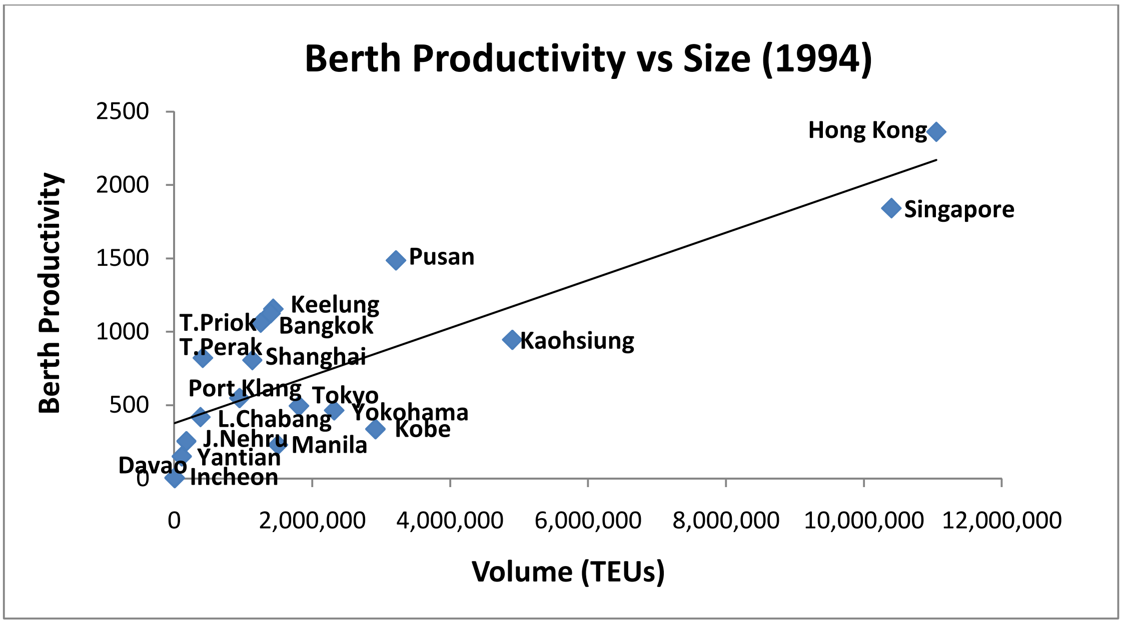

Figure D-1 Berth Productivity versus Seaport Size in 1994

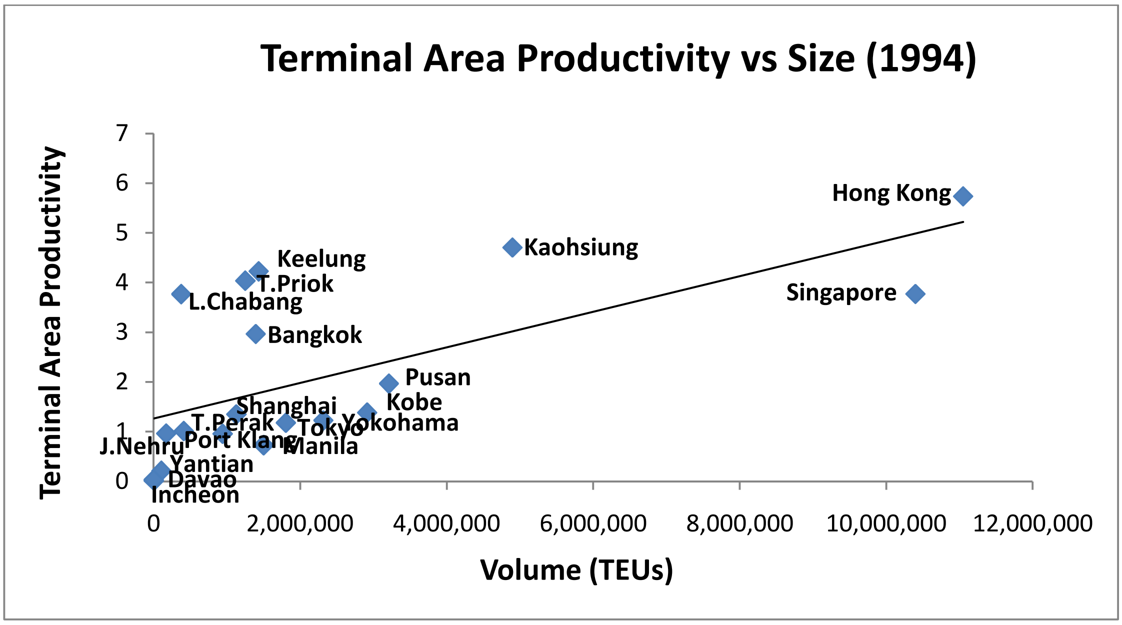

Figure D-2 Terminal Area Productivity versus Seaport Size in 1994

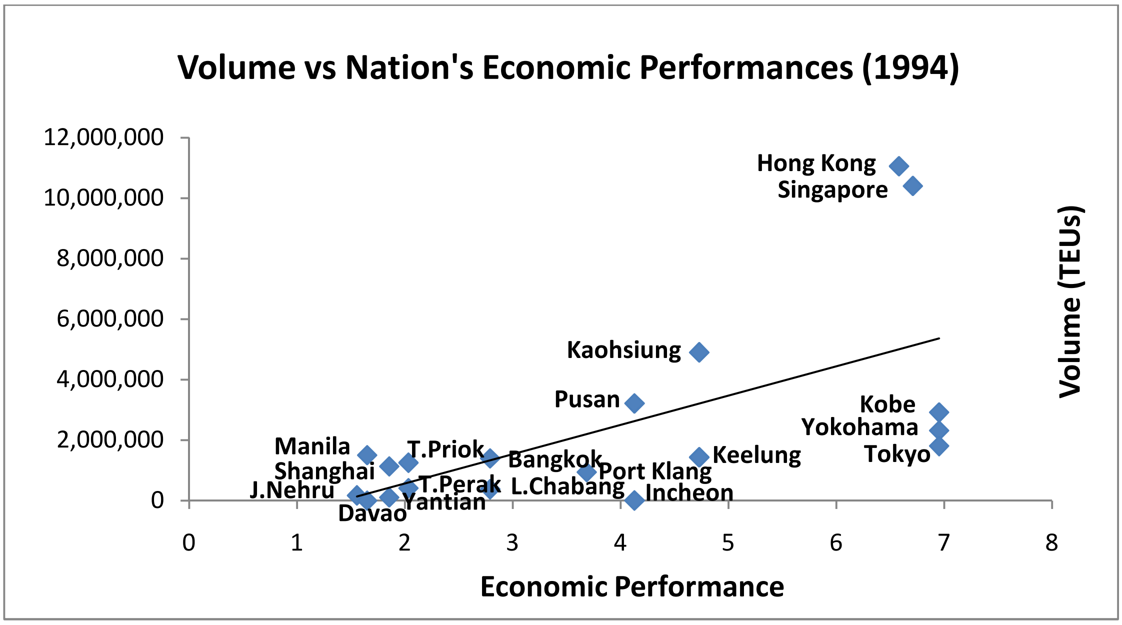

Figure D-3 Volume versus Nation's Economic Performances in 1994

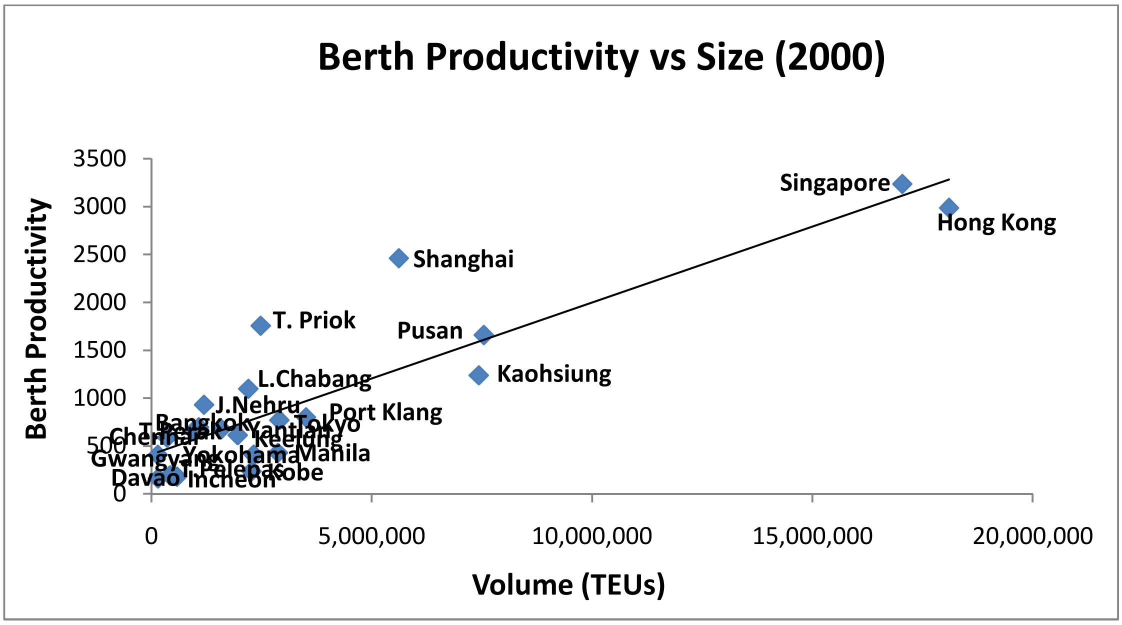

Figure D-4 Berth Productivity versus Seaport Size in 2000

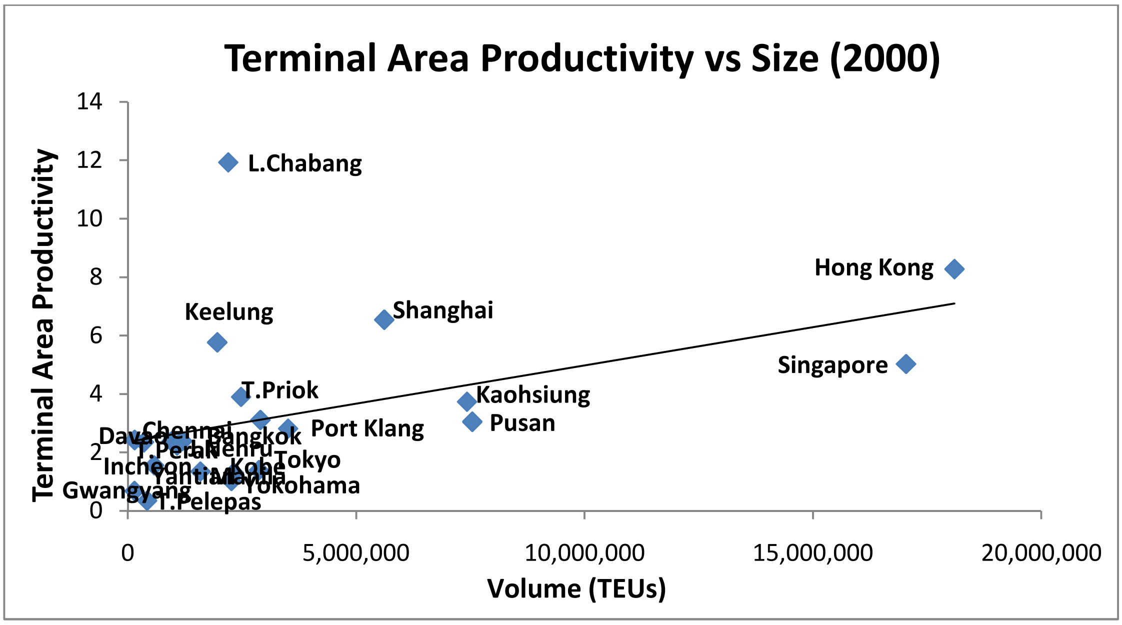

Figure D-5 Terminal Area Productivity versus Seaport Size in 2000

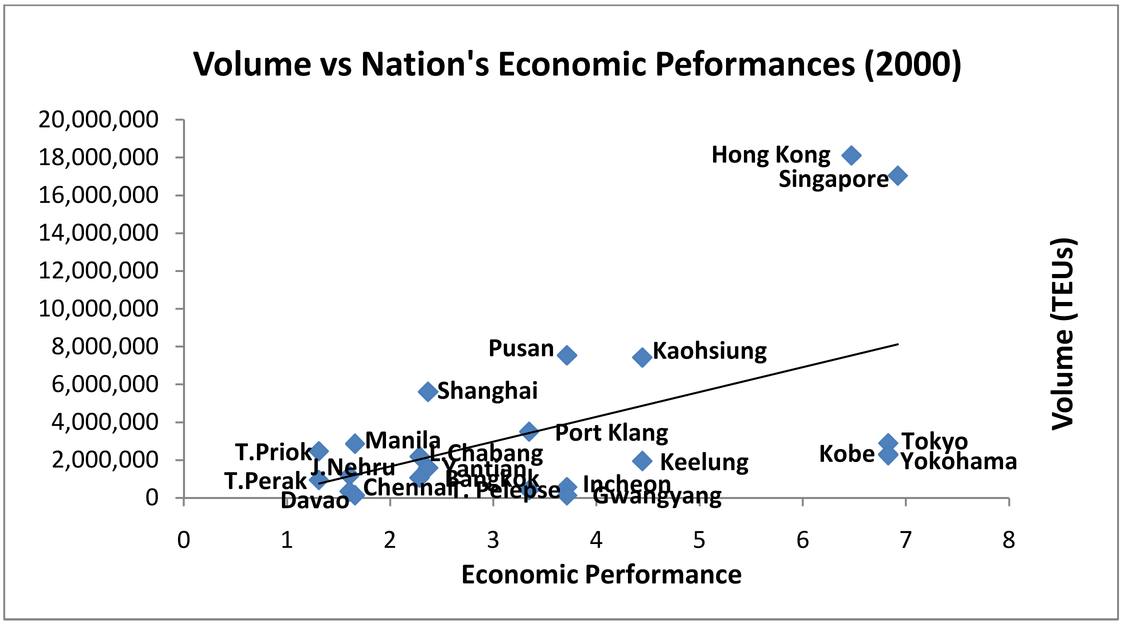

Figure D-6 Volume versus Nation’s Economic Performances in 2000

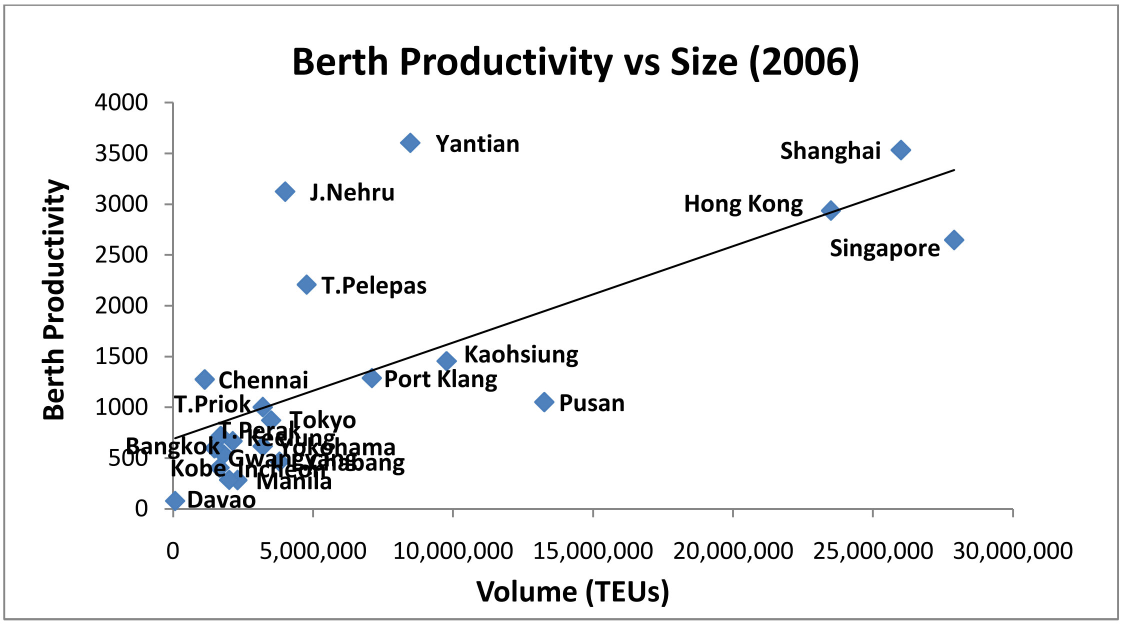

Figure D-7 Berth Productivity versus Seaport Size in 2006

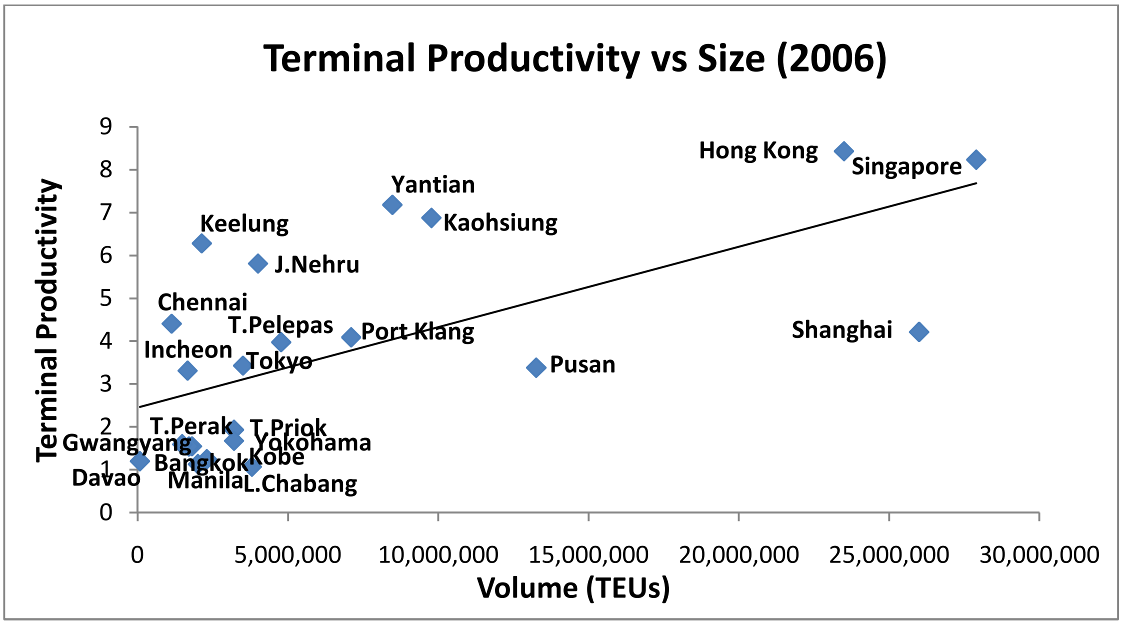

Figure D-8 Terminal Area Productivity versus Seaport Size in 2006

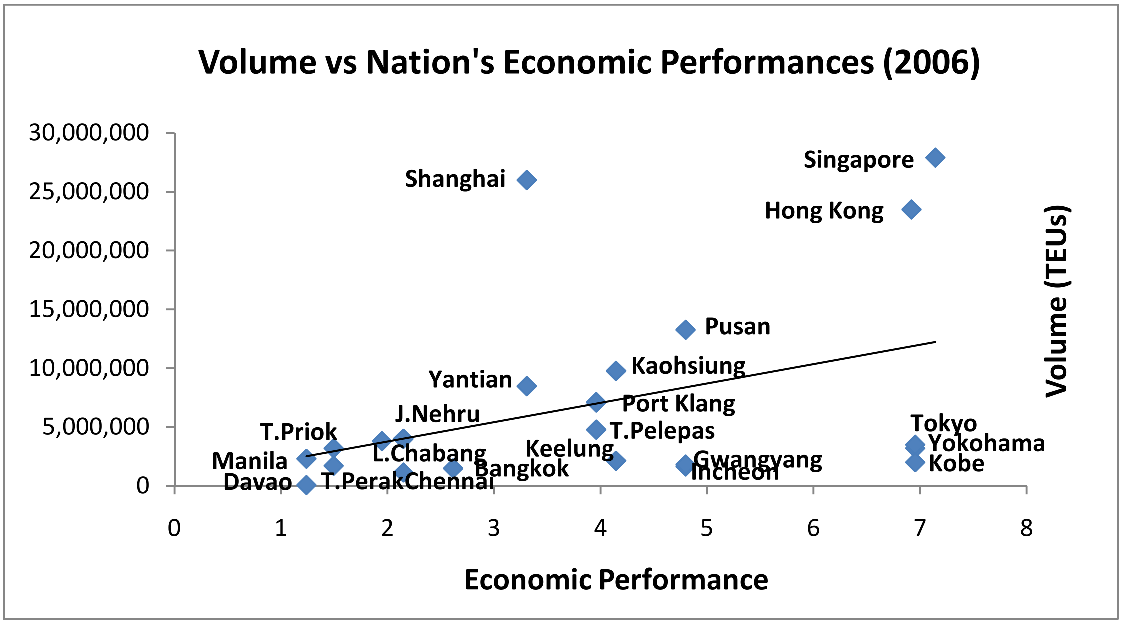

Figure D-9 Volume versus Nation's Economic Performances in 2006

D.2 Airports

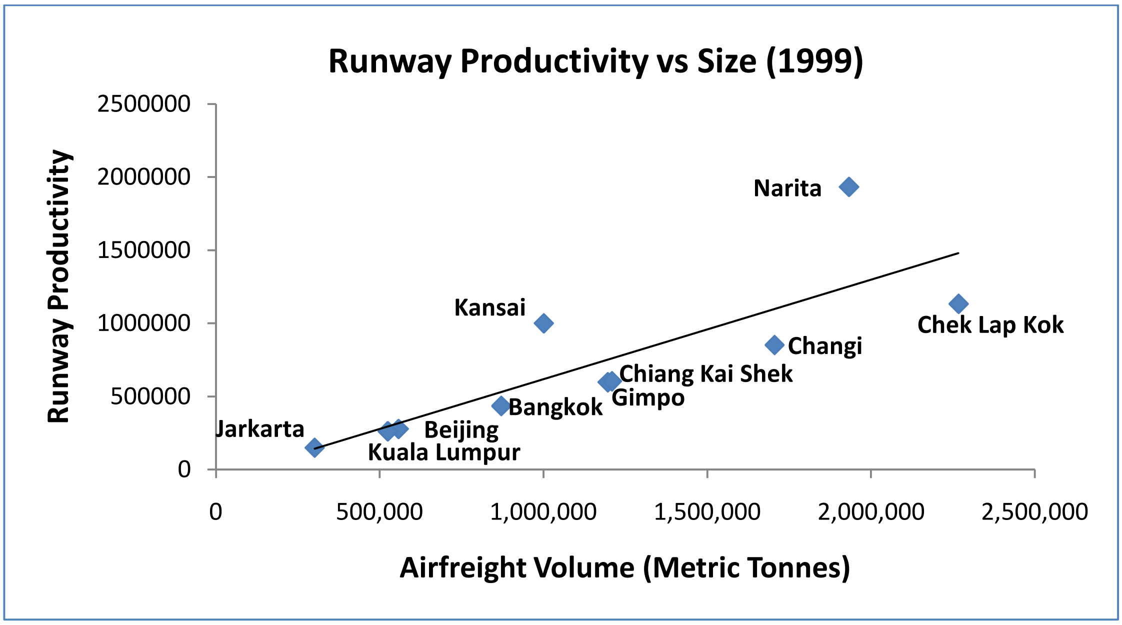

Figure D-10 Runway Productivity versus Airport size in 1999

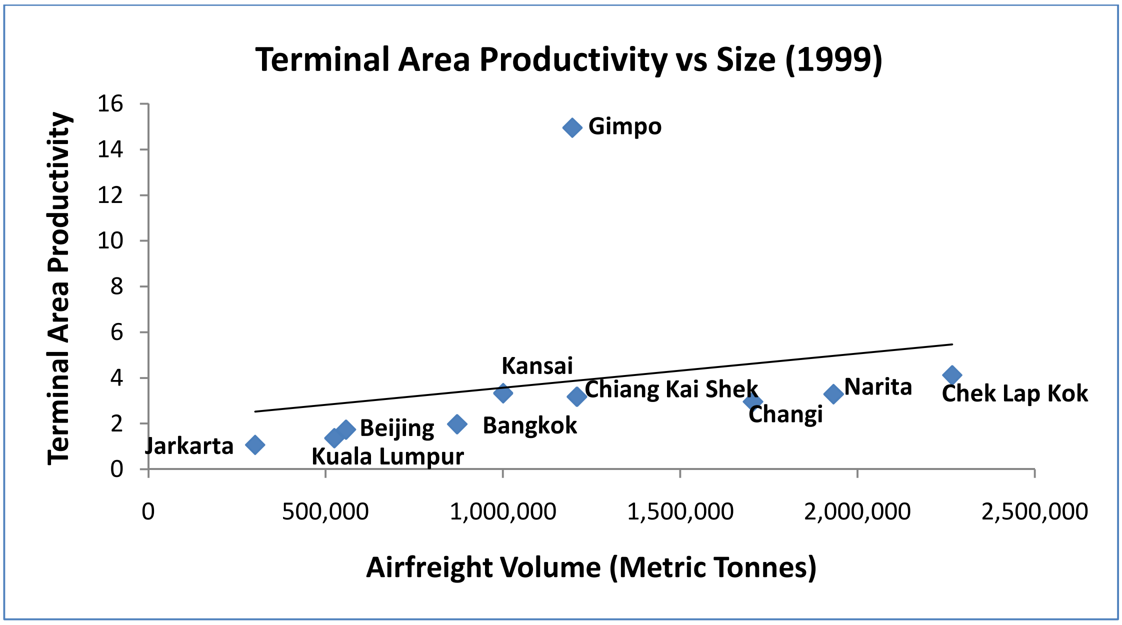

Figure D-11 Terminal Area Productivity versus Airport size in 1999

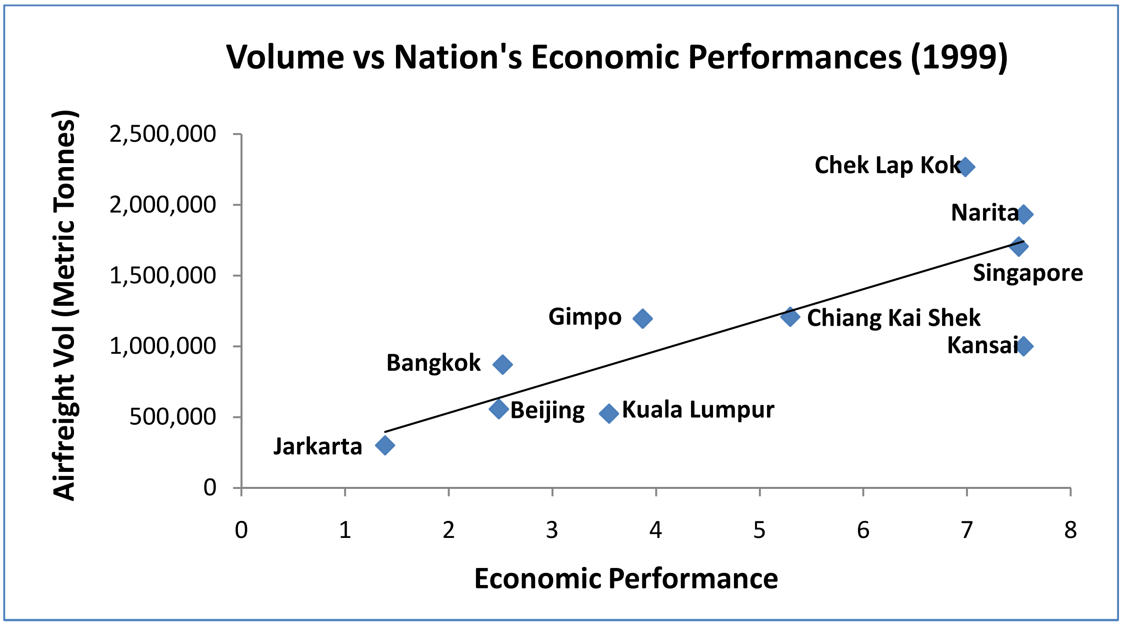

Figure D-12 Volume versus Nation’s Economic Performances in 1999

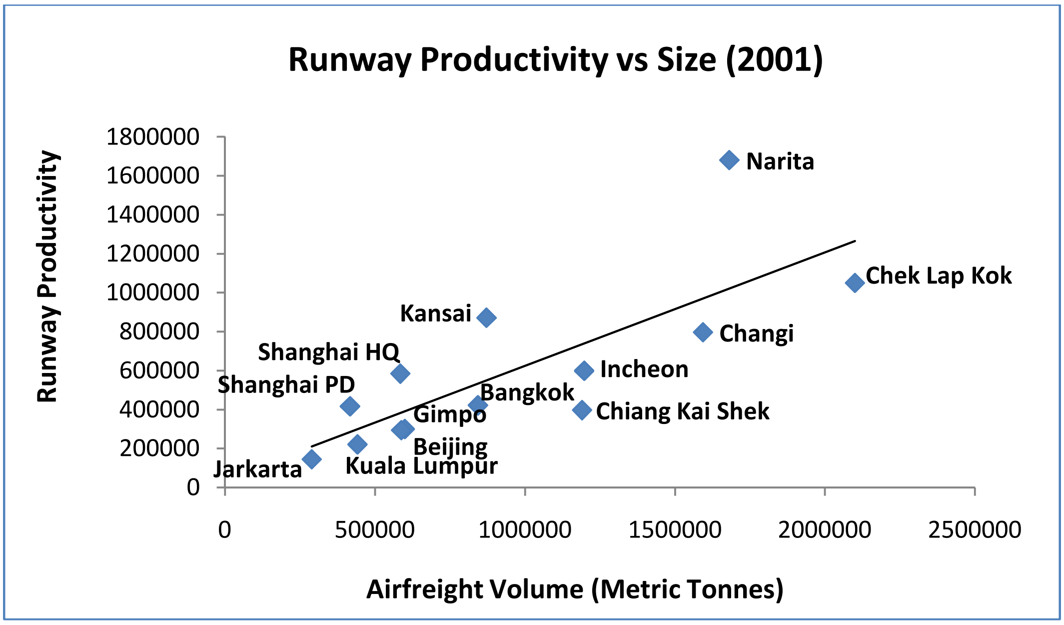

Figure D-13 Runway Productivity versus Airport size in 2001

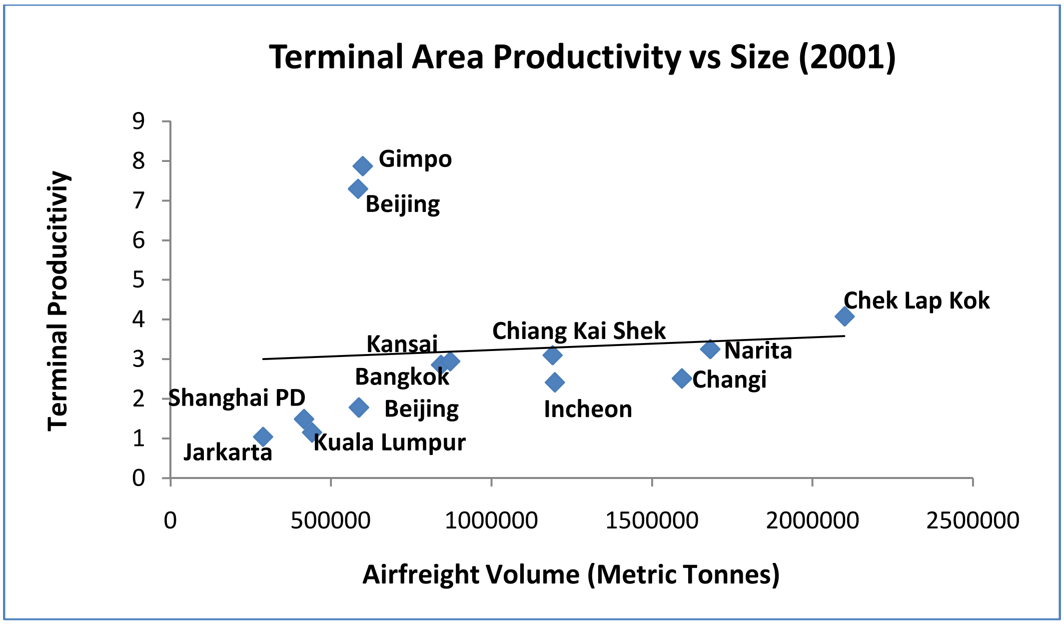

Figure D-14 Terminal Area Productivity versus Airport size in 2001

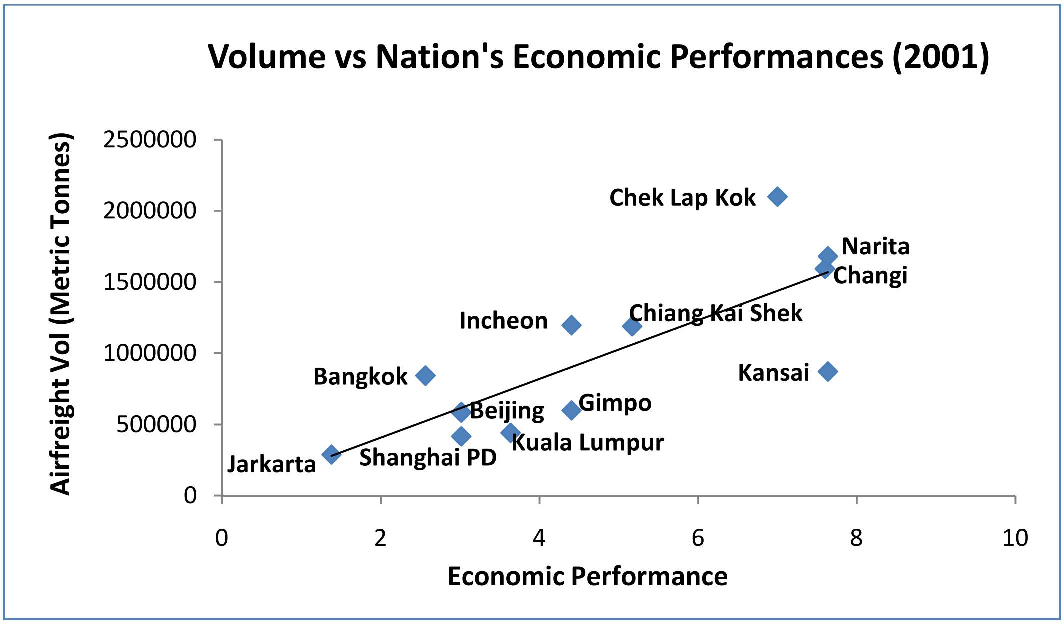

Figure D-15 Volume versus Nation's Economic Performances in 2001

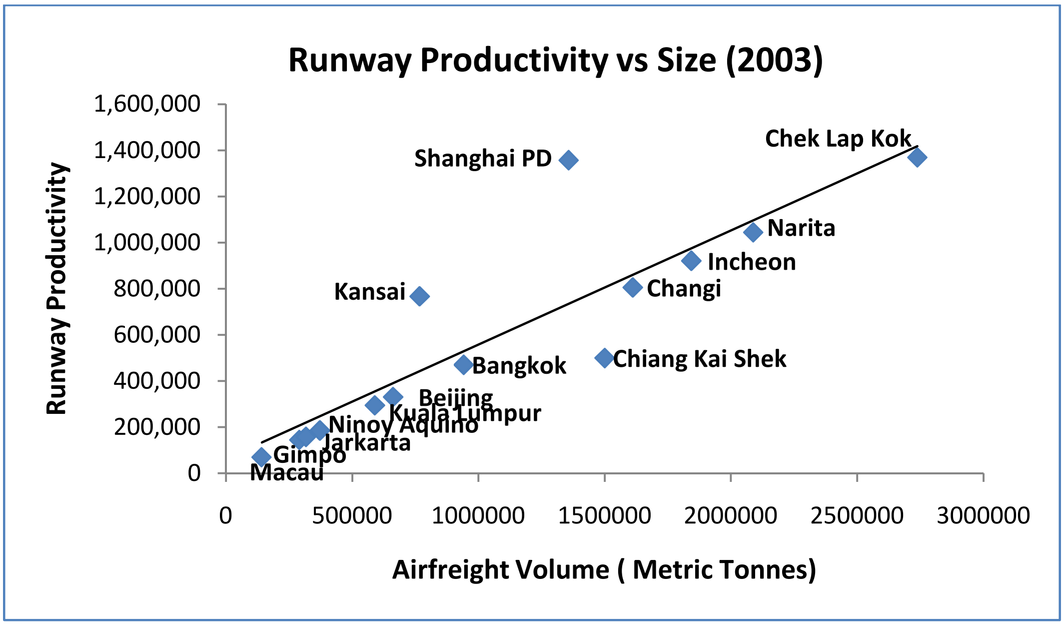

Figure D-16 Runway Productivity versus Airport Size in 2003

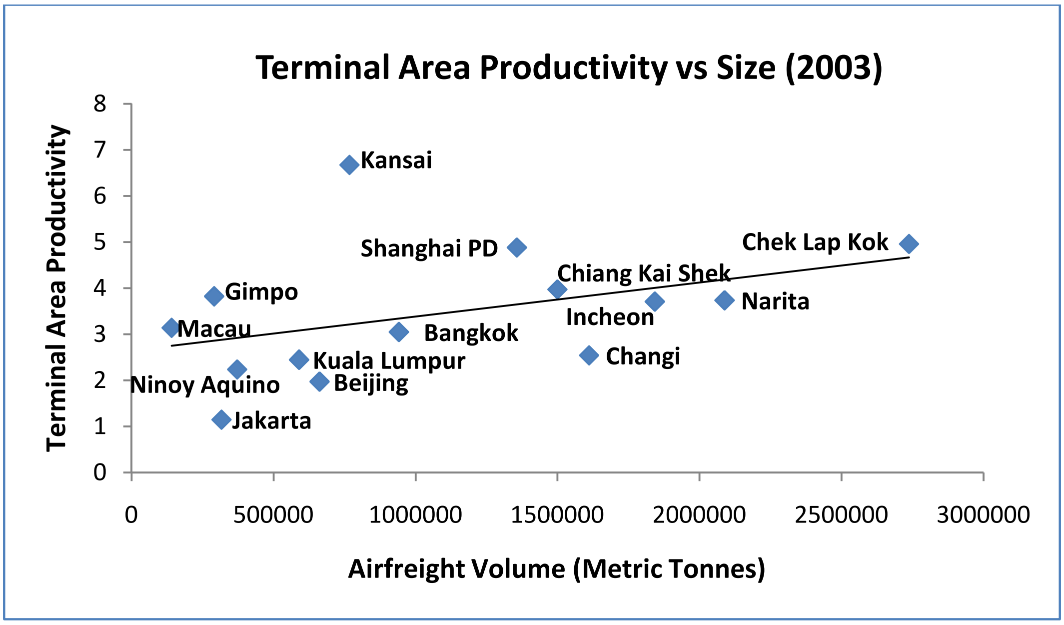

Figure D-17 Terminal Area Productivity versus Airport Size in 2003

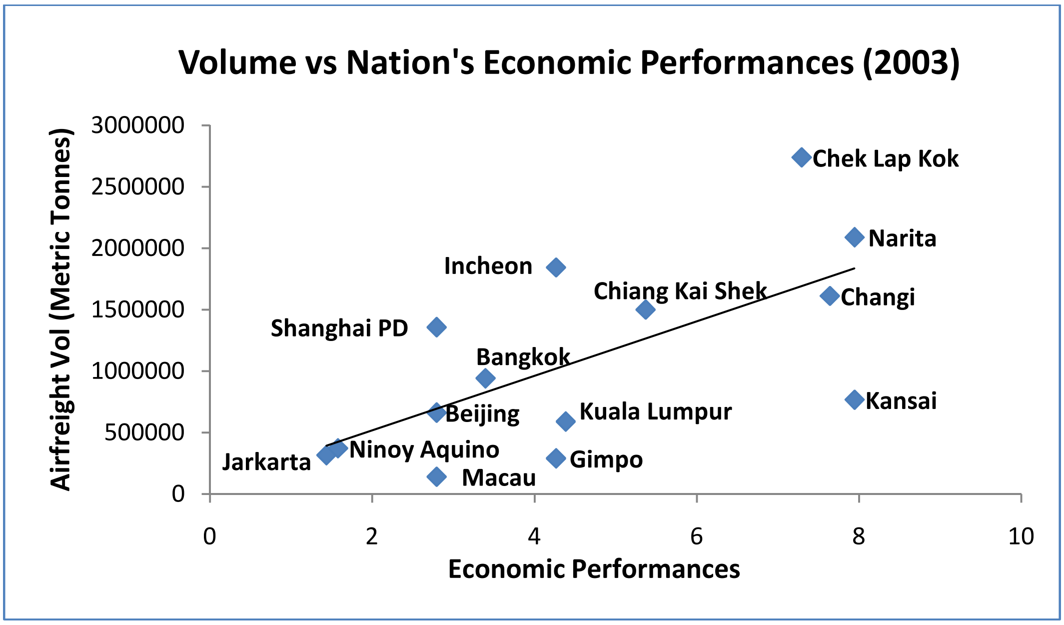

Figure D-18 Volume versus Nation's Economic Performances in 2003

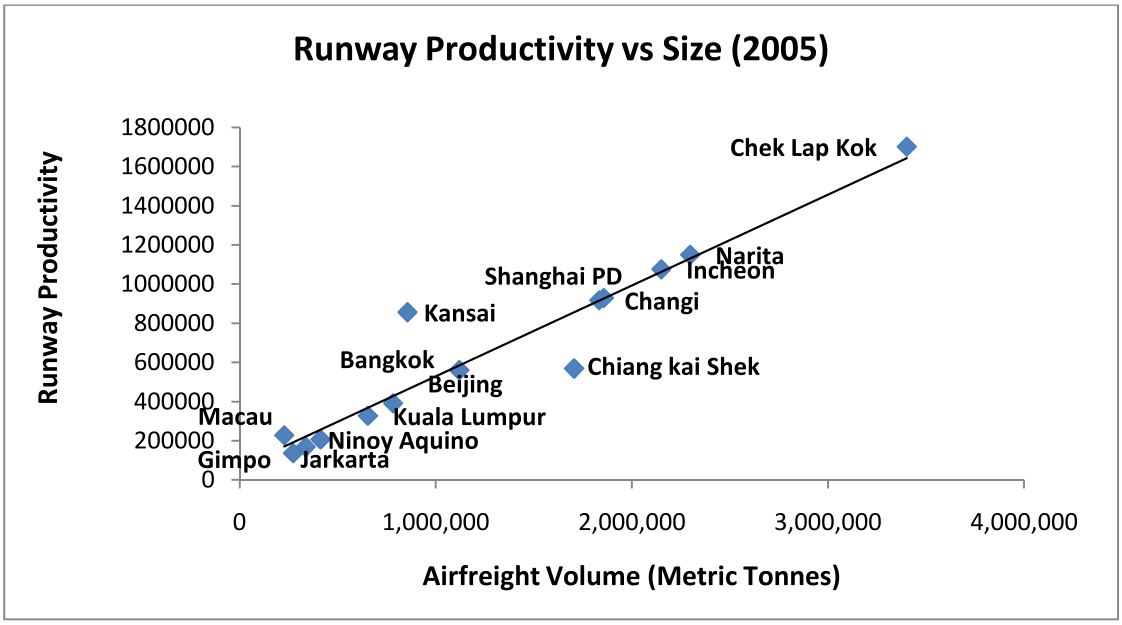

Figure D-19 Runway Productivity versus Airport Size in 2005

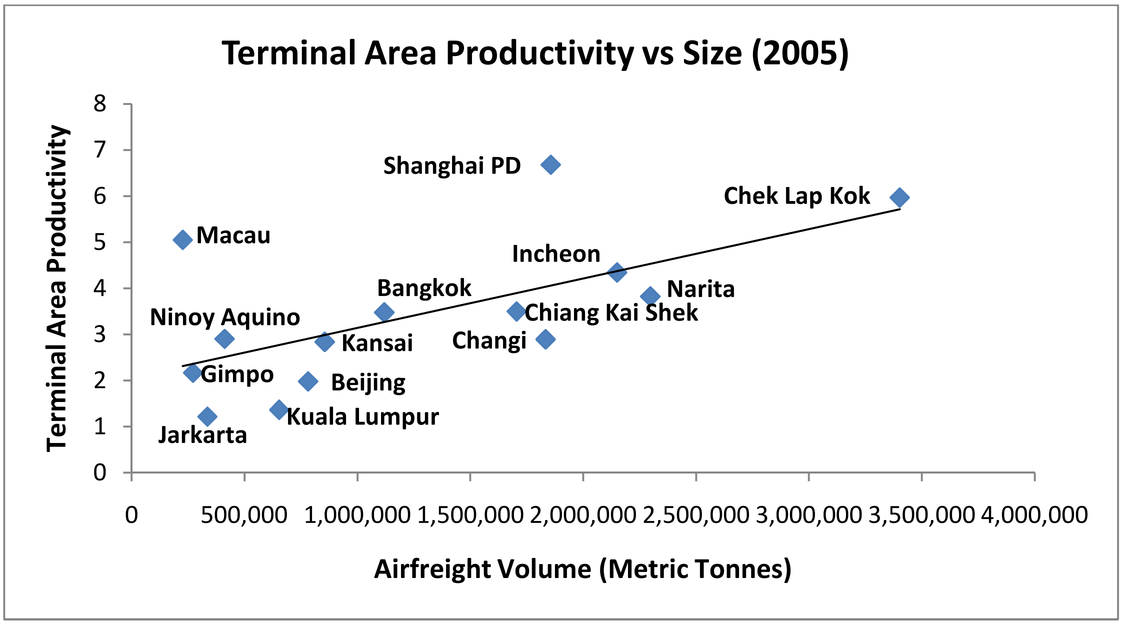

Figure D-20 Terminal Area Productivity versus Airport Size in 2005

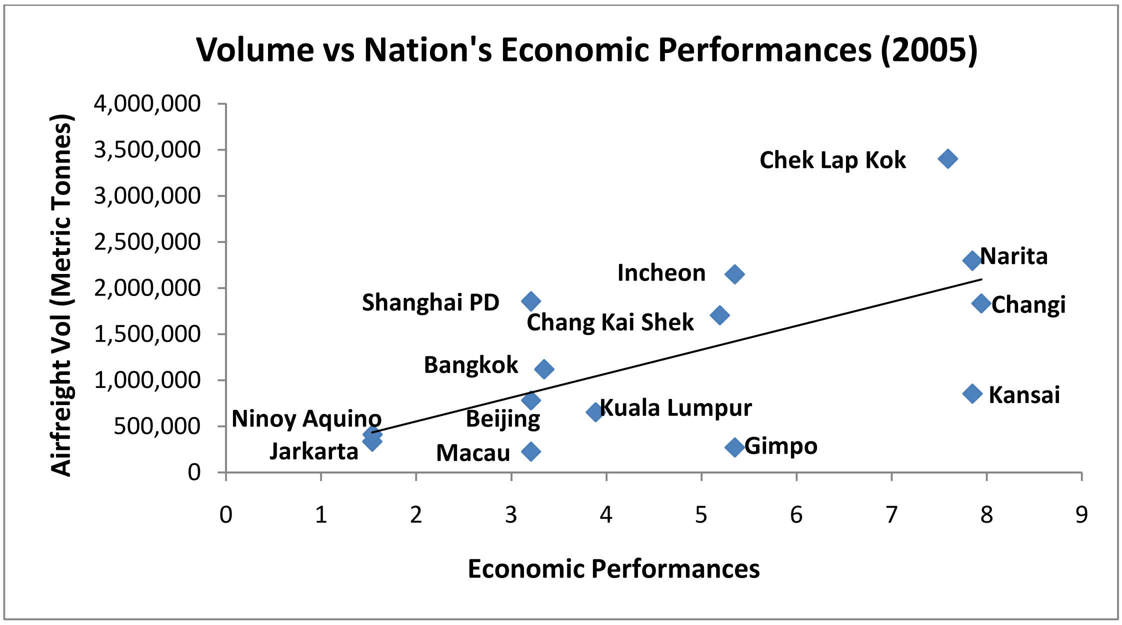

Figure D-21 Volume versus Nation's Economic Performances in 2005

APPENDIX E

TRANSLOG PRODUCTION FUNCTION

The three-input translog production function can be written in terms of logarithms as follows:

$$\ln Y = \alpha + \sum_i \beta_i \ln X_i + \frac{1}{2}\sum_i \beta_{ii} \ln X_i^{\,2} + \sum_i \sum_j \beta_{ij} \ln X_i \ln X_j$$

$$\forall i, j = K, L, O \text{ and } i \neq j \qquad \text{(E-1)}$$

where Y is the output quantity, and X_i is the respective input quantities of capital (K), labor (L) and outsource (O). α is the constant intercept term and β_i is the first derivative. β_{ii} and β_{ij} are the own and cross second-derivatives respectively.

In order to better understand the meaning of the parameters in Equation (E-1), we differentiate equation (E-1) with respect to each of the factor input to get a system of equations as follows.

$$\frac{\partial \ln Y}{\partial \ln X_i} = \beta_i + \sum_j \beta_{ij} \ln X_j \qquad \forall i, j = K, L, O \text{ (E-2)}$$

Equation (E-2) is valid under the assumption of perfect competition for which output elasticity with respect to input equals to the cost share of that input. β_i represents the average cost share of factor i and β_{ij} represents the constant factor i share elasticity with respect to j.

As in the Translog cost function, the symmetry restrictions in the corresponding production function impose the restriction in the form of (E-3):

$$\gamma_{ij} = \gamma_{ji} \qquad i, j = K, L, O \quad \text{(E-3)}$$

For constant returns to scale and the existences of Cobb-Douglas, we also require Equations (E-4) and (E-5):

$$\sum_i \beta_i = 1 \qquad i = K, L, O \quad \text{(E-4)}$$

$$\sum_i \beta_{ij} = \sum_j \beta_{ij} = \sum_i \sum_j \beta_{ij} = 0 \qquad i, j = K, L, O \quad \text{(E-5)}$$

The AES and price elasticities can be computed using Shephard Duality as before.

APPENDIX F

SELECTED PORT AND LOGISTICS INDUSTRIES DATA[#]

F.1 Seaport Traffic and Infrastructure

Port	Year 1994			Year: 1997		
	TEUS	Physical Infrastructure		TEUS	Physical Infrastructure	
	Cargo	Berth Length	Terminal Area	Cargo	Berth Length	Terminal Area
Hong Kong	11,050,000	4,679	1,926,000	14,567,231	6,059	2,198,300
Singapore	10,399,000	5,645	2,757,211	14,135,300	5,265	2,807,200
Pusan	3,212,637	2,162	1,633,783	5,945,614	2,962	1,839,551
Incheon	3,954	1,170	370,000	402,996	1,170	370,000
Shanghai	1,130,000	1,400	838,000	2,520,000	2,281	858,000
Yantian	105,736	698	500,000	638,396	1,650	1,180,000
Kaohsiung	4,899,879	5,182	1,041,000	5,693,339	5,182	1,041,000
Keelung	1,433,348	1,240	339,000	1,180,000	3,192	339,000
Port Klang	943,000	1,719	984,444	1,684,508	3,345	1,168,000
Jawaharlal Nehru	173,071	680	180,000	423,148	680	180,000
Chennai	NA	NA	NA	256,485	600	150,000
Tanjung Priok	1,252,153	1,180	310,000	2,091,402	1,180	310,000
Tanjung Perak	411,321	500	406,000	600,000	500	406,000
Laem Chabang	377,000	900	100,000	1,104,500	1,200	100,000
Bangkok	1,394,769	1,240	470,000	1,100,000	1,542	480,000
Manila	1,501,965	6,548	2,061,530	2,121,074	7,588	2,061,530
Davao	26,038	250	60,000	116,038	250	60,000
Yokohama	2,317,000	4,990	1,890,000	2,347,635	5,360	1,822,750
Tokyo	1,805,400	3,650	1,531,000	2,322,000	4,609	1,316,000
Kobe	2,915,854	8,640	2,106,964	1,944,147	10,685	998,886

Table F-1 Traffic and Infrastructure of Selected Asian Seaports, 1994 - 1997

[#] There is an inevitable lag between the time at which a report is being published and the period of which the published contents covers. In some cases, the time lag is a result of the time consuming procedures of collecting, compiling and validating the data. In other cases, the time lag occurs because of the lag between the financial year and the calendar year. In general, the ATRS reports and the containerization international yearbooks publish data that are dated 2 years before. The World Competitiveness yearbooks report figures of the previous year.

Port	Year 2000			Year 2003			Year 2006		
	TEUS	Physical Infrastructure		TEUS	Physical Infrastructure		TEUS	Physical Infrastructure	
	Cargo	Berth Length	Terminal Area	Cargo	Berth Length	Terminal Area	Cargo	Berth Length	Terminal Area
Hong Kong	18,100,000	6,059	2,186,700	20,449,000	7,999	2,503,100	23,500,000	7,999	2,788,500
Singapore	17,040,000	5,265	3,390,000	18,100,000	5,265	3,390,000	27,900,000	10,536	3,390,000
Pusan	7,540,387	4,547	2,472,736	10,407,809	12,090	3,013,570	13,260,000	12,610	3,922,413
Incheon	574,656	3,201	370,000	821,071	4,076	500,000	1,655,500	4,076	500,000
Gwangyang	142,507	350	210,000	1,184,842	3,700	1,373,503	1,800,000	3,350	1,163,000
Shanghai	5,613,000	2,281	858,000	11,280,000	4,456	4,009,926	26,000,000	7,356	6,169,837
Yantian	1,588,099	2,350	1,180,000	5,258,000	2,350	1,180,000	8,471,000	2,350	1,180,000
Kaohsiung	7,425,832	5,997	1,988,000	8,840,000	6,711	1,421,374	9,770,400	6,714	1,421,374
Keelung	1,954,573	3,192	339,000	2,000,707	3,192	339,000	2,128,800	3,192	339,000
Port Klang	3,506,753	4,392	1,246,000	4,840,000	4,913	1,493,300	7,100,000	5,513	1,736,300
Tanjung Pelepas	418,218	2,160	1,200,000	3,487,320	2,160	1,200,000	4,770,000	2,160	1,200,000
Jawaharlal Nehru	1,189,780	1,280	499,000	2,268,989	1,280	688,400	4,000,000	1,280	688,400
Chennai	352,307	600	150,000	539,625	885	211,000	1,128,000	885	256,000
Tanjung Priok	2,476,152	1,410	635,351	2,757,513	2,788	1,586,000	3,200,000	3,192	1,656,000
Tanjung Perak	949,029	1,450	400,000	1,575,000	1,450	738,000	1,700,000	2,370	1,100,000
Laem Chabang	2,195,024	2,000	184,000	3,181,050	7,600	3,471,800	3,800,000	8,160	3,546,800
Bangkok	1,073,517	1,542	480,000	1,216,781	2,479	927,810	1,480,000	2,479	927,810
Manila	2,867,836	6,705	2,061,530	2,552,187	8382	1,943,730	2,299,610	8102	1,845,058
Davao	145,372	900	60,000	202,016	900	60,000	72,000	920	60,000
Yokohama	2,317,489	5,690	1,779,601	2,504,628	5,830	1,733,601	3,200,000	5,190	1,911,256
Tokyo	2,899,452	3,764	933,040	3,313,647	4,016	891,701	3,500,000	4,016	1,020,901
Kobe	2,265,922	9,655	2,232,911	2,045,714	8,895	1,952,132	2,000,000	6,985	1,766,413

Table F-2 Traffic and Infrastructure of Selected Asian Seaports, 2000 - 2006

F.2 Airport Traffic and Infrastructure

Year 1999	Output				Physical and Human Infrastructure				
Airport	**Cargo (Tons)**	**No. of Aeronautic Mvts.**	**No. of Passengers**	**No. of WLU**	**Terminal (m^2)**	**Runway (m)**	**No. of Runways**	**No. of Gates**	**No. of Workers**
Chek Lap Kok	2,267,175	193,916	32,746,737	19,922,000	550,000	7,600	2	75	1,250
Kansai	1,000,693	122,916	20,472,060	8,700,000	300,000	3,500	1	51	508
Narita	1,932,694	134,521	2,738,915	18,109,000	586,800	6,180	1	104	919
Beijing	557,366	187,190	21,691,077	4,800,000	320,000	7,000	2	44	3,045
Seoul	1,195,900	233,243	36,841,400	36,000,000	80,000	6,800	2	35	1,588
Changi	1,705,410	184,533	28,618,200	15,003,000	576,000	8,000	2	67	1,430

Table F-3 Traffic and Infrastructure of Selected Asian Airports, 1999

Year 2001	Output				Physical and Human Infrastructure				
Airport	**Cargo (Tons)**	**No. of Aeronautic Mvts.**	**No. of Passengers**	**No. of WLU**	**Terminal (m^2)**	**Runway (m)**	**No. of Runways**	**No. of Gates**	**No. of Workers**
Chek Lap Kok	2,312,391	186,450	32,636,000	53,549,000	515,000	7,600	2	75	911
Incheon	1,196,845	87,057	14,546,000	26,500,000	496,000	7,500	2	44	3,000
Kansai	972,151	124,112	20,576,000	28,500,000	296,043	3,500	1	51	536
Narita	1,680,900	131,837	25,379,000	42,188,000	516,800	6,180	2	104	1,000
Beijing	586,700	221,749	24,176,000	30,005,000	330,000	7,000	2	44	6,669
Seoul	708,073	162,012	22,041,000	28,500,000	76,045	6,800	2	35	800
Changi	1,507,062	190,296	28,094,000	43,393,000	634,100	8,000	2	67	1,300
Sydney	435,800	317,339	26,437,000	29,000,000	246,000	8,930	3	70	482
Brisbane	144,010	87,920	13,284,000	15,663,209	100,000	5,320	2	38	145
Auckland	186,954	147,868	8,033,000	10,826,128	94,875	3,635	1	34	282
Christchurch	32,600	82,496	4,308,000	5,613,377	42,220	5,028	2	20	150

Table F-4 Traffic and Infrastructure of Selected Asian Airports, 2001

Year 2002	Output				Physical and Human Infrastructure				
	Tons	Number of			Area	Length	Number of		
Airport	Cargo	Aeronautic Mvts.	Passengers	Workload Units	Terminal (m^2)	Runway (m)	Runways	Gates	Workers
Chek Lap Kok	2,546,000	212,000	34,198,000	58,900,000	515,000	7,600	2	75	941
Incheon	1,016,867	126,049	20,920,000	31,712,296	496,804	7,500	2	44	3,000
Kansai	811,618	121,441	18,750,000	27,563,991	296,043	3,500	1	51	488
Narita	1,941,660	163,131	29,104,000	48,809,971	586,700	6,180	2	104	1,000
Beijing	669,347	242,338	27,160,000	34,602,703	336,000	7,000	2	44	6,669
Seoul	302,240	128,428	17,092,000	20,996,319	76,045	6,800	2	17	800
Changi	1,637,797	186,945	28,979,000	45,756,169	634,100	8,000	2	93	1,300
Cairns	N.A.	43,514	2,991	994,151	43,413	4,122	2	38	125
Sydney	471,000	254,729	23,900,000	29,430,923	360,857	8,929	3	67	409
Brisbane	153,619	75,375	12,320,000	14,791,826	100,000	5,320	2	38	135
Auckland	188,911	142,620	8,804,000	11,615,990	109,275	3,635	1	37	262
Christchurh	27,500	81,944	4,220,000	5,476,220	46,000	5,029	2	20	165
Macau	111,268	37,564	4,172,000	6,235,624	45,800	3,360	1	8	250

Table F-5 Traffic and Infrastructure of Selected Asian Airports, 2002

Year 2003	Output				Physical and Human Infrastructure				
	Tons	Number of			Area	Length	Number of		
Airport	Cargo	Aeronautic Mvts.	Passengers	Workload Units	Terminal (m^2)	Runway (m)	Runways	Gates	Workers
Chek Lap Kok	2,738,000	190,000	27,673,000	54,000,000	552,069	7,600	2	75	958
Incheon	1,843,055	130,185	19,790,000	37,000,000	496,804	7,500	2	44	788
Kansai	767,310	108,366	16,921,000	27,500,000	114,950	3,500	1	51	488
Narita	2,088,514	170,579	26,730,000	47,400,000	559,100	6,180	2	104	912
Beijing	662,141	235,861	24,364,000	30,100,000	336,000	7,000	2	44	8,140
Seoul	290,731	136,819	16,881,000	20,100,000	76,045	6,800	2	11	770
Changi	1,611,407	174,820	24,664,000	40,800,000	634,100	8,000	2	116	1,500
Cairns	N.A.	44,208	2,133	993,293	43,413	4,122	2	38	134
Sydney	500,000	254,487	24,183,000	29,993,441	360,857	8,930	3	65	388
Brisbane	139,302	68,843	12,340,000	14,673,831	100,000	8,820	3	38	133
Auckland	201,225	144,531	9,748,000	12,678,680	109,275	3,635	1	34	276
Christchurch	29,886	86,701	4,593,000	5,872,218	46,000	5,028	2	20	155
Macau	141,223	31,293	2,906,000	5,258,347	450,000	3,360	1	8	250

Table F-6 Traffic and Infrastructure of Selected Asian Airports, 2003

Year 2004	Output				Physical and Human Infrastructure				
	Tons	Number of			Area	Length	Number of		
Airport	Cargo	Aeronautic Mvts.	Passengers	Workload Units	Terminal (m^2)	Runway (m)	Runways	Gates	Workers
Chek Lap Kok	3,100,000	242,000	38,300,000	69,300,000	570,000	7,600	2	96	976
Incheon	2,133,444	149,776	24,084,000	56,000,000	496,804	7,500	2	44	788
Kansai	860,102	102,571	15,112,000	23,989,932	116,126	3,500	1	66	433
Narita	2,311,417	185,243	31,106,000	54,200,000	601,000	6,180	2	104	896
Beijing	668,690	304,778	34,883,000	42,000,000	336,000	7,000	2	49	8,872
Seoul	297,268	105,923	14,842,000	17,341,940	76,045	6,800	2	11	770
Changi	1,775,092	184,932	30,354,000	48,100,000	634,100	8,000	2	68	1,558
Shenzhen	423,271	140,452	14,253,000	18,486,800	146,600	3,399	1	53	3,272
Cairns	N.A.	43,831	3,555,000	4,546,160	43,413	4,122	2	38	135
Sydney	475,000	266,746	26,426,000	31,175,716	360,857	8,930	3	89	286
Brisbane	124,224	72,377	14,373,000	15,615,314	100,000	8,820	3	38	143
Auckland	216,446	154,812	1,120,000	13,284,837	109,275	3,635	1	34	281
Baiyun	632,372	182,780	20,326,000	26,650,750	320,000	7,400	2	71	2,198
Christchurch	26,743	90,794	5,136,000	5,403,528	46,000	5,028	2	20	156
Macau	220,828	40,506	3,714,000	5,922,656	45,000	3,360	2	8	236

Table F-7 Traffic and Infrastructure of Selected Asian Airports, 2004

Year 2005	Output				Physical and Human Infrastructure				
	Tons	Number of			Area	Length	Number of		
Airport	Cargo	Aeronautic Mvts.	Passengers	Workload Units	Terminal	Runway	Runways	Gates	Workers
Chek Lap Kok	3,402,000	263,500	40,270,000	74,800,000	570,000	7,600	2	96	1,000
Incheon	2,150,138	160,843	26,051,000	47,500,000	495,000	7,500	2	44	850
Kansai	855,530	102,862	15,371,000	24,000,000	305,000	3,500	1	66	450
Narita	2,297,555	186,633	31,774,000	54,400,000	601,000	6,180	2	131	850
Beijing	782,066	341,681	41,004,000	49,500,000	395,000	7,000	2	65	7,984
Seoul	272,303	94,787	13,448,000	18,000,000	125,000	6,800	2	24	800
Changi	1,833,721	204,138	32,431,000	51,000,000	634,100	8,000	2	68	1,450
Xiamen	158,700	67,000	6,586,000	8,172,600	14,900	3,400	1	N.A.	600
Meilan	3,511	68,879	7,027,000	7,632,786	60,200	3,600	1	36	691
Shenzhen	466,500	151,400	16,283,000	20,946,461	146,000	3,399	1	53	3,569
Cairns	N.A.	46,452	3,844,000	4,835,160	42,964	4,122	2	38	139
Sydney	554,000	286,484	28,288,000	33,828,185	387,487	8,930	3	65	281
Brisbane	158,102	159,932	15,885,000	17,465,636	100,000	8,820	2	63	158
Auckland	229,348	158,452	11,256,000	13,549,480	113,000	3,635	1	34	280
Baiyun	600,604	211,309	23,558,000	29,564,256	310,000	7,400	2	74	2,252
Christchurch	26,490	88,828	5,556,000	5,821,149	46,000	5,028	2	19	159
Macau	227,233	45,004	4,251,000	6,523,040	45,000	3,360	1	8	236

Table F-8 Traffic and Infrastructure of Selected Asian Airports, 2005

F.3 Airport Cost Components

Year 1999	Income (USD)			Fixed Cost (USD)	Variable Cost (USD)		
Airport	Before Tax/ Interest	Return on Asset	Total cost (USD)	Capital	Wage per worker	Total Labor cost	Outsource cost
Chek Lap Kok	51,000,000	0.010	5,257,383,800	5,100,000,000	35,860	44,824,500	112,559,300
Kansai	-220,000,000	-0.015	14,823,266,667	14,666,666,667	23,291	11,832,000	144,768,000
Narita	5,000,000	0.001	5,273,445,900	5,000,000,000	29,558	27,163,500	246,282,400
Beijing	90,000,000	0.087	1,050,082,759	1,034,482,759	993	3,024,000	12,576,000
Seoul	159,000,000	0.030	5,357,600,000	5,300,000,000	12,242	19,440,000	38,160,000
Changi	163,500,000	0.042	3,946,867,943	3,892,857,143	7,869	11,252,250	42,758,550

Table F-9 Income and Cost Components of Selected Asian Airports, 1999

Year 2001	Income (USD)			Fixed Cost (USD)	Variable Cost(USD)		
Airport	Before Tax/ Interest	Return on Asset	Total cost (USD)	Capital	Wage per worker	Total Labor cost	Outsource cost
Chek Lap Kok	-22,000,000	-0.006	3,829,422,192	3,492,063,492	67,598	61,581,350	275,777,350
Incheon	50,000,000	0.001	50,106,000,000	50,000,000,000	3,975	11,925,000	94,075,000
Kansai	-146,000,000	-0.013	11,778,539,231	11,230,769,231	69,123	37,050,000	510,720,000
Narita	1,000,000	0.001	1,923,917,200	1,000,000,000	79,313	79,313,440	844,603,760
Beijing	75,000,000	0.064	1,279,893,000	1,171,875,000	3,599	24,004,000	84,014,000
Seoul	145,000,000	0.290	571,250,000	500,000,000	31,350	25,080,000	46,170,000
Changi	251,000,000	0.065	4,056,806,962	3,861,538,462	33,379	43,393,000	151,875,500
Sydney	25,000,000	0.017	1,544,538,235	1,470,588,235	53,548	25,810,000	48,140,000
Brisbane	-5,000,000	-0.040	28,976,937	125,000,000	43,209	6,265,284	22,711,654
Auckland	25,000,000	0.063	426,524,013	400,000,000	34,168	9,635,254	16,888,759
Christchurch	10,000,000	0.063	173,752,774	160,000,000	28,067	4,210,033	9,542,741

Table F-10 Income and Cost Components of Selected Asian Airports, 2001

Year 2002	Income(USD)			Fixed Cost (USD)	Variable Cost(USD)		
Airport	Before Tax/ Interest	Return on Asset	Total cost (USD)	Capital	Wage per worker	Total Labor cost	Outsource cost
Chek Lap Kok	110,000,000	0.018	6,464,511,111	6,111,111,111	121,430	114,266,000	239,134,000
Incheon	-78,000,000	-0.017	4,604,408,565	4,588,235,294	5,688	17,062,500	16,173,271
Kansai	-145,660,000	-0.010	15,047,267,281	14,566,000,000	61,002	29,769,110	451,498,171
Narita	100,000	0.001	655,945,575	100,000,000	82,001	82,000,752	473,944,823
Beijing	110,000,000	0.099	1,232,220,571	1,111,111,111	4,929	32,872,568	88,236,893
Seoul	-108,230,000	-0.018	6,023,275,937	6,012,777,778	25,097	20,077,500	10,498,160
Changi	185,900,000	0.058	3,424,802,025	3,205,172,414	38,013	49,416,662	170,212,948
Sydney	75,000,000	0.044	1,784,008,947	1,704,545,455	64,762	26,487,831	52,975,661
Brisbane	-5,000,000	-0.040	154,583,653	125,000,000	43,828	5,916,731	23,666,922
Auckland	50,000,000	0.093	567,835,984	537,634,409	39,902	10,454,391	19,747,184
Christchurch	10,000,000	0.092	117,457,605	108,695,652	24,892	4,107,165	4,654,787

Table F-11 Income and Cost Components of Selected Asian Airports, 2002

Year 2003	Income(USD)			Fixed Cost (USD)	Variable Cost (USD)		
Airport	Before Tax/ Interest	Return on Asset	Total cost (USD)	Capital	Wage per worker	Total Labor cost	Outsource cost
Chek Lap Kok	305,000,000	0.044	7,256,358,182	6,931,818,182	67,641	64,800,000	259,740,000
Incheon	190,000,000	0.038	5,251,666,667	5,066,666,667	28,173	22,200,000	162,800,000
Kansai	408,200,000	0.025	16,812,000,000	16,328,000,000	69,314	33,825,000	450,175,000
Narita	713,600,000	0.090	8,402,888,889	7,928,888,889	91,474	83,424,000	390,576,000
Beijing	110,000,000	0.094	1,293,923,766	1,170,212,766	4,437	36,120,000	87,591,000
Seoul	-66,700,000	-0.014	5,081,440,741	4,940,740,741	19,578	15,075,000	125,625,000
Changi	312,000,000	0.075	4,368,080,000	4,160,000,000	32,640	48,960,000	159,120,000
Cairns	34,140,036	0.155	223,834,152	220,258,297	7,561	1,013,159	2,562,696
Sydney	216,066,284	0.062	3,555,424,652	3,484,940,065	6,725	2,609,429	67,875,158
Brisbane	67,210,228	0.075	926,364,465	896,136,373	58,475	7,777,130	22,450,962
Auckland	59,122,709	0.120	521,850,205	492,689,242	42,722	11,791,172	17,369,791
Christchurch	11,628,217	0.093	139,127,915	125,034,591	36,749	5,696,052	8,397,272

Table F-12 Income and Cost Components of Selected Asian Airports, 2003

Year 2004	Income (USD)			Fixed Cost (USD)	Variable Cost (USD)		
Airport	Before Tax/ Interest	Return on Asset	Total cost (USD)	Capital	Wage per worker	Total Labor cost	Outsource cost
Chek Lap Kok	474,000,000	0.078	6,423,423,077	6,076,923,077	68,874	67,221,000	279,279,000
Incheon	275,000,000	0.044	6,554,514,286	6,285,714,286	29,137	22,960,000	245,840,000
Kansai	400,000,000	0.025	16,414,066,226	16,000,000,000	205,549	89,002,648	325,063,579
Narita	751,000,000	0.090	8,897,284,444	8,344,444,444	105,859	94,850,000	457,990,000
Beijing	150,000,000	0.130	1,328,146,154	1,153,846,154	5,444	48,300,000	126,000,000
Seoul	18,000,000	0.017	1,155,938,393	1,058,823,529	20,270	15,607,746	81,507,118
Changi	225,000,000	0.105	2,378,547,143	2,142,857,143	30,873	48,100,000	187,590,000
Shenzhen	50,000,000	0.137	425,969,944	364,963,504	9,040	29,578,880	31,427,560
Syndey	300,000,000	0.070	4,376,123,862	4,285,714,286	87,205	24,940,573	65,469,004
Brisbane	98,000,000	0.088	1,160,599,816	1,120,000,000	65,519	9,369,188	31,230,628
Auckland	100,000,000	0.138	764,470,271	727,272,727	52,005	14,613,321	22,584,223
Christchurch	18,000,000	0.090	218,912,348	200,000,000	41,566	6,484,234	12,428,114

Table F-13 Income and Cost Components of Selected Asian Airports, 2004

Year 2005	Income (USD)			Fixed Cost (USD)	Variable Cost (USD)		
Airport	Before Tax/ Interest	Return on Asset	Total cost	Capital	Wage per worker	Total Labor cost	Outsource cost
Chek Lap Kok	490,000,000	0.088	5,942,181,818	5,568,181,818	71,060	71,060,000	302,940,000
Incheon	520,000,000	0.085	6,378,897,059	6,117,647,059	40,235	34,200,000	227,050,000
Kansai	507,000,000	0.031	16,797,878,710	16,354,838,710	58,667	26,400,000	416,640,000
Narita	907,000,000	0.105	9,313,199,238	8,638,095,238	120,960	102,816,000	572,288,000
Beijing	185,000,000	0.130	1,571,576,923	1,423,076,923	4,960	39,600,000	108,900,000
Seoul	10,000,000	0.015	806,166,667	666,666,667	27,000	21,600,000	117,900,000
Changi	370,000,000	0.145	2,781,224,138	2,551,724,138	37,986	55,080,000	174,420,000
Xiamen	25,000,000	0.145	186,715,843	172,413,793	5,448	3,269,040	11,033,010
Meilan	22,000,000	0.076	304,739,256	289,473,684	5,965	4,121,704	11,143,868
Shenzhen	75,000,000	0.165	516,671,789	455,927,052	8,804	31,419,692	29,325,045
Syndey	380,000,000	0.085	4,572,072,790	4,470,588,235	89,085	25,032,857	76,451,698
Brisbane	125,000,000	0.076	1,697,133,750	1,644,736,842	66,325	10,479,382	41,917,526
Auckland	125,000,000	0.138	950,510,385	905,797,101	59,521	16,665,860	28,047,424
Baiyun	50,000,000	0.063	891,212,838	793,650,794	17,066	38,433,533	59,128,512
Christchurch	33,000,000	0.138	260,374,022	240,000,000	45,764	7,276,436	13,097,585

Table F-14 Income and Cost Components of Selected Asian Airports, 2005

F.4 Logistics Industry

The data in Sections F.4.1 and F.4.2 are sourced from the Hong Kong Census and Statistics Department and the Singapore Department of Statistics respectively.

F.4.1 Hong Kong

Year	Number of Establishments					
	Air Freight	Land Freight	Supporting Land	Ocean Water	Supporting Water	Storage
1990	59	12,120	99	447	2,259	244
1991	57	14,328	97	392	2,112	222
1992	59	14,081	125	418	2,442	244
1993	63	14,868	139	517	2,755	249
1994	63	14,453	136	504	2,662	319
1995	61	14,001	132	475	2,886	312
1996	63	13,306	132	457	2,841	306
1997	74	11,482	151	493	3,157	267
1998	80	10,144	182	430	3,172	244
1999	80	9,069	173	510	3,173	238
2000	84	8,413	157	502	3,224	260
2001	90	8,705	163	506	3,429	250
2002	87	9,182	165	507	3,567	260
2003	91	9,563	165	468	3,595	267
2004	91	9,078	194	333	3,573	275
2005	83	9,177	139	329	3,659	275
2006	88	8,021	132	309	3,559	275

Table F-15 Number of Establishments in Hong Kong Logistics Industry

Year	Number of Employments					
	Air Freight	Land Freight	Supporting Land	Ocean Water	Supporting Water	Storage
1990	16,636	38,392	2,242	16,631	12,809	4,706
1991	20,509	39,606	2,739	15,769	11,474	5,055
1992	21,229	46,556	3,425	16,729	12,171	5,616
1993	22,333	45,583	3,836	17,643	13,888	5,391
1994	23,436	43,057	5,078	18,213	13,725	5,517
1995	24,021	42,658	5,524	17,466	15,169	5,852
1996	25,400	40,998	5,749	16,727	15,452	5,324
1997	25,862	33,974	6,895	16,176	16,341	5,360
1998	26,136	33,312	7,936	15,300	14,823	4,644
1999	24,742	30,221	7,717	14,265	15,470	4,340
2000	26,943	32,202	7,512	14,678	16,478	4,401
2001	27,332	31,542	8,286	14,897	17,077	4,119
2002	27,541	29,215	8,204	14,932	17,170	4,055
2003	27,389	31,637	8,117	15,694	17,066	3,984
2004	29,288	31,172	8,470	13,588	15,745	4,189
2005	30,834	22,233	7,300	14,465	14,918	4,189
2006	31,431	22,007	8,017	13,821	14,772	4,189

Table F-16 Number of Employments in Hong Kong Logistics Industry

Year	Amount of Value-Add (Million HK Dollars)					
	Air Freight	Land Freight	Supporting Land	Ocean Water	Supporting Water	Storage
1990	9,616	4,476	671	5,819	2,635	1,153
1991	10,492	4,659	797	7,541	2,537	1,255
1992	11,709	5,811	1,128	8,470	2,857	1,369
1993	11,711	6,910	1,270	9,731	3,334	1,268
1994	14,900	7,126	1,601	11,092	3,448	1,279
1995	15,222	7,462	1,819	11,487	3,823	1,545
1996	17,010	7,443	1,909	11,669	3,917	1,563
1997	16,880	6,729	2,241	11,854	4,341	1,385
1998	16,807	6,639	2,757	11,758	4,484	1,356
1999	20,180	6,047	2,887	12,692	4,167	1,116
2000	23,227	6,397	2,851	13,929	4,966	1,149
2001	20,894	5,646	3,016	12,760	5,084	944
2002	26,385	5,424	2,944	12,354	4,895	859
2003	22,695	5,521	2,805	15,283	4,893	974
2004	28,216	6,107	2,976	16,999	5,098	1,062
2005	30,894	5,589	3,084	16,113	5,113	1,062
2006	29,273	5,304	3,173	18,314	5,314	1,062

Table F-17 Amount of Value-Add in Hong Kong Logistics Industry

F.4.2 Singapore

Year	Air Freight	Land Freight	Supporting Land	Ocean Water	Supporting Water	Storage
			Number of Establishments			
1990	N.A.	2811	N.A.	430	703	180
1991	N.A.	3004	N.A.	438	776	169
1992	N.A.	3087	N.A.	430	848	154
1993	N.A.	3315	N.A.	520	776	192
1994	N.A.	3383	N.A.	555	961	197
1995	N.A.	3451	N.A.	589	1145	201
1996	53	3305	38	590	1058	224
1997	60	3679	40	584	1140	236
1998	58	3589	32	568	1158	180
1999	62	3708	30	574	1161	220
2000	61	3661	34	546	1161	220
2001	62	3955	38	525	1289	277
2002	49	4078	48	524	1352	291
2003	51	4215	52	536	1495	306
2004	62	4134	51	491	1642	288
2005	63	4007	49	505	1687	297
2006	63	3906	56	490	1668	334

Table F-18 Number of Establishments in Singapore Logistics Industry

Year	Air Freight	Land Freight	Supporting Land	Ocean Water	Supporting Water	Storage
			Number of Employments			
1990	N.A.	25,986	N.A.	4,835	16,062	1,745
1991	N.A.	26,143	N.A.	5,178	15,701	1,903
1992	N.A.	25,910	N.A.	5,550	16,017	2,166
1993	N.A.	27,181	N.A.	5,846	16,319	2,560
1994	N.A.	28,479	N.A.	5,511	17,474	3,246
1995	N.A.	29,777	N.A.	5,175	18,629	3,932
1996	13,756	28,718	1,079	6,172	18,500	3,742
1997	13,913	29,863	989	6,334	18,489	4,257
1998	13,832	29,509	1,089	5,797	18,301	4,070
1999	14,242	31,152	1,276	5,799	17,324	4,418
2000	14,739	31,654	1,117	5,203	17,866	4,966
2001	14,941	31,493	1,287	5,299	17,988	5,216
2002	14,421	31,943	969	6,334	19,910	3,784
2003	14,291	30,187	905	4,907	18,036	4,604
2004	14,628	28,494	683	4,649	16,528	4,705
2005	15,002	29,847	715	5,320	18,914	5,592
2006	15,780	29,017	725	5,954	20,621	6,264

Table F-19 Number of Employments in Singapore Logistics Industry

Year	Amount of Value-Add (Singapore Dollars)					
	Air Freight	Land Freight	Supporting Land	Ocean Water	Supporting Water	Storage
1990	N.A.	845,865	N.A.	968,199	1,486,568	175,513
1991	N.A.	995,789	N.A.	1,016,493	1,645,265	244,895
1992	N.A.	1,074,894	N.A.	893,636	1,781,968	252,843
1993	N.A.	1,182,487	N.A.	1,148,085	1,932,540	328,195
1994	N.A.	1,093,399	N.A.	931,309	1,799,042	312,807
1995	N.A.	1,595,555	N.A.	1,288,576	2,631,814	461,517
1996	2,541,892	1,605,919	57,512	1,353,669	26,252,333	477,503
1997	2,759,989	1,714,313	53,035	1,443,503	2,782,061	516,294
1998	2,648,162	1,779,343	59,171	1,029,081	2,901,688	580,261
1999	3,149,868	1,768,850	57,713	1,336,526	2,890,457	585,176
2000	3,310,108	1,937,402	55,689	2,199,187	3,027,492	611,429
2001	2,425,088	1,908,774	53,261	1,797,372	3,114,938	727,399
2002	2,414,089	1,813,376	55,975	1,245,729	3,134,997	715,366
2003	2,724,353	1,781,535	57,059	2,459,664	3,474,569	701,987
2004	3,692,483	1,848,310	86,658	3,824,449	4,006,616	692,797
2005	3,666,010	1,886,457	88,447	4,598,978	4,818,037	785,741
2006	4,060,212	1,961,853	62,123	3,159,629	5,459,395	875,825

Table F-20 Amount of Value-Add in Singapore Logistics Industry

APPENDIX G

AUTHOR'S PUBLICATIONS

Journals:

1. Low, J.M.W and Tang, L.C. (2006) Factor Substitution and Complementarity in the Asia Airports Industry, *Journal of Air Transport Management* 12, p.261-266

2. Low, J.M.W, Tang, L.C., Yuan, X.M. (2008) An Empirical Study on the Air Cargo Traffic Performances of East Asian Airports. *Journal of Air Transportation* (accepted)

3. Lam, S.W., Low, J.M.W, and Tang, L.C. (2008) Assessments of Operations Efficiency of International Airports in the Asia Pacific, *Transportation Research Part E*, doi:10.1016/j.tre.2008.11.003

4. Tang, L.C., Low, J.M.W., and Lam, S.W. (2008) Understanding Port Choice Behavior: A Network Perspective, *Networks and Spatial Economics*, doi:10.1007/s11067-008-9081-8

5. Low, J.M.W, Lam, S.W. and Tang, L.C. (2009) Assessment of Hub Status from a Network Perspective, *Transportation Research Part A*, doi:10.1016/j.tra.2009.04.004

6. Yuan, X.M., Low, J.M.W., and Tang, L.C. (2010). Roles of the Airport and Logistics Services on the Economic Outcome of an Air Cargo Supply Chain, *International Journal of Production Economics, forthcoming*

Book Chapters:

7. Low, J.M.W., Tang, L.C. and Yuan, X.M. (2009) Cargo Service Dynamics and Service Oriented Architecture in East Asian Airports, In *Service Science and Logistics Informatics: Innovative Perspectives* (editor: Zongwei Luo), IGI Global, Accepted

Conferences:

8. Low, J.M.W., Yuan, X.M., and Tang L.C., (2008) Performance Linkages between an Airport and the Air Cargo Supply Chain - Evidences from Hong Kong and Singapore. Proceedings of *6th IEEE International Conference on Industrial Informatics* INDIN (13-16 July 08), p. 1-26 Daejeon, South Korea

9. Yang X.J., Low, J.M.W., and Tang L.C. (2009) Asia Port Development. *International Symposium in Maritime Logistics and Supply Chain System,* 23-24 April 2009, Singapore

10. Low, J.M.W., and Tang, L.C. (2009) Economics of Port Development Strategies in Asia. *International Association for Maritime Economist* Conference 24-26 June 09, Copenhagen, Denmark