Title
World Port Institutions and Productivity: Roles of Ownership, Corporate Structure, and Inter-port Competition

Author
Cheon, SangHyun

Publication Date
2007

World Port Institutions and Productivity:
Roles of Ownership, Corporate Structure, and Inter-port Competition

by

SangHyun Cheon

Abstract

World Port Institutions and Productivity:
Roles of Ownership, Corporate Structure, and Inter-port Competition

by

SangHyun Cheon

Doctor of Philosophy in City and Regional Planning

University of California, Berkeley

Professor David E. Dowall, Chair

This dissertation conducts comprehensive analyses on global seaport institutions and port infrastructure productivity. It also examines the determinants of port output and the roles port institutions play in driving port infrastructure productivity. Specifically, the dissertation analyzes the roles of macro-, meso-, and micro-levels of institutional features of ports (inter-port competition, corporate structure, and port asset ownership practice). They are evaluated to understand *why* ports have become productive over the last decade and *how* those factors yield better opportunities for ports to prosper. While influences from external environments are still one of the important factors in shaping port efficiency, the roles of institutions play an increasingly important role, especially in the management of ports over the medium-long term. Furthermore, port efficiency has been shaped not only by macro-level market institutions (i.e. inter-port competition) but also by the capacity of port authorities to implement innovative institutional practices for port ownership and capital asset management.

While port managing institutions maintain a close relationship with their own

historical trajectories, global container ports in the contemporary era search for a *strategic flexibility with institutional bindings* to respond to external challenges and to overcome their limitations. This strategic flexibility can be partly achieved by "vertical unbundling" of container terminal operation functions from the government's hand and by private sector participation for investment in port assets, i.e. concessions or leases - institutional bindings based on neoclassical contracts.

From the view of regulators and policy makers, they should focus their policy making on environmental, safety, and customs regulations. They also need to create a competitive market to reduce oligopoly in the port sector by adopting diverse policy mechanisms. Given the competitive market structure, the business aspects of port operation can be better secured through diverse institutional mechanisms of private sector participation.

From the view of planners in port authorities facing global competition, the capacity of strategic planning to increase *strategic flexibility* of ports based on medium- or long-term scenarios is essential to achieve this institutional flexibility, thereby contributing to a higher productivity level of leading ports. This is a critical time for port authorities, managers, and policy makers to understand that they have a choice in what roles to play with what kinds of policy tools under the global pressure and rapidly transforming environments.

Chair Date

World Port Institutions and Productivity: Roles of Ownership, Corporate Structure, and Inter-port Competition

Research topic and methodology

I evaluate whether and how global port reform efforts since the early 1990s contribute to higher port infrastructure efficiency. By examining determinants of port output and efficiency, it focuses on roles of port institutions and international geography in driving port infrastructure productivity. Specifically, I analyze the role of macro-, meso-, and micro-levels of institutional and spatial features of ports (inter-port competition, corporate structure, and port asset ownership practice). These are significant variables to understand *why* ports have become efficient over the last decade and *how* those factors yield better opportunities for ports to prosper.

I adopt a combination of quantitative and qualitative methods: first, an empirical and historical survey on ownership and corporate structure of approximately 150 global seaports; second, non-parametric mathematical programming models, Data Envelopment Analysis (DEA) and Malmquist Total Factor Productivity Index, to benchmark port efficiency and temporal efficiency changes; third, multivariate analyses to examine the roles of port institutions and geography on port productivity.

Key findings

My dissertation confirms that, in order to become competitive in the international market, contemporary container ports need to structure themselves as large-scale logistics hubs that are substantially integrated into global supply chains. Yet, port infrastructure efficiency has been shaped not just by macro-level market structure and external forces (i.e. globalization and inter-port competition) but also by the capacity of port authorities to implement innovative institutional practices for port ownership and capital asset management. Interestingly, as globalization took stronger initiative in the international shipping and logistics markets during 1990s, the roles of institutions become increasingly important in shaping port efficiency.

While port managing institutions in many countries maintain a close relationship with their own historical trajectories, global container ports in the contemporary era search for a *strategic flexibility with institutional bindings* to respond to external challenges and to overcome geographical limitations. In particular, many global container ports can partly achieve this strategic flexibility by exercising vertical unbundling of container terminal operations functions from the government's hand and promoting private sector participation for investment in port assets, i.e. concessions or leases. These sorts of institutional bindings, based on neoclassical contracts, are one of main drivers that allow major world ports to shape their strategies more flexibly, given the more severe competition in the shipping industries.

Finally, observing lower efficiency of public-operated ports, I emphasize the roles of inter-port competition and strategic planning in shaping better institutional practices and overcoming external limitations. Many successful ports are equipped with the ability to accurately anticipate changing demands of container freight and strategically mobilize their capital inputs and investment in technology to attract and satisfy trade demands.

Innovative aspects of dissertation

My dissertation contributes to research in transportation science and policy and international shipping economics by suggesting several new approaches:

First, previous research has focused on the dichotomy of public vs. private ownership in analyzing the impact of seaport institutions on port efficiency. However, my work analytically clarifies and refines definitions of different aspects of port institutions. Thereby, this research

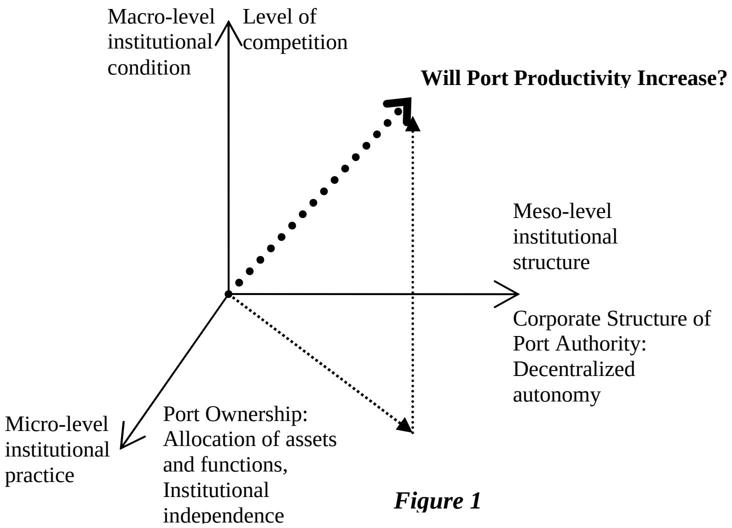


Figure 1

considers the effects of market structure (inter-port competition) in examining the influence of port ownership and corporate structure on port efficiency, as it tests hypotheses in Figure 1. Second, my research can suggest an innovative way to capture an intensity of inter-port competition facing ports, based on concepts of spatial competition and continuous measures of hinterland sizes. Third, my research is an effort to systematically apply comparative frameworks of port efficiency and efficiency changes to a global seaport database. In order to do so, I create an original database that includes information on global port institutions (e.g. ownership and corporate structure). It is particularly meaningful given that previous research in the field has suffered from a lack of comprehensive data on these issues and has been limited to applications of the comparative frameworks to a smaller number of countries in a region. Finally, by systematically analyzing the complex relationships between port output, efficiency, geography, and institutions through triangulation of multiple methods, the dissertation can suggest policy implications in the following:

From the view of regulators and policy makers, they should focus their policy making on environmental, safety, and customs regulations. They also need to come up with strategies to transform their traditionally oligopolistic port sectors into a more competitive market by adopting diverse policy mechanisms. The business aspects of container terminal operation can be better secured through diverse institutional mechanisms of private sector participation, if the competitive market structure is given. From the view of planners in port authorities facing global competition, the capacity of strategic planning to increase strategic flexibility of container ports based on medium- or long-term scenarios is essential to achieve this institutional flexibility, thereby contributing to a higher productivity level of leading ports.

Key references

Cook, Wade D. and Joe Zhu. 2005. *Modeling Performance Measurement: Applications and Implementations Issues in DEA.* New York: Springer.

Cullinane, Kevin, Song, DW, Ji, Ping and Wang, Teng-Fei. 2004. “An application of DEA Windows analysis to container port production efficiency.” *Review of Network Economics* 3, no. 2: 184-206.

Erie, Steven P. 2004. *Globalizing L.A.: Trade, Infrastructure, and Regional Development.* Stanford, CA: Stanford University Press.

Estache, A., Gonza´lez, M., and Trujillo, L., 2002. “Efficiency gains from port reform and the potential for yardstick competition: lessons from Mexico.” *World Development* 30 (4), 545–560.

Gómez-Ibáñez, Jose. 2003. *Regulating Infrastructure: Monopoly, Contracts, and Discretion.* Cambridge, MA and London: Harvard University Press.

Jasinski, P. and G. Yarrow. 1996. *Privatization: Critical Perspectives on the World Economy.* London: Routledge.

To HIM

World Port Institutions and Productivity:
Roles of Ownership, Corporate Structure, and Inter-port Competition

Table of Contents

Appendix:

List of Figures

List of Tables

Acknowledgements

To be sure, I could not have proceeded with this research without the support of everyone who has influenced my life and thoughts for the past several years here at Berkeley. I would like to express my gratitude to all those who gave me the opportunity to complete this PhD dissertation:

I am deeply indebted to my advisor and dissertation chair, David Dowall, who provided me with continuous encouragement, guidance, and companionship. These three words simply cannot fully describe what he intellectually and personally showed me, about which I could easily go on for several pages. Professor Betty Deakin treated me with respect and encouraged me to move ahead whenever I felt discouraged due to personal, financial or academic barriers. It was a privilege for me to meet and work with her. Professor You-Tien Hsing showed me limitless support for my research and taught me comparative perspectives of different worlds. I also thank Professors AnnaLee Saxenian and Fred Collignon for helping me to shape my areas of expertise and to design the topic of this dissertation. Outside of UC Berkeley, I thank Professor Dong-Wook Song, at Heriot-Watt University in the UK, for his friendship and guidance in the professional field of maritime and port research.

I appreciate my colleagues' discussions and comments on my research, and I thank my friends and DCRP staff for continuously supporting me. Kyoung-Mun, who is now in Cambridge, spent much of his time helping me to put together original data, and analyzed them with me to confirm their validity. Discussions with Bumsoo in Los Angeles, Dae-Hwan in Richmond and Jung-moh (now in Seoul) allowed me to clarify strategies to implement my econometric data analysis. Young (now in Dae-duk), Muhammad (now in Alexandria) and Gerardo in Sacramento gave me their support on various issues. I also thank my colleagues and friends at Berkeley (Sungjin, Chang-Deok, Jumin, Brad, Yasuyuki, Liang-Chih, and Ki Won), my friends in Seoul (Jinho, Hyun-Gon, and Seung-Min), Mintai in Tucson, Manish in India and Joori in Los Angeles, for their continuous support over the past few years. Especially, I should express my sincere appreciation and grief for the late Ms. Kaye Bock, who passed away on January 17, 2007. She was one of my best supporters throughout my entire PhD life at Berkeley.

During my research I have had the fortunate opportunities to exchange ideas with many wonderful commentators and interviewees working in ports and research and consulting institutions around the world, and other international development agencies and governments (e.g. Informa, Drewry, Institute of Shipping and Logistics, and Lloyd's Register Fairplay, World Bank, Asian Development Bank, UNCTAD, and Productivity Commissions in Australia, OECD). While I cannot mention all their names here, it would not have been possible to conduct my research without their insight, comments, and help.

Furthermore, this dissertation would have been impossible without funding support from the Department of City and Regional Planning (Block Grants), the UC Berkeley's

Graduate Division (Academic Progress Award, Normative Time Fellowship, and Summer Research Grant), the University of California's Transportation Center (Dissertation Fellowship), and the Pacific Rim Research Program Award.

Above everything else, this is an opportunity to show my gratitude and respect for my mom (Bong-ah) and dad (Sun-ok). They have always encouraged me and showed me their love, trust, and patience for whatever I have done. I also thank my mom-in-law (Youngja), aunt (Bongsoon), uncle (Byung-seok), Jinah, Byung-soo, Seong-yeon, and Hyung-jin for their limitless love and support, although I could hardly repay them for that. Especially, I also thank Paster Hoon Bae from the Richmond Church for his continuous prayers for my family.

Last, first and most important, I thank my wife, SungKyung, for all the things that she has done for me. They are beyond counting. She has gone through a great many hardships in her life to support me since we came to the US. She is also my best friend and strategic advisor for life. She is the treasure of my life. There is no way I can approach her confidence and determination. It is certainly impossible to pay back the debt I owe to her.

CHAPTER 1

Development of Contemporary Global Shipping and Seaport

1.1 Introduction

In the early period of the 20th century, seaports bustled with longshoremen, stevedores, and dockers unloading millions of tons of general cargo, lumber, and ore. Numerous workers and fishermen in canneries were engaged in catching and processing tuna and salmon. Active and vivid commercial quarters mushroomed adjacent to ports to serve these workers as well as sailors that would stay around the ports about a couple of weeks at a time.

The 1954 Elia Kazan's Academic Award-winning film, *On the Waterfront*, shows New York's paradoxical waterfront docks where longshoremen struggled for their living, dignity, and ethics, while the docks were fully infiltrated by militant trade unionism, corruption, and organized crime. The movie's story was formed on the basis of an investigative journalist, Malcolm Johnson's 24-part series, *Crime on the Waterfront* that won the Pulitzer Prize for Local Reporting in 1949. On November 8, 1948, Johnson (2005, 3) noted that in *The Sun*, "[t]he fact that lawlessness and racketeering on New York's waterfront is nothing new…The point is that for many years little or nothing has been done to bring law and order and efficiency to the waterfront."

In the 1986 documentary film directed by Berry Minott, *Longshoremen and Automation: the Changing Face of the Waterfront*, the story revolved around gang workers who faced inevitable pressures to "mechanize" ports since the late 1960s and felt the nostalgia for the old days. The film describes a container as a "coffin" for longshoremen's way of life – "pride" and "sociability." Yet it also depicts those parts of a dockers' life in the pre-containerization era portrayed by their drinking during work hours and stealing cargos such as Chilean wines. Overall, the director shows how technology can atomize sociability of work on the waterfront in a bit romantic way.

Today, ports may seem very different from the old days, almost serene by comparison, while the largest container complex in the United States handles more than 3000 vessel-arrivals a year. Some of the vessels carry more than 5,000 to 6,000 containers for each trip. A documentary by the Travel Channel, *Monster Seaports*, aired in February 2004, illustrating how large volumes of passengers and cargoes are moved efficiently and how mega size container and cruise ships are serviced with diverse operational technology deployed in the port terminals of New York, Oakland, Los Angeles, Long Beach, Rotterdam, and Everglades. It shows that ports have become a gateway for globalized commerce and an economic engine for regions, thereby requiring strong competitiveness in order to rival with other ports under severe global competition.

This study is interested in examining why global seaports show different competitiveness and how port infrastructure achieves its productive efficiency. More specifically, this study attempts to understand: "what forces have shaped port competitiveness and productivity under the contemporary global shipping and seaport sector?" and given the current nodes and networks, "what role does the institutional structure of seaports play, together with differing managerial & institutional practices, in confronting external conditions and in determining the status of ports?" Focusing on the port sector, the relationship among variables such as private sector participation, corporatization, market structure, port strategy, and locational advantage will be explored in order to evaluate how their interplay contributes to port infrastructure productivity and competitiveness.

1.2 Development of Global Shipping and Seaport Sector

As nations, regions, and localities are significantly influenced by "global" forces, they are more and more embedded in international trading systems. From 1985 to 2000, world seaborne trade has increased annually (UNCTAD 2002). In the US, the share of Gross National Product (GNP) exported has doubled over the last two decades. Within the global trading systems, workers and industries in localities and regions face the enormous pressure of international and interregional competition, and therefore international trade and trade policy becomes an extremely important element of economic development (Howes and Markusen 1993).

The success or failure of trade is influenced, if not determined, by the availability and efficiency of transport systems. Without the systems ensuring effective physical access to international markets, localities and regions cannot be successfully engaged in global trading chains. In particular, the larger portion of freight cost in import values can indicate that high transport cost may deter countries from participating in regional and global trade effectively. It is in this context essential to retain timely and reliable service provisions of trade-related transport infrastructure. There exists, therefore, huge demand in most of countries to expand, rehabilitate, and better maintain their physical underpinning of trade such as airports, seaports, and railways, in order to support and propel their economic development.

Despite the importance of reliability and speed of trade-supporting physical infrastructure systems, numerous seaports over the world show the signs of aging; airports suffer from congestion, and railways do not provide effective "just-in-time" delivery of goods for businesses and consumers. The poor performance of transport infrastructure produces excessive transport costs for many developing and developed countries. While the worldwide average freight costs is 6 per cent of import value, some land- or sea-locked countries with unfavorable transport infrastructure conditions bear the costs of 12 to 40 percent of import value (UNCTAD 2001a; UNCTAD 2001b; UNCTAD 2003). It directly and adversely affects the competitive position of these countries in international markets and the delivery of essential goods for people.

Ports provide the direct linkage from international to regional and local transport systems. With this role of ports, their performance is a significant determinant of a region's or a locality's successful engagement in global trade development. There is thus a huge interest amongst port authorities in increasing port throughput and performance. They need to effectively compete with other neighboring ports, on the one hand, dealing with growing pressure from shippers for lower port and shipping charges. On the other hand, by improving their performance, ports can encourage the integration of local and regional economy into global supply chains and thus stimulate structural changes of the economy.

Seaports are complex systems that continuously need large amounts of public or private investment. An analysis shows that total world container throughput will reach more than 360 million TEU[1] by the end of 2007, with an average 6.6 percent of annual growth rate (DSC 2002). Based on the confirmed plans for port expansion, global container port capacity will increase to 450 million TEU by 2007 from 351 million TEU in 2001. Total investment requirements will be approximately US$ 14 billion to meet the global demand, if current levels of port performance and utilization are retained (see Table 1.1). This investment will be directed to provide more than 5,000 ha of container yard, 930 ship-to-shore cranes, and 144 km of additional quayline. In addition, US $ 2.8 billion would be additionally needed for yard equipment globally.

Table 1.1: Container Terminal Investment Requirements from 2002 to 2007[2]

Region	Additional throughput estimated by 2007 (Million TEU per annum)	Investment required for Quay, Yard, and Cranes (US$ billion)
North America	8.3	1.56
West Europe	14.6	2.10
Far East Asia	38.7	4.44
South East Asia	31.3	2.87
Middle East	4.1	0.48
Latin America	9.7	1.51
Oceania	1.2	0.23
Africa	2.9	0.47
East Europe	0.8	0.19
World	111.5	13.85

Part of such demand can be accommodated by current spare capacity. Yet, as the location and suitability of this capacity are not precisely matched, huge investments still need to be made. Table 1.1 shows that Asian Pacific region – Far East Asia and South

[1] Twenty-foot equivalent unit. A standard linear measure used to quantify container flows. Containers generally come in three sizes: twenty, forty, forty-five feet.
[2] Assuming unchanged terminal performance benchmarks and average utilization levels. Source: Reorganized from (Drewry Shipping Consultants 2002)

East Asia – requires the largest investment. In order not to waste public resources, the optimization of port infrastructure becomes extremely considerable.

The productivity of massive investments that can establish port performance has a direct influence not only upon the financial strength of port authorities but also on the fiscal sanguinity of local and state governments associated with the port authorities. Numerous poorly-managed infrastructure systems, with little effective planning and strategies, suffer from large debts accumulated over time and impair the ability of attaining substantial social return on public investment, attracting Foreign Direct Investment (FDI), and making the best use of public resources. Developing strategies with comprehensive views of planning on infrastructure investment and management are vital elements for efficient and equitable allocation and spending of public resources.

The current level of global interactions induces seaports to better perform as a fundamental link in the overall trade chain so that surrounding localities can gain comparative advantage. In order to develop a competitive edge in the global markets and to maintain the dynamism of local, regional economy, it is critical to understand factors that determine efficiency and competitiveness of trade-related transportation infrastructure - seaports in this thesis. A continuous assessment of the port performance and productivity will allow policy makers to devise appropriate strategies for sustainable economic development.

1.3 Contemporary Trends in the International Port Sector

Let us expand our observations for the trends in the global seaport sector that are partly discussed in the sections 1.1 and 1.2. This section summarizes diverse aspects of technological and institutional changes in the last decades occurred in the sector, while the next section discusses about the performance gap between seaports during the period.

Technological change: Containerization and new managerial technology

The port industry has undergone rapid technological innovation for the last a few decades. On the one hand, containerization has emerged in the 1970s as part of the infrastructure needed to accommodate the expansion of trade, and has influenced most of "gateway" ports and surrounding regions (Campbell 1993). On the other hand, a number of managerial technologies such as EDI (Electronic Data Interchanges) in port services continuously contribute to improvement of port efficiency.

Globalization and port: Increasing seaborne commerce and international shipping

World seaborne trade has continuously increased consecutively from 1986 to 2000 and recorded 5.83 billion tons of exported goods in 2001. The average annual growth rate for the last 30 years was about 4 percent. Forecasts indicate that annual growth rates would probably even higher for the next twenty years, and therefore, there will be substantial increase in volume of international shipping (UNCTAD 2002).

Continuing integration of transport modes and services

The creation of intermodal transports and routes has stimulated competition between ports to attract more ship calls and cargo. Furthermore, the development of the "door-to-door" movement has changed the function of ports from a node to transfer cargo between transportation modes to a link in the transport chain. There is a strong need to promote the integration of the ports into the logistics chain connecting forwarders/transport companies. These companies demand port authorities to provide better service at lower price, and they exercise stronger power in their negotiations with ports for the level of services and port charges.

Deregulation and institutional reform in the port sector

Institutional reform in the port sector and, in fact, in many infrastructure sectors, is underway at the national and state government level in many countries. The intended objectives are to increase efficiency and to enhance the quality of services by improving the management of ports with more responsiveness to the needs of port users. The reform efforts are in general directed to the following (ADB 2000):

a. Decentralization of the port system by granting financial and operational autonomy to individual ports, thereby reducing the influence of politics
b. Separation of regulatory and management functions
c. Commercialization of management functions which is encouraged or enforced by the introduction of commercial accounting systems at the national and state level i.e. legislation for accrual accounting, valuation, and capitalization on the public infrastructure assets

d. Improved access to long-term capital such as commercial loans, debentures, and project finance
e. Conversion of port authorities to share companies with an option for public ownership of the shares

Growing private sector participation

Private sector participation in port management and investment has been increased over the last two decades. The port privatization has rarely involved pure privatization as land and basic infrastructure are rarely put up for sale. The practices and processes of private participation are not uniform in the sense that the activities of ports are complex and the services they provide diverse. Yet the transfer of cargo-handling activities to the private sector has been in most cases accomplished through:

a. mainly through contractual arrangement: service contracts; franchises: capital leases; concessions[3]; and
b. partly through the sale of port assets.

Investment in new facilities and services can be made through private sector participation, when the public sector rehabilitates and expands existing assets and services. Private investments in port projects increased from $10 million in 1991 to $4.3 billion in 1997. During the 1990s, a cumulative amount of $12 billion has been invested by the private sector in numerous port projects (World Bank 2001). The private sector

[3] While capital leases are relatively short-term arrangements allowing for service reorganization, concessions are used as long- term arrangements to encourage private investment and service improvement.

participation diversifies the sources of financing and transfers the commercial risk of port operation to the private sector, while the public sector retains the regulatory control and risk.

Although the role of the public and private sector in port investment will vary from port to port, it is argued that privatization must be accompanied by strong policies and appropriate regulations to ensure competitive market environments and to address equity concerns of service distribution (ADB 2000). Therefore, in the port sector, the public authorities and governments generally retain responsibility for the regulation of the port and the provision of basic port infrastructure, while the private sector is responsible for operation, management, and provision for mobile assets.

Emerging importance of strategic management

Due to the complexity involved in port development and management, it is crucial for port authorities to have (a) the ability to determine the efficiency of existing assets, and (b) the capacity to procure new assets on time. Failures to anticipate future bottlenecks and shortages in capacity critically influence the port efficiency and performance. Many port authorities and governments have neglected the sector planning and strategic management for port investment and management and, therefore, offered ports assets and services to the port users in an ad hoc manner.

The basic infrastructure assets in ports require a long period for cost recovery. Moreover, it is often difficult to charge effectively for the use of this infrastructure.

Strategic management is thus important to encourage efficient capital investment. While there are conflicting views on the centrality of the role of port strategy and management in determining port performance[4], concerns are growing on the capacity of governments and port authorities to design and implement effective strategic planning for the port development.

[4] See the section 2.2 in Chapter 2, "Why some ports outperform others?" for the full-fledged discussion on the topic.

1.4 Differing Port Performance

1.4.1 Total throughput

As shown in Table 1.2, based on total container traffic handled, ports in Singapore and some other Pacific Rim countries such as Hong Kong, Korea, Taiwan, and the US have been the leading ports. Since the Port of Singapore has been also ranked in top 1 for break-bulk cargo volume, it has been the top leader in total port throughputs. In the US, two ports - Port of Los Angeles and Long Beach – had been ranked within top 10. If they are combined, their total container traffic handled was ranked in top 3 in 2001 and is now ranked top 5 in the world in 2004. Recently, the development of many Chinese ports is impressive. Their growth rates are much higher than other traditional leading ports.

Table 1.2: Ranking of Total Port Throughput in 1997, 2000, 2004[5]

Container Traffic Twenty Foot Equivalent Units (TEUs)				**Total Cargo Volume** Metric Tons (000s)	
Port	Yr 2004 (Rank)	Yr 2000 (Rank)	Yr 1997 (Rank)	Port	2000 (Rank)
Hong Kong, China	21,932,000 (1)	18,098,000 (1)	14,567,231 (1)	Singapore	325,591 (1)
Singapore, Singapore	20,600,000 (2)	17,090,000 (2)	14,135,300 (2)	Rotterdam	319,969 (2)
Shanghai, China	14,557,200 (3)	5,613,000 (6)	2,519,592 (11)	South Louisiana, US	197,680 (3)
Shezhen, China	13,650,000 (4)	n.a.	n.a.	Shanghai	186,287 (4)
Busan, Korea	11,430,000 (5)	7,540,387 (3)	5,233,800 (5)	Hong Kong	174,642 (5)
Kaohsiung, Taiwan	9,710,000 (6)	7,425,832 (4)	5,693,339 (3)	Houston	173,770 (6)
Rotterdam, Netherlands	8,281,000 (7)	6,274,000 (5)	5,494,655 (4)	Chiba, Japan	169,043 (7)
Los Angeles, US	7,321,440 (8)	4,879,429 (7)	2,959,715 (9)	Nagoya	153,370 (8)

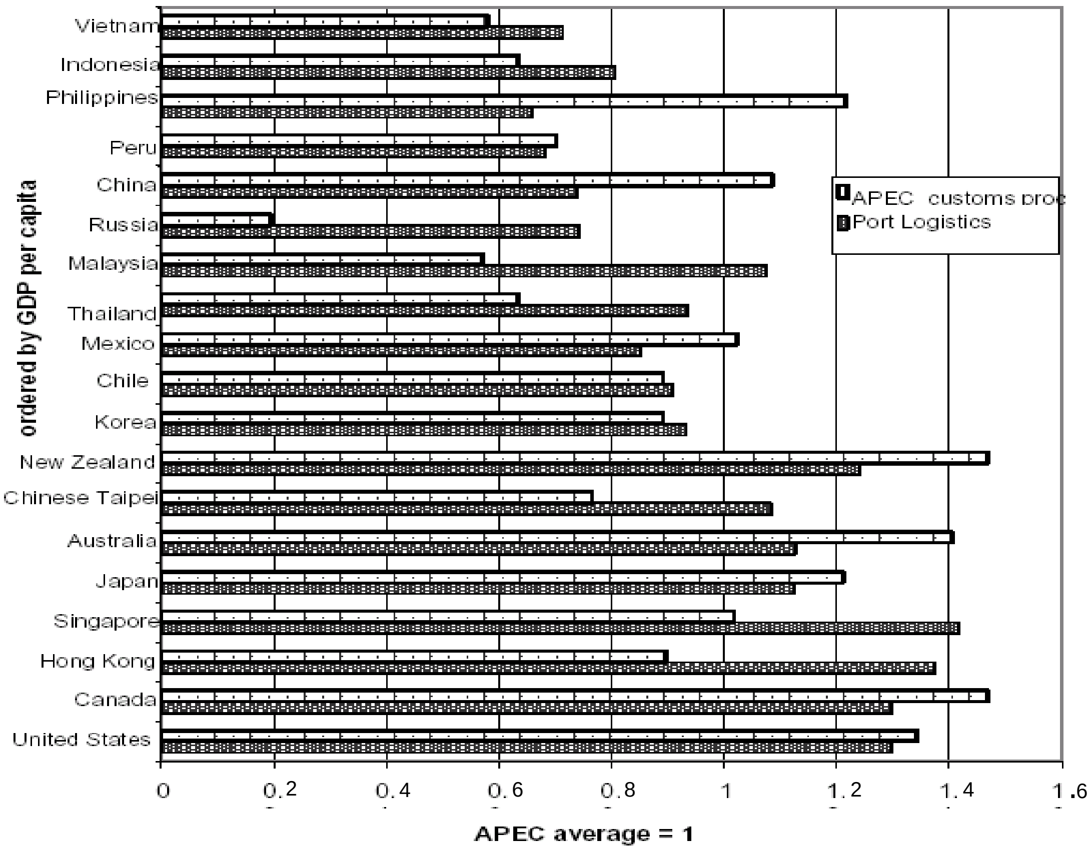
[5] Main source: CI-Online. For the data not available from CI-Online, source: UNCTAD (2002), UNCTAD (2001a) derived from *Container International Yearbook* and *Port Development International*; American Association of Port Authorities Website derived from *Shipping Statistics Yearbook 2001*; and Trujillo and Nombela (2000) cited from Cass, S. 1996. *Port Privatization: Process, Players, and Progress*. London: IIR Publications.

Hamburg, Germany	7,003,479 (9)	4,248,247 (9)	3,337,477 (7)	Ulsan, Korea	151,067 (9)
Dubai, UAE	6,428,883 (10)	3,058,866 (13)	2,600,085 (10)	Kwangyang, Korea	139,476 (10)
Antwerp, Belgium	6,063,746 (11)	4,082,334 (10)	2,969,189 (8)	Antwerp	130,531 (11)
Long Beach, US	5,779,852 (12)	4,600,787 (8)	3,504,603 (6)	NY / NJ	125,885 (12)
Port Kelang, Malaysia	5,243,593 (13)	3,206,753 (12)	1,684,508 (23)	Inchon, Korea	120,396 (13)
Quingdao, China	5,139,700 (14)	2,120,000 (24)	1,030,000 (35)	Busan	117,229 (14)
NY / NJ, US	4,478,480 (15)	3,050,036 (14)	2,456,886 (12)	Yokohama	116,994 (15)
Tanjung Pelepas, Malaysia	4,020,421 (16)	418,218 (115)	n.a.	Kaohsiung	115,287 (16)
Ningbo, China	4,005,500 (17)	902,000 (66)	n.a.	Guangzhou, China	101,521 (17)
Tianjin, China	3,814,000 (18)	1,708,000 (32)	935,000 (*)	Quinhuandao, China	97,433 (18)
Laem Chabang, Thailand	3,624,000 (19)	2,105,262 (25)	1,104,500 (33)	Ningbo, China	96,601 (19)
Tokyo, Japan	3,580,000 (20)	2,898,724 (15)	2,322,000 (14)	Marseilles, France	94,097 (20)
Bramerhaven, Germany	3,469,104 (21)	2,712,420 (17)	1,706,423 (21)	Osaka	92,948 (21)
Guanzhou, China	3,308,200 (22)	1,429,900 (38)	n.a.	Richards Bay, South Africa	91,518 (22)
Gloia Tauro, Italy	3,261,034 (23)	2,652,701 (18)	1,448,531 (28)	Kitakyshu, Japan	87,346 (23)
T. Priok, Indonesia	3,248,149 (24)	2,476,152 (19)	2091,402 (17)	Quingdao	86,360 (24)
Algeciras, Spain	2,937,381 (25)	2,009,122 (26)	1,537,627 (24)	Hamburg	85,863 (25)
Xiamen, China	2,871,200 (26)	1,084,700 (49)	n.a.	Dalian, China	85,053 (26)
Felixtowe, UK	2,700,000 (27)	2,793,217 (16)	2,222,726 (15)	Kobe	84,640 (27)
Manila, Philippines	2,629,340 (28)	2,288,599 (21)	2,121,074 (16)	Tokyo	84,257 (28)
Jeddah, Saudi Arabia	2,425,930 (29)	1,043,617 (53)	920,861 (40)	New Orleans	82,400 (29)
Jawaharlal Nehru, India	2,2,68,989 (30)	889,978 (67)	423,148 (82)	Dampier, AUS	81,448 (30)
Yokohama, Japan		2,317,393 (20)	2,347,635 (13)	Corpus Christi, US	75,461 (32)
Kobe, Japan		2,265,992 (22)	1,944,147 (19)	Beaumont, US	75,032 (33)
Yantian, China		2,139,680 (23)	638,396 (57)	Newcastle, AUS	73,871 (34)
Keelung, Taiwan		1,954,573 (27)	1,978,594 (18)	Tubarao, Brazil	73,482 (35)
Nagoya, Japan		1,904663 (28)	1,498,137 (26)	Tianjin	72,980 (36)
San Juan, US		1,884,494 (29)	1,914,828 (20)	Vancouver, Canada	76,646 (31)
Oakland, US		1,776,922 (30)	1,531,188 (25)	Port Hedland, AUS	72,914 (37)
Colombo, Sri Lanka		1,732,856 (31)	1,687,184 (22)	Hay point, AUS	69,379 (38)
Charleston, US		1,629,070 (33)	1,151,401 (32)	Le Havre	67,492 (39)
Genoa, Italy		1,500,632 (34)	1,179,954 (31)	Port Kelang	65,227 (40)
Seattle, US		1,488,020 (35)	1,455,814 (27)		
Osaka, Japan		1,4,74,201 (36)	1,200,000 (*)		
Le Havre, France		1,486,108 (37)	1,185,000 (30)		
Barcelona, Spain		1,363,695 (39)	971,921 (36)		
Tacoma, US		1,376,379 (40)	1,159,000 (*)		
Cristobal, Panama		1,353,727 (41)	128,494 (171)		
Virginia, US		1,347,364 (42)	1,232,725 (29)		
Melbourne, Australia		1,327,789 (45)	970,255 (37)		
Bangkok, Thailand			1,099,005 (34)		
Durban, South Africa			984,000 (38)		
Southampton, UK			890,364 (41)		
Montreal, Canada			870,368 (42)		
Taichung, Taiwan			841,970 (43)		
Valencia, Spain			831,510 (44)		
Santos, Brazil			629,486 (59)		
Houston, US			935,600 (39)		
Sidney, Australia			765,000 (*)		
Miami, US			685,000 (51)		

1.4.2 Port efficiency

APEC (2002) developed port efficiency index measuring infrastructure quality, direct customs costs, and customs procedure efficiency for its member countries' ports.[6]

Figure 1.1: Port Efficiency Index 2000: Ports and Customs Measures



According to the country level index (Figure 1.1), Singapore is still the top leader. US, Canada, and Hong Kong show also relatively high levels of efficiency in the port sector. It is interesting that Australia and New Zealand are very high-ranked in terms of their

[6] This index is based on previous efforts of developing port efficiency index: (1) Clark et al. (2002); (2) Surveys from Global Competitiveness Report (1996-2000) by Harvard University and World Economic Forum.

port logistics efficiency, while the total throughput handled in their largest ports are ranked in the top 40 to 50 level. While it is plausible to assume that many ports in these countries show differing levels of port efficiency depending on such factors as location, organizational structure, and the level of involvement in regional trade, yet a comprehensive database containing the statistics of port-level efficiency is not currently available to the public.

1.4.3 Container handling charges

Table 1.3 shows that there are substantial gaps in the levels of container handling charges across the world-class ports, which can be interpreted as one proxy statistics of port performance and efficiency.[7] While some Asian Pacific ports, in particular Singapore, are the top leading performers in lowering their container handling charges, the US Pacific Rim Ports are laggers in comparison.

Australian ports such as Sydney, Melbourne, and Adelaide are medium performers in terms of container handling charges in 1995-1996, but this statistics does not reflect the results of their corporatization implemented since 1996. The port of Auckland in New Zealand, corporatized in 1988, earlier than Australian ports, shows lower container handling charges than Australian ports. Many North European ports have relatively inexpensive container handling charges, even though they are not the top leading

[7] In terms of container handling charges of ports, relatively old statistics are publicly available.

performers in this index. Yet South European ports are mostly behind in lowering the container charges.

Table 1.3 Container Handling Charges across World Regions in 1995, 1996, 2001[8]

Region	Port	Container Handling Charges,1996[9] (US$ per loaded TEU)	Water Front Charges,1995[10] (AUS$ (US$) per loaded TEU)	Container Handling Charges, 2002[11] (US$ per TEU)
Asia	Singapore	US$117	A$180 (US$118)	US$ 117
	Manila	US$118		US$ 118
	Port Kelang		A$120 (US$80)	US$ 75
	Kaohsiung	US$140		US$ 140
	Pusan	US$175		
	Hong Kong		A$295 (US$195)	
Australia & New Zealand	Adelaide		A$275 (US$180)	US $ 199
	Sydney		A$290 (US$190)	US $ 199
	Melbourne	US$199	A$295 (US$195)	US $ 199
	Auckland		A$215 (US$140)	
North America	Halifax	US$168		US$ 190
	Oakland		A$380 (US$250)	US$ 259
	Los Angeles	US$256		US$ 259
North Europe	Antwerp	US$120		US $ 120
	Zeebrugge	US$123	A$160 (US$105)	US $ 120
	Rotterdam	US$156		US $ 156
	Felixstowe	US$173		US $ 173
	Hamburg	US$182		US $ 163
South Europe	Algeciras	US$193		US $ 200
	Pireus	US$203		
	Barcelona	US$211		US $ 200
	Marseilles	US$233		
	La Spezia	US$240		US $ 228

[8] Source: Reorganized from Clark et al. (2002; 2004) derived from the World Bank internal data; Trujillo and Nombela (2000) derived from Drewry Shipping Consultants (DSC). 1998. *World Container Terminals: Global Growth and Private Profit*; and Meyrick & Associates and Tasman Asia Pacific (1998:8) derived from Bureau of Industry Economics. 1995. *International Performance Indicators: Waterfront 1995*.
[9] Source: Trujillo and Nombela (2000).
[10] Source: Meyrick & Associates and Tasman Asia Pacific (1998) Water Front Charges include pilotage, towage, mooring, navigation, berthage, wharfage, and stevedoring charges for 17000 GRT vessel with a container exchange averaged over 200, 400, 600, 800 and 1000 TEUs. While it is unsure whether water front charges in this report are calculated with the same definition and method of Cargo Handling Charges in Trujillo and Nombela (2000), the two statistics appear to be compatible as some overlapped port charges show similar values.
[11] Source: Clark et al. (2002; 2004), national averages

1.5. Organization of Dissertation

With the issues in mind raised in the previous sections, this study examines port competitiveness, sources of port infrastructure productivity, and roles of institutions in shaping port productivity. The study is divided into eight chapters that are organized as three different parts in this dissertation: For Part I including Chapter 1, 2, and 3, the main focus is placed on understanding the current global system and the performance gap in the world container port sector (Chapter 1), defining and clarifying theoretical concepts regarding container port performance, competitiveness, and port infrastructure productivity (Chapter 2), and proposing a research design and frameworks to probe major empirical research inquiries and hypothesis tested for this study (Chapter 3).

Part II includes three different chapters that investigate the independent and the dependent variables of this study. Chapter 4 mainly addresses issues and frameworks for and results from surveying and analyzing such ports' institutional features as port corporate management structures, asset ownership practice. The chapter also details regional differences and similarities of the port institutions and temporal changes over the last decade. Chapter 5 firstly attempts to clearly conceptualize the concept of port productivity and efficiency and the ways they can be measured, and secondly, present analyses for cross-sectional and temporal benchmarking of productive efficiency of global seaports based on the concept of relative efficiency through Data Envelopment Analysis (DEA). Chapter 6 deepens the benchmarking by introducing the contexts of temporal changes of port efficiency since the 1990s through by presenting Malmquist Productivity Index (MPI).

In Part III, lastly, this study attempts to comp up with a final analytical interface between port institution and productive port efficiency and competitiveness in Chapter 7. Several approaches through bivariate analyses and the multivariate models are developed and presented to investigate what factors can determine higher port productivity and what role port institutions play in improving port output and productivity, given the contemporary global port system. This study concludes with a summary of findings and policy implications in Chapter 8.

CHAPTER 2

Review of Theory and Defining Concept

2.1 What is a Port and What does it do?

> "Basically the port does *only one thing*…; it may also do it in a myriad different ways. Unlike a factory a port has no end product – it provides services and facilities for ship turn around. In short, it *picks up and puts down* again millions of single packages. Each picking up and each putting down advances the cargo units one stage on its journey from the factory to the shop counter or as part of its transfer from raw materials to finished article." [Emphasis mine]
>
> (Oram and Baker 1971, 4)

Oram and Baker (1971) straightforwardly state the view on a major function of ports in the 1970s, which may not closely reflect an up-to-date view on contemporary ports. While the ports in the peak of the mass production era might function for only one thing, the contemporary ports are viewed as integration of complex activities including manufacturing and logistics in order to buttress transcontinental cargo flows in the globalizing world.

However, their perspective still does capture the critical role of ports that should not be undervalued, especially if the centricity of container handling activities among multiple port functions is fully respected in designing and evaluating productive ports. On the one hand, significant interest and task of ports are still directed toward efficient "picking up" and "putting down." On the other hand, the necessary functional conditions for the contemporary ports have become more and more complex and diversified. Table 2.1 shows essential service a port provides and specific activities to back up these services.

Table 2.1: Port Service Functions[1]

Service	Activities
Cargo services	Stevedoring; Longshoring; Equipment operations; Transit storage; Receiving and delivery; Cargo tracking; Assembly and processing (consolidation, bagging, mixing); Storage and warehousing; Transfer to land transport
Vessel services	Navigational aids; Pilotage; Towage; Mooring; Bunkering; Utilities; Garbage removal; Stowage; Anchorage; Buoys; Launch services; Vessel repair
Infrastructure	Hydrographic surveys; Dredging; Repair and maintenance; Engineering design; Port construction; Equipment procurement
Marketing	Market research; Promotion and sales
Management	Billing accounting, Data processing; Staffing
Security	Security forces, Fire and rescue, Pollution control

While internal port functions have become complex than ever, the roles of ports can be differently viewed based on the larger socioeconomic contexts and ideologies faced by ports. Hall (2002) reviews how previous studies have defined ports in terms of their roles and functions that are related to broader social contexts and economic impacts. It is useful to review his comprehensive typology in order to understand how ports face multiple, but sometimes, conflicting identities and roles in relation to various environments.[2] Hall categorizes previous port-related studies into three distinctive approaches that utilize the assumption about the concepts of ports and their functions:

---

[1] Source: reorganized from (ADB 2000, 31)

[2] The objective of the discussion is to understand the roles and identities of ports. For the discussion of specific advantages and disadvantages and methodological critics for each approach, one should refer to Hall (2002).

(a) "cargo-based description of ports," (b) "infrastructure-based description of ports," and (c) "network-based description of ports."

In the perspective of "ports as cargoes," ports are major economic enterprises that deal with cargoes traded, and hence creating substantial economic impacts on regional economy. The key roles of ports are thus to generate revenues, jobs, incomes, taxes, and multiplier effects over hinterland areas. The studies adopting this view implicitly and explicitly attempt to measure the economic impacts of port cargo handling activities on hinterland areas (e.g. Campbell 1993; The Martin and Associates 1995; Heikkila et al.1991). Therefore, ports are conceptualized based mainly on such characteristics as: (a) cargo volumes; (b) cargo forms (e.g. liquid bulk; dry bulk; breakbulk; containers; ro-ro); (c) modes of ocean carriage (e.g. tanker; tramp; liner); (d) direction and origin and destination of cargo movement; (e) end use of cargoes (e.g. production; consumption); and (f) degree of substitutability for shipping modes (e.g. ocean carriage; rail; airlines).

In the studies that see "ports as infrastructure," ports are a type of firms in search of optimizing their inputs and outputs for providing quality services to consumers and maximizing their returns. The efficient utilization of resources like physical capital, land, and labor are normative values under this view. The focus of this approach is placed upon examining how port services are influenced by qualities or quantities of port infrastructure (e.g. berths depth, terminals, cargo handling and managerial technology). It also examines port conditions created by the interface between terminal areas and other shipping systems.

The third approach, according to Hall, is "ports as nodes in networks." In this line of research, the emphasis is placed on the fact that ports are nodal points in trade networks through which regions can link up to the global economy. Technological changes such as containerization, mega ship, intermodal logistics, and electronic data exchange system to support ship service and container handling have changed the features and boundaries of networks. In addition, such changes of external conditions as transportation deregulation in the 90s have also given a shock to the global shipping networks. With the processes shaped mainly by enormous external force, seaports are increasingly differentiated in the roles played within the global shipping systems, and therefore, hubs and spokes are naturally comprised as parts of much larger systems.

Seaports embrace all the identities above stated in many ways. The emphasis can be made on somewhat differing aspects, depending on social, economic, geographical, and historical environments facing each port. At the same time, however, it is notable the fact that ports have both strategically and accidentally attempted to confront these socioeconomic conditions by exercising discretion that is granted through diverse mechanisms of port institutions. It is interesting to empirically examine the formal and informal structure of port authorities, organizational and intergovernmental relationship, and managerial practice by port managers and other players, since they can influence productivity and performance of port infrastructure in the container production system. It is particularly interesting for this study to inspect how the interface between the external conditions and the discretion can shape better performance and productivity of ports, to be developed throughout Chapter 2 and Chapter 3.

2.2 Why Some Ports Outperform Others?

There exist conflicting views on key factors that influence port performance and competitiveness. They are largely associated with different levels of emphasis on discretion and environment facing ports in achieving better port performance and productivity. In particular, they address important issues in the following:

- Whether a variance in capacity of ports results from strategic management and institutional changes?
- What role does strategic management and institutional features play in handling environments and designing organizations' future?
- To what degree and scope are roles of management and institution influential? Do they play only a secondary or trivial role?

2.2.1 Technology and market as exogenous forces

One view is that environments (e.g. market forces, technological innovation) principally induce organizational adaptation needs. Strategic management is supposed to engineer suitable organizational structures and processes to determinants of external environments. It is confined under the hierarch of market forces, geography, and technology, not having a power to change or selectively transform the external environments. Since this view does not seriously respect an organization's capability to "innovate" and "result in change," organizations have *little* control over external forces that largely shape organizational postures (Aldrich 1979). Strategic planning and management are thus given a secondary importance.

Denning (1985) argues that technological and market forces, not infrastructure governance systems, predominantly form and constrain local infrastructure policies and outcomes. In Denning's view, containerization revolution is external market pressures that have tremendously transformed ports from conservative public-utility-type monopolists to public entrepreneurs. This pressure is the strongest factor to oblige port authorities to shift their one of the most important policies as monopolists: Pricing. Since market sensitive terminal leases have replaced harbor tariffs that were determined through administrative processes in the past, their pricing policies have been oriented from the public-good perspective of port service to the private-good perspective.

Campbell (1993) shows that, due to enormous technological forces, or containerization, economic externalities generated by port activities are not restricted to the local area surrounding ports; rather, they are dispersed throughout broader regional hinterlands. The author's analysis is well in communication with the view regarding seaports as places and landscapes formed and flowing under “global” force. It is emphasized in his view that seaports are nodes to connect places in global networks.

Along the similar line, Airriess (2001) contends that the process of “glocalization” and the production of transnational corporations (TNCs) have revolutionized the structure of global ports and induce them to adopt new information technology to better articulate the spatial movement of goods. The author argues that the structural synergies between TNC production, communication technology, and container transport allow the Port of Singapore to be the world leader in the port industry and become a TNC by operating container terminals over the world.

2.2.2 Primary role of strategic choice

Those who emphasize the role of strategic choice argue that internal planning ability can provide the ways to decide series of action, resulting in structural adaptation. "By selecting a domain of customers, products, and technologies, organizational strategists choose the environments with which they will interact (Boschken 1988, 13)." For the case of public sector, Miles (1982, 253) argues that "even the detailed charters of pubic agencies leave considerable room for strategic maneuvering on the part of executive leaders…the extent of domain choice flexibility is more a function of the creativity and imagination among members of the executive cadre than of formal mandates and informal traditions embedded in their external context."

Olson (1988) identifies seven elements that port *governance* can make a difference: strategic planning, finance, pricing, investment, regulatory requirements, commercialization, and stability. According to Olson, officially autonomous structures such as regional authorities and public corporations tend to be organizationally better than "more politicized local structure such as the Los Angeles and Long Beach municipal port and airport systems." It is because autonomous structures can better "engage in long-term strategic planning while they face fewer local short-term pressures to be revenue generators for supervisory jurisdictions."

Boschken (1988), comparing six Pacific Rim seaports in the US, examines the factors of variance in strategic performance of seaports, where turbulent transition of container revolution and environmentalism is present. While criticizing too much attention being paid to formal institutional structure and legislation, he claims that strategic performance can be closely associated with (a) organizational *perceptions* about performance gaps and inter-government relations. "The increased power of a consolidated port authority would skew intergovernmental relations toward a (not democratic and autonomous) center-peripheral structure, and increase likelihood of a power-dependency perception that might encourage a port monopoly to be more cavalier in its dealing with regulatory agencies" (p.495). He also argues that, in times of transition, what matters most for organizational effectiveness is the design of microstructure of strategic planning, while the macrostructure of whole organization of port authorities may explain why ports perform well in a static "fit" context. Finally, he claims that encouraging pubic agencies to achieve higher organizational effectiveness requires view the issue not as a separation of politics and administration, but as one involving different levels of administrative decision making, since politicians set institutional arrangements. However, once the arrangements are set, knowledge of legislative actors are not sufficient to deeply involve in operation at the organizational level, since the factors of management are too complex in states of turbulent transition.

Gulick (1998) shows that institutional *relationships* will matter in other ways as well. The author raises the importance of “regional development alliances,” which can be facilitated or retarded by governance structures. The competitiveness of a container port is influenced by whether regional development alliances can be built with neighboring communities and environmentalists to alleviate the negative externalities of port development. In his view, port performance is not explained by technological and market forces or organizational responsiveness, but by institutional relationships among agents seeking to development.

Erie (2004) makes a compelling analysis of how the Los Angeles region’s rise as a leading global trade and transportation center is based on civic leaders’ continuous efforts to invest in port and airport infrastructure. He argues that, until recently, powerful and semi-autonomous entrepreneurial bureaucrats and leaders implemented effective long-term planning that allow Los Angeles to realize its important projects. This is based on the fact that at the early 20th century, “Southern California rejected the Eastern model of regional public authorities in large part for their port services because of the extensive development powers granted to “home rule” cities under the California Constitution” (Erie and Kim 2002, 11). Therefore, Los Angeles created powerful municipal proprietary departments to develop and manage the region's early harbor facilities. These powerful *semi-autonomous public enterprises* created strong incentives for public entrepreneurs to engage in long-range strategic planning and devise innovative development and financing policies. Municipal “home rule” charters historically provided the proprietary departments with considerable autonomy and powers to ensure their ambitious capital improvement programs. Voter-approved local constitutional protections once limited the ability of the mayor, city council, or the city manager to micro-manage their affairs.

In summary, those who regard external environments and forces as critical factors for port performance assume administrators can direct change minimally. Yet those who believe strategic choice see environments as more compliant to organizational manipulation. The previous approaches have their own stance on the role of strategic choice based on institutional frameworks and practice. In my view, it is difficult to consider one of these factors is always predominantly shape port activities, performance, and productivity without having difference influenced by temporal and regional contexts. The interaction between strategic management based on institutional transformation and external influence continuously and dynamically occurred, thereby resulting in change and improvement of organizational performance and productivity. In this sense, as Boschken points out, "transitional change in an industry often results simultaneously from less adroit organizations being eliminated from the population by the environment, and perceptive organizations learning optimal responses, exploiting opportunities, and adjusting organization design accordingly (Boschken 1988, 13)."

Moreover, especially in the port sector, it is not always clear where the boundaries between institutions and external forces. For example, on the one hand, the concept of inter-port competition includes characteristics of geographic forces as well as locational advantages. Inter-port competition is inherently related to the number or capacity of ports competing for capturing economic opportunities (e.g. trade or GDP) of hinterlands. Especially, unlike other manufacturing industries, the production system, practice, and performance in the port sector are much strongly attached to the hinterland conditions. On the other hand, inter-port competition is, by itself, the macro-level institutional conditions of market and industry structure that act as the play ground of port production activities and competition in a region. National and local governments, who often act as or influence managers and planners of their ports in the region, are involved in creating, shaping, and restructuring the market structure. No matter whether they result in success in creating and harvesting advantages for their ports, the governments attempt to enforce and exercise diverse policy and institutional mechanisms to make the market structure more "advantageous" for their ports. In this sense, it is relatively difficult to draw the acute distinction between "institution" and "geography" at the macro-institutional level in the port sector.

With these issues in mind, an overall goal of this study is to understand how port organization and port infrastructure service can become more innovative, adaptive, and productive by adopting a proactive institutional transformations and restructuring, in order to confront and integrate the external forces and conditions (e.g. globalization). The interaction between discretion and environment is not something that can be easily separable in examining the critical factors for higher performance and productivity that develops future domains of ports under the impact of globalization and technology development.

2.3 Institutional Structure, Privatization, and Port Performance and Productivity

2.3.1 The role and problems of public sector infrastructure management

Central or regional governments have traditionally been the main providers of infrastructure services including port infrastructure here. Recently, increasing numbers of studies discuss that government-dominated infrastructure provisions have experienced failures in efficiency and equity.

Several main reasons are discussed: (a) governments cannot always come up with the accurate figures of demand and supply, thereby leading to either the under- or over-provision of infrastructure services. Moreover, the government failure in the infrastructure sector are also attributed to (b) ineffectiveness of government subsidy, (c) unresponsiveness to user demand; (d) financial inefficiency arising from ineffective pricing, billing, and financial management (UNCTAD 1995; OECD 1991; OECD 1998). Most of all, public sector's infrastructure provisions are (e) not independent of political processes to gain political support and interest (Hyman 1995). It generates the problems of an over- or under-supply of the services and a labor redundancy through various ways in infrastructure sectors. Since their overall performances are poor in supplying efficient and equitable infrastructure services, governments are under the pressure to design and take alternative institutional arrangements through which policy makers have actively attempted to increase accountability, respond to user demand, reduce fiscal burden, and adjust incentive structures.

2.3.2 Institution, privatization and port performance

While private sector participation has been one of the popular ways to address the productivity problems of port infrastructure service, several distinctive views exist concerning the relationship between institutional structure and port performance:

One of the views emphasizes the diversity of institutional structures and management styles of ports. This view appreciates current diverse modes of ownership, administration, and management in the port sector, which have been mainly conformed by social, political, cultural, and geographical forces. In this perspective, no single model for ownership and organizational structure is optimal, and “the port should be able to seek ways to improve their efficiency [based on] circumstances” and conditions that ports face (Song et al. 2001, 121).

Another view is to concern inefficient and costly port services owned and operated directly by government. One branch of this view, property rights theory, claims that, as rights to profits are not as clearly defined in public organizations as in private organizations, the public sector fails to achieve higher productivity, lower cost, and recover full expenditure (Barzel 1989). In this view, the source of inefficiency in the public sector is the attenuation of property rights.

Meanwhile, some public choice theorists focus more on the essence of decision-making within government (Jasinski and Yarrow 1996). Politician and bureaucrats seek their own or departments' interest rather than the public interest. They simply attempt to obtain as many votes as possible within their term-limits and maximize department budgets before the next budget decision. Yet, because of the asymmetry of information between the public and bureaucrats, public monitoring cannot be effective, and therefore, political decision deviates from productive efficiency and social welfare objectives of ports.

Haarymeyer and Yorke (1993) also recommend private sector participation as a way to resolve inefficiency problems by US public ports. According to the authors, the US public ports suffer from inefficient operation under political interference, risk aversion, over-manning, and non-optimal pricing and investment. Private sector participation in the port sector, with full commercial practices, can broaden capital sources and increase the productivity of port activities.

Gómez-Ibáñez (2003) shows why some types of institutional design for infrastructure provision and regulation have been developed and restructured, in relation to historical and sectoral contexts. Predicated on his analysis of transaction-cost and opportunistic behaviors of players in providing infrastructure service, the author shows that market-oriented contractual approaches are, in general, effective in regulating naturally monopolistic infrastructure service. Overall, private contracts between infrastructure service consumers and suppliers are more effective than concession contracts where a government plays it role as an intermediary. The advantage of concession contracts outpaces that of the models of government regulation and public enterprise which are primarily based on relational contracts. It is so because contracts usually not only provide protection for consumers and suppliers but also better-tailor services for their benefits, except the case where situations are unpredictable for contracts to work.

In contrast, Posner (1984) argues that politicians and bureaucrats in fact seek the public interest and centralized and hierarchical arrangements may be more efficient in monitoring of public service provision. The hierarchical system is helpful to take immediate action when there are deviations from social welfare objectives. Besides, De Monie (1996) points out some deficiencies caused by port privatization policies. Private investors and operators are profit maximizers with cost minimization behaviors. They thus may abandon facilities and services that are less rewarding but socially and environmentally essential, given that intra-port competition prevails rather than inter-port competition. In addition, when only a limited competition exists in a region, a public monopoly will likely be turned to a private monopoly. Finally, privatization could bring about unfair treatment of the port's customers, and ordinary users could have a weak negotiating position, resulting in corporate control and market failure.

According to the arguments given previously, it could be possible, to some extent, to draw distinction between private and public organizations in port management. However, solid empirical evidence is lacking if we were to demonstrate a superiority of private ownership over public ownership or vice versa. A simple dichotomy between public and private ownership, may takes the risk of disregarding important differences of organizational forms and managerial practices of port authorities in each sector as well as other formal and informal relationships with other players. In essence, as Iheduru (1993) points out, choice between advocacy and discouragement of privatization policies may fail to make a distinction between ownership structure and management practice with efficiency. In order to understand the mechanism through which institutional structure and practice shapes port productivity, it is essential to distinguish the roles of different levels (e.g. region, country, port, and terminal) of institutional structure and management practice that will be suggested in the research design.

In addition to the management structure and ownership practice, port performance could be attributed to competitive environment, effective regulation, and organizational relationship as intervening variables, partly discussed in the previous studies. Therefore, it is utterly crucial to examine institutional structure and managerial practice and their interplay as influencing factors in increase of port productivity with a careful consideration on political, cultural, and economic backgrounds facing ports.

2.4 Conceptualizing Port Institutions

2.4.1 Actors and functions in port infrastructure service

In the port sector, there are various alternative models of port ownership and institution (Baird 1997; Goss 1990; Liu 1992). Some ports are owned and operated under the control of central governments, while others face a more decentralized system under the power of local governments. There are also ports which are entirely owned and operated by private or non-government entities. These entities are involved in various production and service activities related to port functions (Table 2.2).

Table 2.2: Port Functions and Activities[3]

Function	Activities
Regulation	Application of laws and rules in order to facilitate and regulate port production and service provided by port authorities
Landlord	Management of real estate including port land area
Planning and Marketing	Strategic and long-term planning for terminal lease and concession and capital investment for infrastructure and superstructure
Port operation	Allocation of berths and coordination services to berthed and un-berthed vessels
Terminal operation / Cargo handling	Loading and unloading of vessels, warehousing, intra-port transport
Ancillary services	Towage, fire protection, repairs, etc

The port functions are typically performed by diverse private and public agencies: federal, provincial, local governments, port authorities, terminal operators, and other

[3] Summarized from World Bank (2001) and organized as a table.

service providers (World Bank 2001). Table 2.3 presents an example involving three main entities: Ministry of Transport (Federal, Provincial, and Local Government); Port Authority; Operator. However, the degrees of involvement by each entity in different activities for port production and services are different depending on (1) the historical and institutional contexts in each country and (2) the institutional structure of the ports.

Table 2.3: Roles of Port-related Agencies[4]

Actors	Function and Activities
Ministry of Transport	In most countries, the Ministry of Transport (or equivalent) is mainly responsible for major macro-level policy making and regulation; financial affairs; environmental regulation; customs procedures; international relations; auditing. Furthermore, in countries that have high degrees of centralization in port ownership and management, the national level transport ministry is also closely engaged in port planning and marketing and the landlord function in Table 1.
Port Authority	There are diverse types of port authorities constructed at the level of national, state, municipality, and independent entities. Depending on the corporate structure of the port authority, they can be either public or private entities. Also, in terms of corporate structure, they can function on the basis of special law (as a statutory authority or corporation) or general corporate law or sometimes as a department of government. As various forms of a port authority's institutional structure exist, the functions for which port authorities are responsible are diverse. Most port authorities are in charge of the tasks to perform the landlord function, the planning and marketing function, and the port operation function. Often

[4] Summarized from World Bank (2001) and further developed based on my research.

	they are either partly or fully responsible for long-term planning and capital investment for infrastructure or superstructure of ports, licensing, and port labor policy, with a close relationship with the national or state level governments. For some with a highly centralized system of port management, the port authorities are also responsible for terminal operation and other cargo and vessel services.
Operator	Operators are basically specialized terminal operating companies, cargo handling companies, and stevedoring firms. They pursue micro-economic objectives such as profit maximization and additional market share at the terminal level. In terms of institutional forms, terminal operators are sometimes separate entities from port authorities or governments, but they also can be the same or a subsidiary entity. Usually, high degrees of institutional complexity exist at this level of port function. For instance, even if they are legally separate entities, they are often politically and financially closely related to governments; e.g., there are many East Asian models such as China (joint venture), Japan (financial control by governments to stevedoring companies through constructing subsidiary companies) and Korea (close financial and political control and managerial relationship). The degrees of relationship are quite different depending on the historical and institutional contexts in each country and different port management models.

These entities are involved in various activities related to port functions from the macro-level policy making and regulation to the micro-level terminal and labor management: economic regulation, environmental regulation, customs, safety regulation, aids to navigation, road and rail access, land ownership, port planning and development, procurement of port infrastructure, bidding and contracting, procurement of fixed and mobile equipment, vessel traffic control, vessel clearance, technical regulation, towage, mooring, cargo handling and storage, consolidation and packaging, maintenance and operation of equipment and buildings, terminal security, etc (Asian Development Bank 2000; World Bank 2001). In essence, conceptualizing the ownership of ports is to find the boundaries of port-related functions and activities among national and provincial governments, local government, port authorities, and terminal operators and service providers.

2.4.2 Conceptual development of port ownership

Different patterns of port ownership can be typified by (i) the allocation to a variety of entities of property rights over port infrastructure and superstructure and (ii) the degrees of autonomy to exercise controls for port functions and services. Several distinctive and important approaches have been developed in order to conceptualize complex structures of port ownership:

Goss (1990) classifies ports into three different categories, comprehensive, landlord, and hybrid, emphasizing the role of port authorities in performing activities for port production and service. According to him, if the port authority, by itself, performs all of the activities carried on within the area of the port, it should be classified as a comprehensive port. The landlord port model is conceptually opposite to the comprehensive port model. In the landlord port, the port authority is only responsible for port planning and exercising overall controls over the activities carried on within it, but delegating these extensively to private sector companies. Finally, a hybrid port lies somewhere in between the two.

His approach is useful in understanding the existence of a general spectrum of port institutions. Yet, more often than not, most ports are not operated in reality under the model of a "perfect" comprehensive port or a "perfect" landlord port. According to his criteria, the majority of ports in the world can be located somewhere in between comprehensive ports and landlord ports. Recently, most ports have had mixed systems in terms of the ownership of port assets and the operation of port services. Therefore, most of them fall into the category of a hybrid port.

Liu (1992; 1995) further develops this classification by creating four different types of port: a service port, a tool port, a landlord port, and a private port. This approach basically reflects the spectrum of how much a "public" port authority is involved in major activities for port production – mainly cargo handling and provision of infrastructure and superstructure. A (public) service port entails the highest involvement of the public sector, which is responsible for the provision of all services and facilities including fixed and mobile equipment. A tool port is so named as the port authority provides only "tools" for port production and service, namely, port infrastructure and superstructure, while the actual port services are licensed to private terminal operators or cargo handling companies. In a landlord port, the port authority is usually limited to the provision of port land and major nautical infrastructure, while port operation and investment in superstructure such as terminal buildings and container handling equipment are the responsibility of private operators. Finally, if the provision of all the port facilities and services is left to the private sector it is classified as a private port. Therefore, private ports involve the least amount of public sector activity in port management and terminal operation.

This approach is particularly helpful in the sense that the typology can effectively capture the identities of port authorities, the multiple features of port services, and levels of involvement of the public sector at the same time. In other words, this categorization implies that ports have multiple identities: what identities a port has in terms of corporate structures of the port authority (public or private). At the same time, it also implies how much the port authority is involved in infrastructure investment, terminal operation, or cargo handling, and equipment leasing and other service provision. While it is unclear whether the author actually intends to integrate these two aspects of port institutions into a single framework, the principle of this categorization, in my view, can be illustrated in the 2X3 matrix in the following:

Table 2.4: Information captured in Port Ownership Variable

Typology		Degree of port authority's involvement in port service		
		High (Service)	Medium (Tool)	Low (Landlord)
Port authority's institutional identity	Public	Type 1	Type 2	Type 3
	Private	Type 4	Type 5	Type 6

Out of these six foundational classifications, the author's approach aggregates Type 4, Type 5, and Type 6 into a single category called "private port" by emphasizing the aspects by which that port authority is a private entity. It is reasonable that the degrees of public sector involvement in Type 4, Type 5, and Type 6 are higher than Type 3. Yet this theoretical framework cannot consider whether terminal operation and other services are carried out by a separate entity other than a port authority within a private port.

Some recent studies (e.g. Baird 2002) argue that fully privatized ports are not as effective as public ports by their own nature since they have less capability for the large-scale resource mobilization and long-term investment that are needed to consistently develop port land and maintain port infrastructure in a timely way. In the meantime, there is increasing attention paid to examining how intra-port competition is one of the determining factors in creating port efficiency.

If a port were transferred from Type 3 (Public landlord port) to Type 4 (Private operating port)[5] it would theoretically create two different effects that would compensate for the impacts on each other. On the one hand, as the public sector transfers port management and administration to the private sector's hand, it may (or may not) increase port efficiency, according to the incentives and benefits proposed by property rights theory and public choice theory. On the other hand, the level of intra-

[5] This case does not usually happen in reality but it could theoretically happen if a public landlord port were sold to the private sector that kept all the port assets and services proprietary.

port competition may be lower in Type 4 than in Type 3 in which multiple terminal operators and service providers can compete with each other.

Consequently, if the existence of multiple private service providers through leasing or concessions created positive effects on port and terminal efficiency, moving from Type 3 to Type 4 might be compensated for by the efficiency increased possibly by the transfer of ownership for port assets at the first stage. Or, if the existence of privately devoted terminals reduced terminal efficiency, the overall port efficiency would also be influenced by changing from Type 3 to Type 4. The point of this discussion is that the source of port efficiency or inefficiency cannot be easily attributed to either the former effect or the latter, if multiple characteristics of institutional information are highly aggregated in the framework.

In addition, in perspective of institutional practice, an unbundling of actual operation and management from larger umbrellas of planning and regulation may be more important than the issue of public vs. private at a port level. Since the separation can provide organizations with more objective and transparent ways of seeking goals and evaluating achievement. The typology does not fully consider the aspect as it focuses mainly on the concepts of public vs. private.

Some of the weakness is partly resolved by another alternative for probing port ownership (Baird 1995; Baird 1997). He identifies three major functional aspects of ports: regulation, land ownership, and operation. By highlighting whether these functions are either in public or private hands, he suggests the following matrix shown in Table 2.5.

Table 2.5: Key Port Function and Baird's Ownership Models

Models	Regulator	Landowner	Operator
PUBLIC	Public	Public	Public
PUBLIC/Private	Public	Public	**Private**
PRIVATE/Public	Public	**Private**	**Private**
PRIVATE	**Private**	**Private**	**Private**

According to Baird, a regulatory function can involve the statutory nature of the port authority that holds control of the area defined as the 'Jurisdiction' of the port. The regulatory responsibilities include: (a) maintaining the conservancy function; (b) providing pilotage and vessel traffic management or surveillance; (c) enforcing laws and regulations related to health, safety, and pollution; (d) licensing port works and developments; and (e) safeguarding port users' interests against risk of monopoly formation. A landowner function allows the responsible entity to control areas of port land in general. The essential tasks related to the function are to manage and develop port estates and to implement strategies for the physical development of ports' superstructure. Often, the landowner function also requires provision and maintenance of such infrastructure as channels, fairways, breakwaters, locks, turning basics, piers, and wharves. It also requires supervision of major civil engineering works and arrangement for road and rail access to the port facilities. Coordination for port marketing and promotion activities should be another aspect of the landownership function of ports. Finally, Baird defines that an operator function is solely associated with the physical transfer of goods and passengers between sea and land.

This approach again has strengths, especially in clearly explaining the multiple functions entailed in port production and services. Based on this framework, it is also possible to conceptualize what types of combination between the public and private sectors are used in carrying out complex port functions and services. Yet the emphasis of the typology is still placed on what “kinds” of entities – public or private – exercise controls over different port functions rather than the aspects of institutional separations and independence to be responsible for implementing different functions.

Another point is that Baird’s notion of the landowner function is relatively broadly defined. The tasks that define his landowner function are not just the responsibilities of one entity but are usually performed by the collaboration between two or more different entities in world ports – national governments, port authorities, and terminal operators. For example, major nautical infrastructure is mostly funded and maintained by a national level entity in close collaboration with the port managing unit. Furthermore, in reality, the boundaries between terminal operation and landowner function are not clear cut; it is sometimes ambiguous exactly which entities perform the functions due to complex institutional relationships. For instance, there are cases where, theoretically, the landowner function is conducted by public port authorities while the operator function is performed by “legally” separate private companies or government-owned corporations.

However, in implementing real policies and decision making, the separate entities work like the subsidiary companies of national governments or statutory port authorities in many cases (e.g. many Japanese ports). And the companies are managerially closely connected with port planning and management agencies. It is therefore possible that the suggested framework may not fully reflect the managerial and institutional practice. Therefore, in paying particular attention to the boundaries of public or private in carrying out different port functions, this framework may less directly capture how much port authorities are involved in operating production activities and providing port services.

2.4.3 Comments on previous approaches

Let us summarize the previous discussion and move on to more specific ways to capture port institutions. In general, previous approaches have merits in conceptualizing the multiple functions and institutional features of ports. They try to integrate different sorts of institutional information into one single variable. In other words, they effectively aggregate the institutional identities of port authorities and levels of involvement of the public sector in port services. However, by paying more attention to dichotomous types of entities (public vs. private) to implement port functions, the previous typologies loosely define the issue of actual institutional independence and separations - e.g.

whether a port authority and public government is in fact institutionally separated from terminal operation and assets. Moreover, the effects created by the institutional structure and actual practice of service provision may create interaction effects or may compensate each other, thereby making it complex to measure the relationship between port institution and efficiency.

Private sector participation in the port sector may firstly generate increased levels of unbundling (intra-port competition) through leasehold and concessions for container handling and services. Secondly, according to property rights theory, technological and managerial improvement can be expected if private entities become actual owners and managers of ports. We have to realize that private ports may not always have more intense levels of intra-port competition if they do not operate as private landlord ports but as private operating ports. When a whole port is privatized and managed by a single private entity it is theoretically probable to expect that, on the one hand, the port may theoretically achieve higher levels of managerial efficiency produced by becoming a private entity rather than a public authority. On the other hand, it could not reap benefits from intra-port competition if the private ports operate as service (operating) ports than as landlord models.

This logic may lead to the idea that different privatization methods (concessions vs. corporatization vs. divestiture of port assets) may create varying effects on port efficiency. For example, concessions implemented at the level of container terminals may intensify intra-port competition, while they produce relatively small changes in the organizational structure of a port authority as a port manager. In contrast, corporatization is usually implemented at a port level by directly changing the corporate structures of a port authority. As it brings more private sector participation through such methods as public offerings, it is reasonable to expect to experience some influence from this sort of organizational and incentive change. Yet corporatization by itself does not increase levels of intra-port competition or it does not practice unbundling of port functions and separate port authority from day-to-day terminal operation unless the corporatization scheme is designed to do so by legal obligations. Finally, the impacts of divestiture for port assets can also be evaluated depending on the contexts of how port divestiture is implemented. If it brings multiple terminal operators and service providers into port production, it creates more intense intra-port competition, in conjunction with the effects from changes of organizational structure.

The previous ways of measuring port institutions are not fully disaggregated into the levels that can separately capture both the effects of organizational structure and functional and institutional practice. Therefore, the results of empirical examination and the evidence does not fully identify where port efficiency comes from in relation to the implementation of private sector participation. Does or can the efficiency of privatized ports mainly come from intra-port competition through bringing multiple service providers and terminal operators into a port? Or does it originate from inherent incentives to organizational efficiency of private entity vis-à-vis the public sector in managing a port organization and owning port assets? Or are the benefits produced by institutional separation of public sector from day-to-day terminal and port operation? All of these are in fact different questions and subjects.

To design variables capturing the institutional features of ports including port ownership is a primary foundation to carry out further analyses to examine the relationship between port ownership and port efficiency. It is useful to dissect multiple meanings from the port ownership variable so that it can reflect coherent aspects of port institutions. Therefore, it should be disaggregated into two different variables of port institutions: (1) corporate structure of port managers or authorities; and (2) port ownership practice focusing on the division of port assets and functions among multiple port-related agencies. These two aspects are closely related to the role of intra-port competition, the degree of separation of the public sector authority from terminal operation, and the role of corporate structure (corporatization) on port efficiency.

2.4.4 Role of competition on performance

Regarding the role of differing institutional factors, Parker (1994) examines the industrial structure and firms' productivity in the telecommunications industry. He contends that both levels of competition and types of ownership are positively associated with an increase in a firm's productivity. He argues that, as levels of competition are more intense and ownership is more decentralized, a firm's productivity increases in general.

In port sector, inter-port competition has been one of the central theoretical and practical themes in port management during the last decade when the new technological developments and the flexibility of logistics peaked. In the past, ports were believed to be mostly subject to regional monopoly or national oligopoly based partly on (a) the natural monopolistic nature of port and nautical infrastructure, (b) the concentration of cargo traffic and inflexibility of port locations.

Nonetheless, this notion has recently changed for many parts of the world, as we observe increasing levels of global competition in the container handling industry. Such factors as recently emerging globalization, development of post-panamax container ships and intermodal transportation, and diversification of shipping routes and trade activities allow shippers to search for new ways and capabilities of reducing costs, which in turn leads many port authorities to compete with each other for capturing newly emerging larger and more flexible markets.

Especially, since the last decade it is difficult for some dominant incumbent ports to be able to always secure their oligopolistic power any longer in their hinterlands. They currently must attract shippers and cargoes by improving their service and reducing container handling charges in order to survive the present global market. For example, this is particularly so in the East Asian and the South Asian markets, the Northwest European region, and some parts of the Middle Eastern market. Recently, even in the U.S., Port of Long Beach and Port of Los Angeles have to start competing with Port of New York and New Jersey as an entry point of cargoes from Asia, as new shipping routes have developed and the concept of hinterland becomes more and more vague and broad.

These aspects allow shippers to become more flexible in choosing and changing ports, although path-dependent characteristics still exist in shippers' choosing ports. The move of its transshipment hub from the Port of Singapore to Tanjung Pelepas in Malaysia in 2002 by the world's largest shipping line, Maersk Sealand, is a symbolic example illustrating new levels of inter-port competition in the global port sector.

Given the contexts, if there is a lack of consideration regarding the role of competition intensity on port productivity, it can possibly cause the under-specification of models that examine the performance benefits of private vs. public ownership since there are "inseparable effects of ownership and competitive rivalry on firm performance" (Ramaswamy 2001). Some evidence can be found from studies on other industries. According to Ramaswamy (1996), based on his analysis of the Indian State-Owned Enterprises (SOEs), higher competition in a product market does indeed propel SOEs to achieve greater levels of technical efficiency. His finding is also in agreement with the classical assessment of x-efficiency by Primeaux (1977) that found the effect of competition on municipally-owned electric utilities. Leibenstein (1966) also pointed out that the firm's operating costs are likely to decline given an increase in competition.

In the port sector, differing views exist regarding the relationship between port performance and inter-port competition. Cullinane et al. (2005, 3-4) summarize the following regarding the market structure of the container port industry:

> [A]dvocates [for inter-port competition] attest that competition can encourage innovation, increase the sense of responsibility of staff, free a port from the constraints of bureaucracy and, partially as a consequence of these and other influences, promote high efficiency. It would seem that policies to encourage inter-port competition are gradually being accepted by an increasing number of governments and Heaver (1995) reports that the policies of governments are moving in ways consistent with a more competitive market structure, brought about by decentralization. In contrast, certain economists and governments also appreciate the advantages of a monopolistic market in the port industry, equivalently brought about by a policy of centralization. Among others, Heaver (1995) argues that the main advantage of a central planning policy for the port industry is to avoid the risk of excess capacity.

Heaver (1995) points out that there are reasons that the overcapacity of ports can exist under the competitive market structure: (a) the capital intensity and long life of container terminals, (b) ship owners' interest in minimizing ship turnaround time, (c) the optimistic view of port and terminal managers toward the future expansion of cargo traffic. Turnbull and Weston (1993, 119) argue that privatization in the UK has not been sufficient to resolve the duplication of the investment.

Cullinane et al. (2005, 4) comments that some individual ports in the UK are in fact working to full capacity and there are insurmountable short-term problems in servicing the largest container ships in certain container ships (e.g. Southampton, Felixstowe). This is a desirable state of affairs for such ports in that, "they are succeeding in balancing their supply with demand." However, "the problems of overcapacity in the provision of capacity certainly exist at an aggregate industry level, with certain individual ports having significant spare capacity."

2.4.5 Impact of institutions on port productivity and efficiency

There have been conflicting views on the impact of port institution on port infrastructure productivity: Liu (1995), examining the relationship between technical efficiency of ports and port ownership controlling port size with a dummy variable, argues that there is no significant advantage to private or public ownership when the policy environment is competitive. Notteboom (2000) similarly shows that it is difficult to prove that port ownership has a significant effect on port performance.

Some studies reach different conclusions. Coto-Millan et al. (2000), in examining port efficiency of 27 Spanish ports from 1985-1989, claims that the most efficient Spanish ports are those that are smaller in size and had adopted a significantly more centralized management system than clearly showed a greater level of management autonomy. Baird (2000) also argues that an outright sale of port land, combined with a transfer of operation and regulation functions to the private sector will not definitely increase the operation of efficiency, and it may even be counterproductive. Due to long-term pay back and high capital costs in the port industry, an almost total dependence on the private sector will result in significantly delayed investments on the crucial operation of facilities and equipment. Consequently, port ownership has an inverted U-shaped effect on port operation efficiency.

Estache et al. (2002), based on analysis of the Malmquist Productivity Index (MPI), claims that the reform of decentralization and privatization taken at Mexican ports has generated large short-term improvements in the average performance of the port industry. Cullinane et al. (2002), employing both cross-sectional and panel data versions of stochastic frontier models, assessed the relative efficiency of selected Asian container ports and concluded that privatization should have some relation with an improvement in efficiency. Tongzon and Heung (2005) examines the issue at the terminal level in order to evaluate whether port privatization is a necessary strategy for ports to gain a competitive advantage and concludes that private sector participation in the port industry, to some extent, can improve a port's operational efficiency.

The previous studies suggest meaningful intuition and improved understanding of the global port sector. Despite the merits of the studies, a few things should be pointed out: Firstly, many studies gather and utilize data from the largest 10 to 30 container ports as targets of port productivity evaluation. In many cases, ports selected for the analysis can already be regarded as successful ports. This relatively small and biased scope of sampling, directed by data availability, makes it difficult or inadequate for sorting out and clearly examining the issues: "whether the efficiency gap between successful ports and unsuccessful ports are mainly explained by the difference of port ownership and institutional structure?" and "whether transform of port institution and private sector participation have allowed ineffective ports to become more successful?"

Secondly, in analyzing the roles of port ownership and organizational structure on port efficiency, the studies do not consider the region's market and industry structure (e.g. how intense is market competition?) to any significant degree; nonetheless, it is a critical macro-level institutional environment with pressure to encourage or discourage port agents to work progressively. In the port sector, the concept of inter-port has been paid increasing attention in recent years as a factor to shape market structure in the region. Nonetheless, there has been no attempt to integrate the concept in the model to explain the impact of port internal institutional structure on port productivity, as discussed in the previous sections.

Thirdly, as discussed previously, the variable capturing port ownership does not mean one coherent aspect of transformation of port institution. Certainly, it effectively captures multiple aspects of port institutions. However, multiple aspects should be disintegrated and distinguished when they are examined as a source of productivity improvement in the model. Port institutional features such as decentralized corporate structure and autonomy at a port authority are not always synonymous with more strategic institutional practice and asset management through diverse mechanisms at container port operation levels. Therefore, it is difficult to sort out where the sources of efficiency gap or improvement come from. Did it originate from the fact that port managers and authorities can become more productive through exercising their autonomy based on decentralized organizational structure? Or is it caused by the separation of container terminal operation function from government hands and putting the function in the control of more specialized entities?

Finally, many studies have focused more on productive efficiency in terms of port infrastructure productivity than allocative efficiency in examining the roles of institution on port productivity. While allocative efficiency may a give better picture considering the costs of port production, an inevitable limitation of the studies has been the lack of data on the port management and operations.

In terms of determinants of port infrastructure productivity, not only institutional factors but also other geographical and exogenous factors have been identified through diverse studies. The issues are discussed in the sections 7.4.3 and 7.4.4 in Chapter 7 and Appendix 7.4. The detailed approaches of previous studies and the reviews for important selected studies on the impact of port institution and ownership and other determinants are presented in Appendix 7.4.

CHAPTER 3

Defining Concept and Research Design

3.1 Research Goal and Question

The central question this study attempts to address is: *"Whether and how institutional structure and/or strategic managerial practice do shape port productivity?"*

In specific, I will concentrate on probing the question, "how does port private sector participation and corporatization influence port management practices? And, "how does their interplay establish port efficiency and performance?" The dependent variable in this research is port productivity. For the major independent variables, I suggest that three levels of institutional variables – macro-, meso-, micro-levels of institutional structure and practice (inter-port competition, corporate structure, and asset ownership and management practice) can interplay together to shape port productivity. The detail discussion about the dependent and major institutional independent variables will be clarified in the later sections.

The objectives of this study are to understand "what factors cause higher port infrastructure productivity?" "What role institutional structure of seaports plays, together with strategic capital management and ownership practices, in improving the efficiency and performance of port infrastructure and service delivery?" Focusing on the port sector, this study examines the relationship between institutional structure and managerial practice of seaports; how this interplay contributes to medium-term port infrastructure productivity.

Regarding the relationship between institutional structure, management practice, and port productivity, on the one hand, a port's institutional structure and management practice can be causal factors by which port authorities or corporations are allowed to exercise higher or lower autonomy and discretion. On the other hand, it is also possible for port authorities that have enjoyed strong, effective management practices to adopt institutional restructuring including private sector participation and corporatization as mechanisms to achieve higher productivity and to expand their business boundaries. This strategic moves and postures are particularly critical for them to take action to dominate the market, responding to severe global competition in the port and logistics sectors.

This study aims to test that the models can sustain as ways to affect dependent variables – port productivity. As a result, I suggest that the roles of institutional structure and managerial and institutional practice can shape seaports' productivity, under the working hypothesis in the following:

- While the variance in performance among ports was often possibly attributed to certain market or locational advantages enjoyed by some ports, the strong strategic capital management in ports may increase the concentration of technical expertise and financial strength.

- The process of building the strong capacity of strategic management begins with: (1) the creation of autonomous port authorities – represented as a meso-level institutional structure (corporate structure) that gives the authorities either higher or lower levels of discretion to effectively face with external environments, (2) the private sector participation at terminal levels – represented as a micro-level institutional and managerial practice that separates the port major production functions from the direct government involvement, and finally, (3) the more intense levels of inter-port competition – represented as a macro-level institutional environments that geographically and institutionally creates the pressure for multiple players in port production to act more innovatively and productively.

In formulating autonomy, accountability, and specialties of port production, port policies and reform efforts at the national, state, and local levels are utilized importantly, along with diverse mechanism of institutional layouts, characteristics and practices. In order to achieve better productivity in port production and service in the long run, port enterprise need to be free of certain interferences from politicians through diverse mechanisms that will be discussed in the later sections.

3.2 Research Hypothesis and Methods

3.2.1 Proposed hypothetical test and data gathering

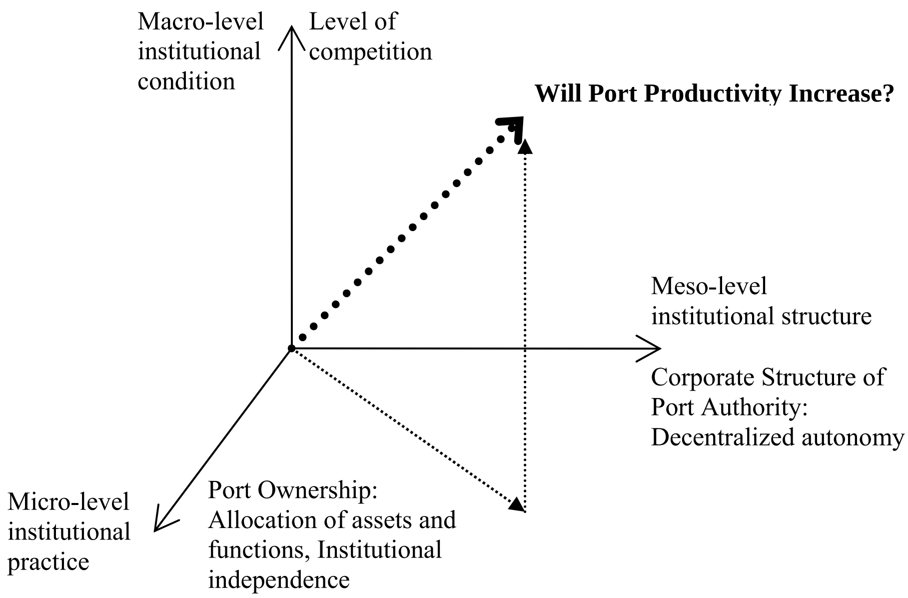
Let us briefly summarize the conceptual framework in order to propose the framework of data gathering for this study:

The intense levels of inter-port competition have pushed a number of ports into adopting various new strategies to occupy the higher ground of competition, some of which are to emphasize effective resource mobilization for a large scale capital investment that will possibly lead to port development and substantial improvement in port efficiency. Ports can thus reduce cost and time for handling containers and attract more cargoes, thereby eventually creating self-reinforcing mechanisms faster than their competitors. Given this context, national policy makers and port authorities seek various institutional reform mechanisms – particularly focusing on private sector participation in areas such as leasing, concessions, corporatization, and divestiture of port assets.

In terms of the role of ownership in productivity, a decentralized ownership can create autonomy for managerial functions to pick and implement strategies effectively in favor of the benefits of their own agencies. According to Parker (1994)'s logic, as a firm enjoys a more decentralized structure of ownership, there is strong internal organizational incentive that the firms can better strategize against external conditions and environments. It is possible partly because it keeps the public sector from being directly involved in the day-to-day operation.

I argue that the mechanism of port production and service is relatively complex: substantially various kinds of services are provided, often multiple service providers exist for one service, and assets and financial sources are shared by diverse public and private agencies. In order to more clearly examine and sort out the complexity inherent in the relationship between institutional features and the efficiency of ports, I suggest that port institutional characteristics are captured by using two different variables reflecting institutional structure and managerial and institutional practice of ports. As can be seen in Figure 3.1, there are three critical institution variables that may influence port efficiency:

Figure 3.1: Proposed Concept for Data Gathering



First, the intensity of inter-port competition is the macro level of industrial environments. As economic theory suggests, these institutional (market) as well as external conditions (geographical) may force a port to be keen on acting more strategically to preoccupy the market demand in their hinterland.

Another focus of this research is also placed on the two different organizational variables related to port ownership, administration, and management:

Second, the corporate structure of port authorities (meso-level institutional structure) reflects the general organizational layout and condition for port management. Economic theories imply that, as the corporate structure and administration of port authorities is more decentralized, the level of autonomy that the port authorities can exercise becomes larger partly because they can be free from politics. The more decentralized administrative structure can thus be a necessary condition in which port managing agencies act more proactively and effectively with better management. It is particularly so since port managers are able to seek their own interests in managing ports (e.g. increase port productive efficiency). A more clear definition of port management will follow in the section 4.2.2 in Chapter 4.

The third variable, port ownership, focuses more on capturing actual institutional practice regarding the assignment of port assets and functions among different levels of governments, port agencies, and terminal operators. It also actually measures whether a port authority and public government is separated from day-today terminal operation and management of terminal assets. This reflects micro-level institutional practice on port asset management because it mainly tries to capture how port assets and functions are actually transferred to leaseholders and concessionaires in general, and whether a port's terminal operation is actually separated from the overall port management and regulation. When the transfer is implemented, more players can be brought into port production and service. It may create managerial effects that would be influenced by some mechanisms including a more intense level of intra-port competition and more independence of actual production system. While the variable of corporate structure is an institutional condition that can partly reflect the level of proactive and strategic management of ports, the variable of port ownership, in fact, focuses more on the actual practice of port management and operation.

The design of institutional variables implies that the level of autonomy at a port level may not be always synonymous with the actual practice of terminal operation and port management in the port sector. In other words, autonomy at a port level may not automatically lead to better and strategic management and improving port efficiency, unless it is accompanied by the actual practice of port management and operation at the port and its terminals. I contend that examining the two variables separately can allow measuring sources of port efficiency more coherently and effectively. This approach contributes to further developing the frameworks by the previous studies on the relationship between ownership and port efficiency in the port sector.

Finally, the discussion of the dependent variable is detailed in the section, 3.3.

3.2.2. Research methods and strategy

It is expected that the research questions can be answered by addressing a set of related questions in the following:

i. Are corporatized or corporate port managers or authorities more productive?
ii. Are ports that separate terminal assets and operation functions from the government hands more productive?
iii. Are ports under the higher intensity of inter-port competition more productive?
iv. What factors causes higher productivity? What role does port institution and managerial practice play in influencing port productivity?

In order to address the questions, I propose a combination of two methods: a quantitative analysis supported by a qualitative review of cases, documents, and interviews:

Firstly, to deal with the questions and identify the independent variables of this study, an empirical survey should be conducted to explore global seaport institutions. The survey is based on secondary literature, surveys of primary port planning documents and port websites, and short telephone interviews with port planners. More details are discussed in the section 4.2.1 in Chapter 4.

Secondly, for the dependent variables of this study, port productivity indicators for global seaports are developed and examined based mainly on the concept of total factor productivity of port infrastructure. In addition, the port infrastructure productivity for each port is relatively benchmarked based on Data Envelopment Analysis (DEA) described in the section 3.3.3 in Chapter 3 and 5.2 in Chapter 5.

Thirdly, the relationship between port institutional features and relative port efficiency will be quantitatively examined based on statistical inference and bi- and multivariate models with port institution and productivity data created in the previous stages. The quantitative models are designed in order to identify factors that cause higher port infrastructure productivity and to evaluate the role of port institutions in shaping port infrastructure productivity. However, quantitative, cross sectional comparisons on port productivity indicators are difficult tasks that require a careful design to ensure compatibility and comparability of ports' condition. A careful attention should be paid to control variables such as natural environments (e.g. weather), geography (e.g. location and the role of ports in regions), and macroeconomic conditions (e.g. amounts and characteristics of regional trade), presented in Chapter 7. One possible way to deal with the problem is to expand the analysis to examine the relationship between "quantitative changes of the port efficiency indicators" and "changes of port institutions." By looking into trends and changes of port infrastructure productivity and by comparing the patterns of temporal changes of differing port institutions, it is possible to assess whether port institutions have in fact influenced port productivity. It is in this perspective that both time-series and cross-sectional examinations are important to evaluate whether institutionally restructured ports can become more productive through corporatization and private sector participation.

3.3 Conceptualizing and Measuring Dependent Variable

3.3.1 Port infrastructure productivity and efficiency as dependent variable

The concept of productivity, defined as the relation between input and output, has been an important concept applied in differing levels of aggregation in the economic system. It has been also argued that productivity is not only the most basic but also the most important indicator to govern economic production activities (Singh et al. 2000). At a firm level, productivity is often seen one of the most vital factors that impact a firm's competitiveness (Sink 1989; Tangen 2002). At a national level, it is also argued that the "only meaningful concept of competitiveness at the national level is *productivity*" (Porter 2002, 160).

According to Porter (2002), "[p]roductivity is the value of the output produced by a unit of labor or capital. Productivity depends on both the quality and features of products" and the efficiency with which they are produced" (p.160). He further argues that "an industry [of a nation] will lose out if its productivity is not sufficiently higher than foreign rivals' to offset any disadvantages in local wage rates" (p.161). In order to explain the national level competitiveness, the determinants of productivity and the rate of productivity growth should be understood focusing on "*specific industries and industry segments"* (p.161). It is therefore meaningful and interesting to understand port infrastructure productivity as a dependent variable and its determinants, given the severe competition and technological progress in the global market.

3.3.2 Comparison of productivity measurement

While the core concepts of productivity and efficiency are discussed in detail in the section 5.2.1 in Chapter 5, this section compares differing ways to measure productivity that are applicable for the port studies.

3.3.2.1 Partial Indicator

Table 3.1 shows examples of indicators measuring port efficiency and performance. Performance is a more comprehensive but vague concept than efficiency. Performance refers to the degree of success in achieving intended goals and objectives (Devine et al. 1985; Song et al. 2001, 150). In other words, performance is a concept that focuses on the status of outcomes that are achieved through certain behaviors (production and service) as a result of pursuing goals. In contrast, efficiency is based more on the concept of behaviors, that is, production and service activities, themselves.

Since partial indicators reflect partial factor productivity and fractional views of performance and efficiency evaluation, they inherently mirror various, but sometimes conflicting aspects of port operation and management. Thus, they oftentimes give distorted information on port efficiency and performance depending on the focus of objectives entailed in different ports. Therefore, if one needs to carry out cross-sectional comparisons by using partial indicators, it requires a careful design to ensure compatibility and comparability of various conditions and goals of ports. For example, evaluations based on the partial indicators can more easily be influenced by such external factors as natural environments (e.g. weather), geography (e.g. location), and macroeconomic conditions (e.g. intensity of regional trade), and so on. It is thus difficult to systematically measure and evaluate the status of port efficiency and performance.

Table 3.1: Port Performance Indicators and Weakness[1]

Indicators	Variables	Notes
Productivity Indicators	•Total throughput: - Container traffic handled - Number of vessels handled •Average stevedoring productivity for container handling: - Total container traffic handled per working hour - Container movement per crane per hour •Average output per berthing: - Total ton per ship hour - Average output per hook - Land use efficiency (TEU/hectare of yard) •Working time over time at berth	• Sensitive to macroeconomic conditions (e.g. amount of regional trade) • Sensitive to current spare capacity of ports, frequency of ship calls, and size of ports
Economic & Financial Indicators	•Port charges (charge/TEU) •Average cost (cost/TEU) •Total income and revenue growth •Operating surplus •Financial liquidity	• Financial targets can be set and controlled at a certain level by port authorities
Other Performance Indicators	•Market share •Average turn-around-time •Average pre-berthing delays (in days) or waiting rate •Ship detention list (monthly) •Berth occupancy rate	• Sensitive to natural environments of ports (e.g. weather)

Moreover, recently, port production has been organized in a more complex environment. As Marlow et al. (2004) argues, traditional partial performance and efficiency indicators

[1] Source: summarized from reviews of various literature based mainly on UNCTAD (1975)

provide little information about the actual quality of service offered by a port. According to Marlow, in order to design a complete quality index of port performance, it should be considered that ports have become more "agile," requiring an integration of such logistics elements as supply chain and visibility of internal processes of port management. While his suggestion on port efficiency and performance indicators is theoretically comprehensive, ports and governments still suffer from a lack of data to support, design, and apply this type of comprehensive index.

Among various partial indicators shown in Table 3.1, port productivity indicators usually measure various aspects of port resource utilization under the relationship between inputs and outputs. For example, cargo handling per one unit of crane, berth, or working hours and total cargo tonnage handled per terminal area are some examples of productivity indicators. Yet, again, partial productivity indicators reflect only incomplete aspects of port production and operation. And each indicator illustrates different parts of port productivity (Tongzon 1995).

In spite of its weakness, this approach prevails among practitioners and policy analysts who carry out inter-port comparisons on port efficiency. In the 1990s, several studies adopting this approach attempted to assess the performance of Australian ports (Australian Transport Advisory Council 1992; Australian Bureau of Industry Economics 1993; Australian Productivity Council-Productivity Commission 1998; Australian Productivity Council-Productivity Commission 2003). Since then, many port authorities started publishing productivity indicators in their annual reports for performance comparisons. These studies tried to ensure the comparability of ports by taking examples of simulation with similar-sized ships to berth, un-berth, and operate within the benchmarked ports. Yet, as one of the interviewees in the Production Commission in Australia mentioned, port performance and efficiency studies in the Australian government had recently moved away from this approach due to the difficulties of ensuring the completeness of information and the compatibility of conditions faced by ports that can be acquired by partial efficiency indicators.

In general, partial productivity indicators do measure productive efficiency, but not economic efficiency, or cost efficiency. They reflect aspects of the application of labor or capital resources on the production of ports and terminals. They thus do not indicate whether cargo handling rates are achieved using the most economically efficient mix of the resources, given their relative costs. In addition, since the partial indicators demonstrate limited views of port operation, they do not often produce analytically consistent results. In most cases, since one single measure cannot suffice for the purpose of productivity evaluation, multiple indices are examined. Yet, as it is usual to observe existing conflicting indices at the same time, it is difficult to decide how to show benchmarks (Zhu, 2003, 2).

In sum, in assessing productive efficiency, the benchmarks based on partial indicators can even be misleading: while port productivity stems from the joint contribution of various inputs, the use of a single factor may ignore the effects of any interaction, substitution, and trade-off among input factors on production (Estache 2002).

3.3.2.2 Total Factor Indicator: Frontier-based Efficiency Measurement

The concept of total factor productivity mainly began to be applied in the 1990s as a way to compare inter-port efficiency and competitiveness. While a few different methods have been proposed and applied, the main idea is predicated on the concept of production frontiers explained in the previous section. The bottom line of these approaches is that efficient firms are operating on the cost or production frontier. According to De Borger et al. (2002), these frontier models have successfully found their way into the transport sector in the late 1990s. The models have been applied to studying productivity of not only transport modes such as ports and airports but also other infrastructure sectors such as water and education facilities (Cullinane et al. 2004).

There are two major different directions in this line of study: parametric and non-parametric. The parametric approach adopts econometric techniques, pursuing a particular functional form to explain the relationship between inputs and outputs. Based on a frontier production function – usually Cobb-Douglas, it measures efficiency relative to the function that is statistically measured. On the other hand, the non-parametric approach uses mathematical programming techniques that are often called Data Envelopment Analysis (DEA).

Parametric Approach

The parametric approach involves econometric specification of models represented and interpreted by parameters. In the past, parametric production frontier models were deterministic under the assumption that all firms shared a common fixed frontier lines (e.g. Aigner and Chu 1968; Afriat 1972). It is, however, criticized in the sense that this is an unreasonable assumption because it ignores "the possibility that the observed efficiency of the economic unit may be affected by exogenous (i.e. random shock) as well as endogenous (i.e. inefficiency) factors," (Song et al. 2001, 163). The econometric point is that it is dubious to generalize these factors into a single disturbance term by referring to inefficiency. In order to correct this problem, a stochastic frontier model is suggested, replacing the deterministic frontier models. Unlike the deterministic model, this approach takes into account the fact that the production frontier is not fully under the control of economic units. The approach is further developed as refined econometric techniques that clearly split an error term into two different error structures. One part represents inefficiency of firms with a negatively skewed half-normal distribution, while the other part indicates normally distributed statistical noise.

Measuring stochastic frontier models requires several conditions. There should be one single overall output measure or relatively complete price data (SCRCSP 1997). Yet this is not often the case for many analysts, researchers, and planners in port authorities, given the limitation of compatible, comprehensive, and quality data in the sector. In addition, the models require two critical methodological conditions: (1) the distributions underlying productive inefficiency should be either half-normal or exponential; and the distribution of statistical noise has a normal distribution; (2) regressors, i.e. input variables, and productive inefficiency are mutually independent. The latter is an unrealistic assumption, however. If a firm knows its level of inefficiency, it typically takes actions that influence its input choices in management and production processes (Cullinane et al. 2002) unless it is inhibited by external conditions and forces.

Non-parametric approach: Data Envelopment Analysis (DEA)

Another branch of methodological frameworks to apply the concept of total factor productivity is suggested based on non-parametric, mathematical programming techniques, called Data Envelopment Analysis (DEA). DEA is a methodology directed to creating efficiency frontiers based on a piecewise linear surface, instead of fitting a regression plane through the center of data (least-squared regression approach). DEA is a more flexible tool compared to stochastic production frontier models since DEA has been developed as a way to evaluate efficiency where market prices are not available. If price, or unit cost, data is available, it can also be extended to measuring cost and profit efficiency by utilizing the newly emerging models in the area (Cooper et al. 2004, 3).

3.3.3. Supports for DEA

Let us discuss more reasons to apply DEA models to port productivity analysis. Firstly, DEA, in general, makes benchmarking easier and more realistic. DEA provides both accuracy and flexibility in efficiency measurement under the condition of limited data. Three examples can be raised: (i) DEA does not require an explicit *a priori* determination of the relationship between inputs and outputs, or the setting of rigid importance weights for the various factors. (ii) DEA enables derivation of an efficiency envelope, which contains the most efficient ports of the group analyzed, against which all other ports are compared, rather than choosing the most efficient port. The choice of one port representing the best international practice may be unfair due to differences in contexts. (iii) DEA permits "unconventional variables" such as the number of students graduated, number of patients served, even journal ranking (Burton and Phimister 1995) to be used for input and output variables for efficiency evaluation. For many applications, these features make DEA a more flexible tool compared to other efficiency measures.

Secondly, the concept also allows an evaluative analysis to take into account multiple input variables and output variables, which is different from the stochastic frontier models that only allow a single output variable. In this chapter, DEA refers to each port as a Decision Making Unit (DMU), in the sense that each is responsible for converting inputs into outputs. While this chapter uses one output variable, DEA can involve multiple inputs as well as multiple outputs in its efficiency evaluation. This makes DEA analysis more suitable for port efficiency measurement because ports produce a number of different outputs. Ideally, these outputs can be the quantity and the variety of cargoes handled, the types of ships serviced, the interchange with land transport modes, and the additional services rendered, such as warehousing and so on (Roll and Hayuth 1993, 153). In this sense, this chapter's framework can be further developed when data are available.

Thirdly, DEA is the model that has the capacity to identify the sources and amount of wastage in inputs, or shortfalls in outputs, for each DEA-inefficient DMU. In practice, the sources of inefficiency can be an important piece of information as it can enable managers and policy makers to identify the problematic areas for the inefficient DMUs and provide precise information about the corrective efforts required to achieve efficient performance.

Finally, it provides an effective framework to measure the temporal change of efficiency for each DMU through Malmquist Productivity Index (MPI), which is presented in Chapter 6.

One thing that the designer of the DEA analysis should pay attention to is closely related to the coverage of DMUs included in the analysis. Ideally, the more organizations included in the sample, the better the explanatory power of the DEA model. In this ideal case, there will be fewer organizations found efficient by default. And, conceptually, there will also be more to learn by including a more diverse range of organizations. However, the cost of possibly including too much diversity is that comparisons may no longer be sufficiently like-with-like. This may require adjustment for differences in operating environments to ensure that the study is both fair and credible.

3.4 Scope of the Study

3.4.1 Why choose port infrastructure to study the role of institution in productivity?

The port infrastructure is long-lived and costly, similar to many utility sectors and transport infrastructure such as highways. However, unlike utilities and highways, ports provide a wide variety of services and functions rather than a few specific outputs (See Table 2.1 in Chapter 2). In addition, there are multiple actors in the public and private sectors and complex decision-making and production involved in port development, management, and operation.

Complexity, diversity, and uncertainty engaged in port management and implementation of port policy will severely increase the need for developing appropriate institutional structures and strategic practice, in order to achieve better port performance and infrastructure productivity. Therefore, the stark evidence can be shown with contrary outcomes depending on the capacity and the role of port institutions.

Containerization has changed the seaport sector from a sector requiring labor-intensive operations to a more capital-intensive sector. Hence, seaports now need to procure diverse kinds of capital-demanding infrastructure to accommodate oversized ships and to deal with massive amounts of freight within short time. In this context, long-term capital investment through diverse and strategic institutional mechanisms becomes the center of attention among diverse aspects of institutional restructuring and design.

3.4.2 General sampling framework to select ports for this study

This study focuses on world scale and major national gateway container ports. Since container handling is still one of the major port functions, it is reasonable to focus on container ports to draw implications on the objectives of this study. For this study, I firstly select world container ports that handle more than 800,000 TEU in 2001.[2] While the selection of 800,000 TEU is a bit arbitrary, my logic to cover almost all important container ports in the world is described in the following:

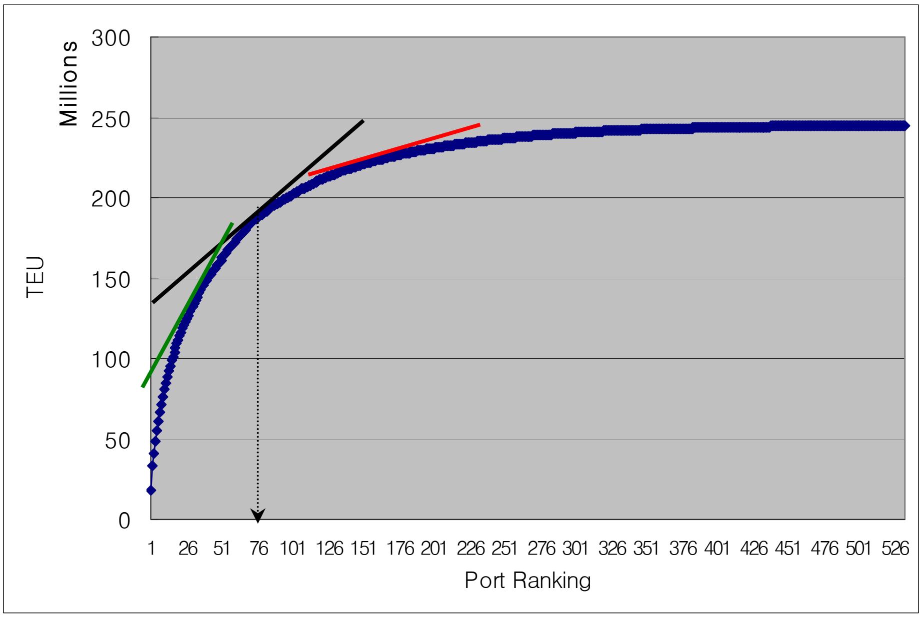
As shown in Figure 3.2, the total number of container ports reporting their throughputs in 2001 to Containerisation International is 533, which may not cover all container ports in the world but is the most exhaustive list of them. In 2001, a total of 245 millions of TEUs was handled by the 533 ports. Approximately 75 % of the tonnages are handled by the top 75 ports. In Figure 3.2, an inflection point from the relationship between port ranking (production size) and the accumulated throughputs is found at this size of container production. The smaller ports than this point were regarded as less interesting, since the slope of decreasing returns implies that adding one more port beyond this point does not add much throughput to the global container port production. The top 75 ports handled at least more than 800,000 TEU in 2001. I then collected data for the largest ports in the countries that do not possess the top 75 ports in the world. The

[2] When my data gathering began for this study, the port throughput data for 2001 was the most recent data for which port throughput are confirmed by the Containerisation International Yearbook (CIY) and Containerisation International Online. It takes two to three years to confirm the throughput data after the initial report of the data.

resulting data cover the largest ports and the fairly large ports situated in almost all countries.

Figure 3.2: Accumulated Port Throughputs by Port Ranking in the World

(Ranking 1= the largest scale of production)



The data on a total of 154 ports were collected for the year 2004 after eliminating some landlocked countries that do not have major seaports and some countries for which port data are not accessible. Another goal is to trace institutional changes for these ports between 1991 and 2004. Among the 154 ports, the ownership and corporate structure of a total of 98 ports can be identified for the year 1991, while there is partly missing information for some cases in the data. By doing so, the major world scale and national gateway ports in the world are covered for data collection and analysis.

No currently available data set contains complete information on ownership for world port institutions. In fact, a few previous attempts to construct a public database regarding ports' output, efficiency, capital investment, and institutions have turned out to be failures.[3] I discussed the reasons for failure in the following:[4]

Firstly, many port terminal operators keep their production, service, and institution information confidential, mainly for business reasons. While there have been many previous attempts to adopt a way of voluntarily reporting data to a central databank or website, they did not usually provide any incentive or disincentive for terminal operators or port authorities in order to guarantee their voluntary participation. Secondly, commercial consultancies providing this sort of database in the field are still highly profitable and so quality information is only possessed by commercial data collectors and providers. Finally, in terms of port ownership, the unit of analysis (terminal level vs. port level) interested in by commercial information providers have often been different than the ones interested in by academic researchers. The main objectives of commercial information providers are to consult terminal operators by comparing their performance to propose effective marketing strategies. More often than not, their databases do not hold the specific or specialized information about port-level institutions that is essential for this study: i.e., port ownership and corporate structure.[5]

---

[3] For example, APEC attempted to construct an online port database in the early 2000s

[4] Findings are based on interviews with port specialists and consultants, reviews of literature, and my original observations.

[5] Such a database from Drewry Consulting has similar types of data on port institutions. The database may be useful partly for certain types of research. However, it is compiled at each terminal level without having comprehensive information for all terminals. This makes it difficult to aggregate the data to a whole port level: a Port = terminals 1, 2, 3,…,N.

CHAPTER 4

Survey and Analysis of World Port Institutions: Port Ownership and Management Structure

4.1 Introduction

This chapter analyzes the institutional structure of world seaports, particularly focusing on the ownership practice and corporate structure of port authorities or institutions responsible for port management. It traces how the ownership and management structure of world ports has changed over the last decade by comparing the two time periods 1991 and 2004. The implementation of privatization has been flourishing in the port sector since the late 1980s and early 1990s (Asian Development Bank 2000; Cullinane and Song 2001; Ircha 2001; Juhel 2001; Notteboom and Winkelmans 2001; Hoffmann 2001; Trujillo and Nombela 2000). It has allowed for the diverse mechanisms of private sector participation such as leasing, concessions, and corporatization to be adopted by a variety of port authorities around the world. The role of public sector has continued to be transformed, while it still remains critical until recently (Baird 2002). Yet, only a small number of recent studies have systematically traced how the institutional mechanisms dealing with the management and operation of world scale ports have changed during the last decade (e.g. Baird 2000). This therefore has led to a lack of empirical evidence on the role of institutions in port production and efficiency, while full theoretical attention has been paid to the issue.

The lack of data hampers statistically meaningful analyses in examining the role and efficiency of port institutions (See Chapter 3). It has been criticized that most studies in the field of port economics thus far take econometric analyses with cross-sectional data (Cullinane et al. 2004) or panel data with a limited numbers of ports (only 20 to 30) in the world. When the total number of ports is not large enough in the analysis, it is difficult to acquire statistically meaningful results in analyzing the role of the institutional structure in port efficiency. If the number of samples for different categories in the institutional typology (i.e., public port, landlord port, and private port) is even smaller, it is difficult to interpret and generalize the results.

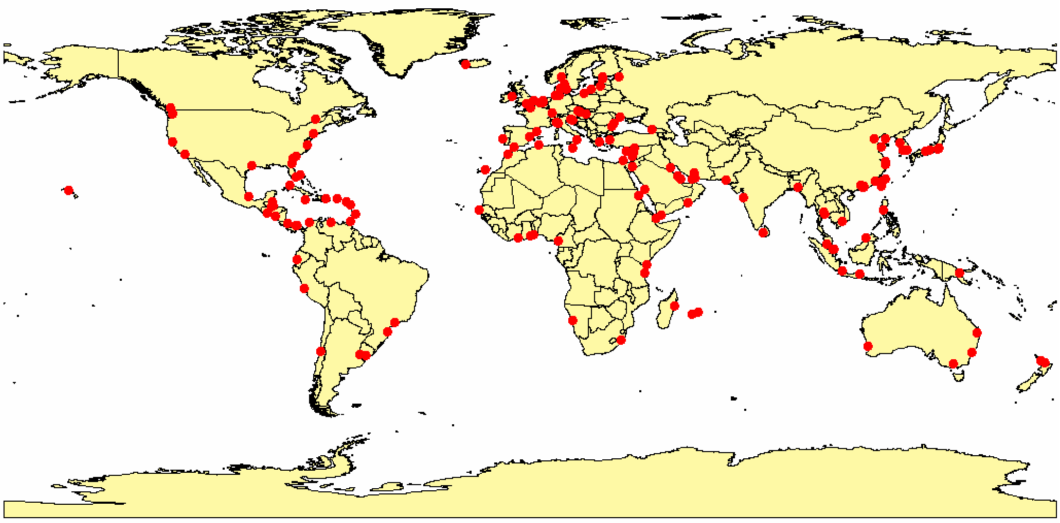
This chapter aims to survey institutional features by reviewing approximately 154 international hub ports and national or regional gateway ports. This chapter also becomes the foundation of Chapter 7 by generating variables of port institutions regarding ownership, corporate structure of port authorities, and temporal changes of them, which will be used as institutional variables to explain port efficiency.

4.2 Analysis framework

4.2.1 Data collection and methods

The main goal of data collection is to survey institutional structures for world-scale ports and major national gateway ports in almost all countries. Specifically, port institution data collected in this chapter consist of two different aspects: (a) port asset ownership practice and (b) corporate structure of port authorities/managers. I collected data for 154 ports for 2004.[1] Among the 154 ports, I identified the ownership and corporate structure of a total of 98 ports for the year 1991. As the data were compiled for the two years, temporal changes in the two variables can also be traced.

Figure 4.1: Ports for Data Collection



[1] See Chapter 3 for sample frameworks

The ports selected for collecting data are globally distributed and located in seven continents and therefore include a wide range of environments (Figure 4.1). Often, depending on countries, port regulations and the institutional environment faced by ports are different in many ways. For example, a port-regulating organization is a separate entity at the national level in some countries, while management is carried out at each port level. In other countries, seaports can be subject to self-regulating systems together with management carried out by its own port authority.

Under these complexity and diversity, one of the challenges I faced was to conceptualize the core institutional characteristics in terms of ownership and corporate structure of units responsible for port planning, management, and operations. In order to identify core institutional features under the consideration of more rich historical and institutional contexts, I collected the data through multiple methodologies such as (a) reviews of secondary literature, (b) surveys of primary port planning documents and online websites, and (c) short telephone interviews with port planners. The multiple methods allowed me to evaluate information more qualitatively in deciding port ownership and the corporate structure of organizations for port management (e.g., port authority, government, private entity). The approach captures the similarities of port institutions and organizational frameworks in many countries, while understanding the diverse ways of applying specific institutional mechanisms to port production, management, and organizations. For instance, there were various mechanisms to induce port investment and involve governments in port management and terminal operation (joint venture vs. direct government investment).

The institutional survey follows systematic processes in the following: Firstly, I developed some criteria (See sections 4.2.2 and 4.2.3) to clearly define what port asset ownership practice is and what types of organization are responsible for port management. At the same time, I gathered broad background information and reviewed a regional difference and a national level port policy and crosscheck its port management systems. They were done through primary and secondary literature published from port and terminal business consultants, international organizations for maritime and port policies, and countries' internal policy documents.

Secondly, based on an understanding of the broader context, I collected more specific information about each port through surveys of secondary literature, port websites, and port planning documents or performance evaluation reports. Most of the documents managed by public port authorities were publicly available either in an electronic format on their websites or as a hard copy. Moreover, a variety of ports also published their port policies, efforts for private sector participation, and the ownership status of each terminal on their websites.

Finally, I conducted short telephone interviews with planners for some ports for which it was usually difficult to acquire information or to clearly define institutional features from the above mentioned methods. I was usually directed to port authorities' departments responsible for terminal management, capital planning, or strategic planning and simply asked the three or four steps shown in Figure 4.3 and developed in the section 4.2.3. The telephone numbers of port authorities were first identified through *Ports and Terminals 2005* published by Lloyd's Register Fairplay or, secondly, directly through websites for ports. These short telephone surveys helped to conceptualize the status of ownership for each terminal and for cargo handling equipment and the corporate structure of organizations for port management. The total time for each port usually took less than 10 minutes.

A descriptive transcript about institutional contexts and aspects for ports, acquired through these processes, were transformed to codes depending on the categorization following the logics noted in Figure 4.2 and Figure 4.3. The coded data were classified and analyzed for both periods (1991 and 2004) and/or location (countries or continents) for the further analyses presented in the sections 4.3 and 4.4.

4.2.2. Analysis framework for port management and corporate structure

The first institutional variable is the corporate structure of the main body for managing ports. A main body of port management is defined based on three important authorities, while it is sometimes regarded as a port authority. The definition is to try to capture what institutional identity a port management unit has for the given port. The role of a main body of port management should have three important authorities:

- Firstly, the body should have the authority to plan and design ports strategically and in the long term (e.g. financial, strategic, and master plans for nautical and physical infrastructure).
- Secondly, the body has an authority to lease or give concessions for its property (mainly container terminals here) in a port.

- Thirdly, the body has an authority to decide port tariffs, including container handling fees, or can transfer the authority to terminal level operators.

In terms of the first criteria, it is a relatively difficult task to clearly judge who has the main responsibility since the long-term and strategic planning for some ports is usually the product of collaboration among many layers of government agencies including port authorities. For the second, there are many cases where a port authority or a responsible department deals with practical procedures to give concessions for terminals while they still need some types of administrative approval or consultancy from higher levels of governments. Finally, for many landlord ports, the authority to decide container handling charges is passed down to each terminal operator while ports with more centralized port administration decide the port tariff at national or regional government levels.

It is not unusual that diverse actors are involved in the above stated criteria. If a certain level of government department or port authority is responsible for major parts of them, I regard it as a main body of port management. The institutional analysis and survey conducted in this chapter has the task of identifying where the boundaries exist among different players in a port and uncover what types of institution a port manager is. I find that the following six categories can be generalized based on the institutional similarities of world ports:

(1) national government (or national port authority)
(2) state or provincial government (or state port authority)
(3) local government department
(4) statutory authority or corporation
(5) government owned corporation
(6) private enterprise

4.2.2.1 Supra-local government department (National, State, or Provincial)

My institutional survey finds that ports can be managed by the above six types of organization. While some ports with a centralized system are managed by national and state level government departments and port authorities, others are managed by local level governments. In terms of the fourth category, statutory port authority and corporation, there are ambiguous areas of corporate structure. In many countries, port managing agencies are established and run based on special laws whereas they can run at various levels including national, state, or local levels. However, if the port authorities are established at the national level governing all the major ports in the nation, it is classified as a national level manager. The same rule applies for the state level ports. Examples exist in the Indonesian case. Indonesia has a national level port corporation that governs almost every major container port in the country. Because of this, the Port of Tanjung Priok, for example, is categorized as a national level port authority.

4.2.2.2 Local government department

The boundaries between ports managed by Type (3): local government department and Type (4): statutory authority or corporation include some gray areas, as many local ports also run based on special municipal laws and codes that are enacted for the municipality's one and only port. In this case, a more qualitative decision has been applied based on whether the port managing departments should transfer their revenues to the local government so that their financial autonomy should be compensated. For example, Port of Los Angeles is classified as a municipal port since the L.A. harbor department is required to transfer parts of its revenues to the Los Angeles government.[2]

4.2.2.3 Port corporations (Statutory, GOC, and Private enterprise)

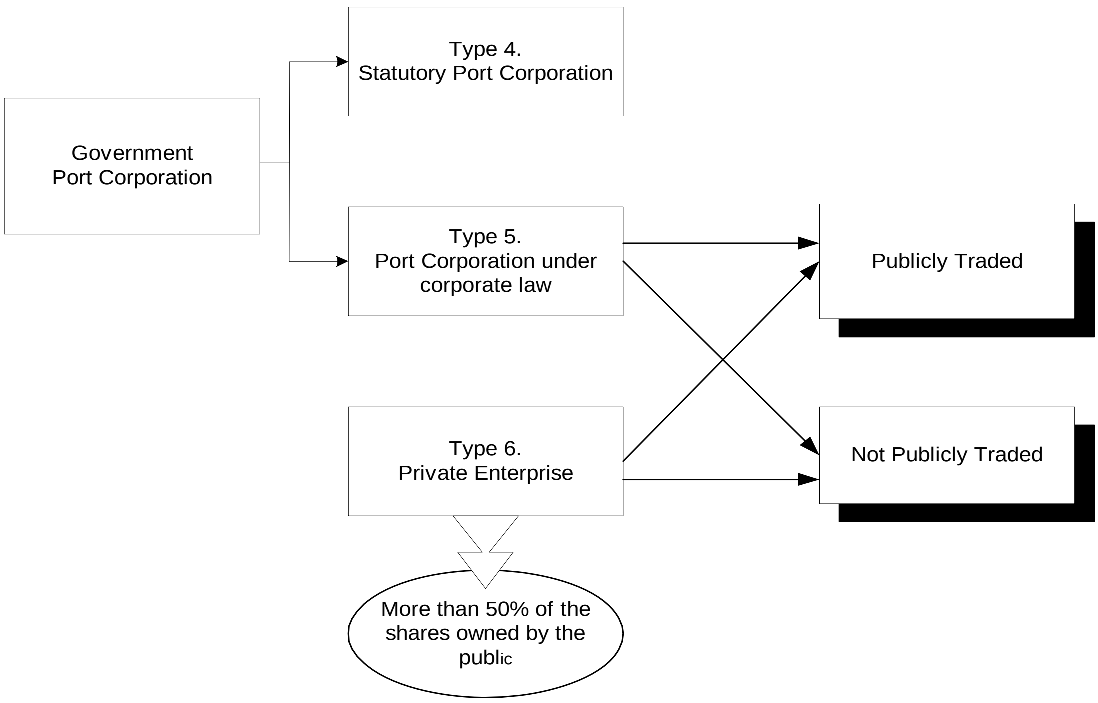
In terms of definition of port corporation or port corporatization, there is little agreement among countries. Australia, New Zealand, Malaysia, Singapore, South Korea (Busan), United Arab Emirates (Dubai), and recently a few North European ports such as Antwerp, Rotterdam, and Bremen announced that they had adopted corporatization, but their mechanisms vary in many ways. There has also been a different view in academia as to the concept of corporatization. Corbett (1996) claims that corporatization is a conversion of a "government owned organization into a company operating under the same legal conditions as a private enterprise (79)." Quiggin (2002) has a different view, contending that corporatization is "the conversion of statutory authorities or corporations into publicly owned corporations." World Bank (2001) suggests that corporatization is "the process in which a public sector undertaking, or part thereof, is transformed into a company under private corporate law," which can usually be "achieved by selling shares in a new company that conducts the port's business and hold its assets (Module 3, 44)." Beresford (2000) argues that a corporatized port is a "halfway house" between private and public ownership, which is an extended notion of statutory authority (71).

---

[2] See sections 4.3.1 and 4.4 for discussions of the corporate structure of surveyed ports and regional trends.

My review of theoretical concepts of port corporatization and the legal definitions of corporation adopted throughout different countries in the world allows port corporations to be categorized in general as three different kinds: Statutory Port Corporation (SPC), Government-Owned Corporation (GOC), and Private (non-governmental) Enterprise. Figure 4.2 shows more clearly a typology of corporations in the world port sector.

Figure 4.2: Typology of Port Corporation



Especially, the difference of institutional models between Statutory Port Corporation (SPC) and Government Owned Corporation (GOC) can be illuminated by Everette (2005a; 2005b)'s discussion on Australian models of port corporation: Statutory State Owned Corporation (SSOC) and Government Owned Company (GOC). In general, the difference exists in the sense that a statute specific to the port organizations establishes Statutory Port Authorities and Corporations. On the other hand, GOC is subject to the general corporate law that governs all private firms in a country. Charters, articles and *modus operandi* under a SPC "are embedded within the specific legislation itself (Everette 2005a, 11)." For this reason, they are possibly attached to government and political needs, especially when multiple portfolios are carried by the shareholding ministers. These factors usually lead to the fact that the structure and accountability can be significantly different from those of a private firm.

In her discussion of Australia's Statutory State Owned Corporation (SSOC) model, Everette (2005a) points out disadvantages of the model:

> Within the SSOC model, government, or its representative(s), are central to the operation of the organization. The much needed distancing from government has not usually occurred. Shareholding and portfolio ministers remain pivotal to the day-to-day operation of the port. They can set pricing structures not necessarily based on commercial criteria; they determine investment and divestment policies; they determine strategy… Under this system, they are unable to employ strategy in a sense of a pattern of purposes, policies, programs, actions, decisions, or resource allocations that define what an organization is, what it does and why it does it (Bryson 1998). Rather while a CEO of a statutory corporation wishes to run his/her organization in ways that secures its future, the means of operation is constrained by the processes, procedures and routines of Ministerial and Cabinet government (Stewart 2004). These policies frequently are *ad hoc* with short term objectives to meet political rather than commercial needs and as such are subject to frequent change destabilizing the organization. (p.11)

In essence, while government-owned businesses are in general established to come up with better and innovative ways of achieving efficiency and performance, a debate has been around its specific institutional structure on how government-owned port corporations are organized: Whether are they statutorily created with special power or governed under the general corporate law being treated equally with a private company.

Statutory Port Authority or Corporation (SPC)

According to my review, the concept of “Statutory Port Corporation (SPC)” is in fact similar in practical ways to “Statutory Port Authority,” unless governing legislations give statutory port corporations substantial amounts of managerial freedom or autonomy. Yet the substantial level of autonomy in port management is usually acquired through adopting the GOC model. In fact, the statutory port authority models adopted in northwestern America (e.g. Tacoma, Seattle, Vancouver) equally enjoy managerial and financial autonomy under the statutory port corporation model. Their corporate identities are mainly created based on special legislation governing the port regimes. The model of Statutory State-Owned Corporation (SSOC) adopted in many Australian ports (e.g. Sydney, Melbourne) is another model of a statutory port corporation. Both Statutory Port Authority and Statutory Port Corporation are classified as Type 4 since they are relatively close to each other in comparison to Type 5, Government Owned Corporation, which is governed and managed under the general corporate law.

Government Owned Corporation (GOC)

Type 5 refers to port corporations operating under the general corporate law rather than operating under the special law. A “Government-Owned Corporation” (GOC) is significantly different from the concept of Statutory Port Corporation (SPC). To specifically define the concept of GOC, I follow Everette (2005a)’s model of Government Owned Company. “A GOC is identical to any other company, publicly listed or privately owned (10).” The organization’s constitution, which defines the objectives and the operational modes of port corporations, is registered and subject to the general corporate law in a country. It is therefore “created along the same lines as a publicly listed company – the only difference being that the government is the shareholder (10).” There are different sorts of Government Owned Corporation. The company can be either “proprietary or public”, “listed or unlisted”, and “limited by shares or by guarantee.” The common aspects are that “the government’s interest may be represented through membership and/or through board representation (10).”

In theory, a Government-Owned Port Corporation is an institutional model to create a port managing entity that functions and “operates at arm’s length from government (Everette 2005a, 10).” Therefore, the model compared to a statutory port corporation, reduces the role of government from the day-to-day operation of business. The government acts purely “as a shareholder suggesting strategic directions to the business” through board representation (11).

This type is in line with Corbett’s concept of corporatization in the sense that this type of government-owned port corporation operates as a company operating under the same legal conditions as a private enterprise. If the majority of their shares, i.e. more than 50%, is owned by government agencies they are classified Type 5.

Private Enterprise

Finally, Type 6 is named private enterprise, in that their shares are proprietary, or privately owned. They can be either unlisted or listed through Initial Public Offerings

(IPO) and exchanged in the stock market. If the minority of their shares, i.e. less than 50%, is owned by government agencies, they are classified as Type 6.

4.2.3 Analysis framework for port ownership practice

Our approach to designing a typology of port ownership first begins with the concepts suggested by Liu (1992; 1995) and the World Bank (2001). I then create and revise the typology based on the empirical survey on port ownership for 154 ports in the world. The theoretical concepts by Liu (1992; 1995) and the World Bank (2001) are based on four different categories: (Operating) Service port, Tool port, Landlord port, and Private port, identified in Table 4.1. The World Bank's typology is created based on ownership and authority to control four major categories of asset and function for production and service organized in seaports: (1) land; (2) port infrastructure (e.g. breakwater; dredging; pier and berth); (3) port superstructure and cargo handling equipment (e.g. terminal building, container crane); and (4) cargo handling service and labor.

Table 4.1: Port Ownership Model[3]

Type	Land	Port infra-structure	Super-structure & cargo handling equipment	Cargo handling / Port labor	Note
Operating Service port	Owned by public (port authority)	Owned by public (port authority)	Owned by public (port authority)	Carried out by public (port authority)	-Full public control over planning, regulation, and operation. -Direct control from Transport ministry thorough the chairman appointed by the Minister

[3] Table 4.1 is created by summarizing and reorganizing Liu (1995) and World Bank (2001, 20-21)

Tool port	Owned by public (port authority)	Owned and developed by public (port authority)	Owned, developed, and maintained by public (port authority)	Carried out by **private, contracted** by the shipping agents or licensed by port authority	-While port authority owns and operates the cargo handling equipment, the private cargo handling firm contracted with ship/cargo owners is not able to fully control the cargo handling operation itself. -The cost using the capital assets is absorbed by the port authority.
Landlord port	Owned by public (port authority)	Owned by public, but **leased to private**	Owned by **private**	Carried out by **private**	-The lease needs to be paid to the port authority (usually a fixed sum per square meter per year) -Dock labor is employed by private terminal operators
Private port	**Private**	**Private**	**Private**	**Private**	**-** In the absence of a port regulator, privatized ports are self-regulating (e.g. UK)

However, as Asian Development Bank (2000) points out, most ports' institutions use a hybrid of the four theoretical categories. Our empirical survey finds that many ports do not necessarily fall exclusively into one of the four categories that were theoretically defined. Rather, the institutional arrangement of most ports is shaped as a hybrid of two or three categories which is simplified in Table 4.2. This typology attempts to capture the actual institutional practice observed in the global port sector.

Table 4.2: Terminal-level Operation and Ownership of Assets

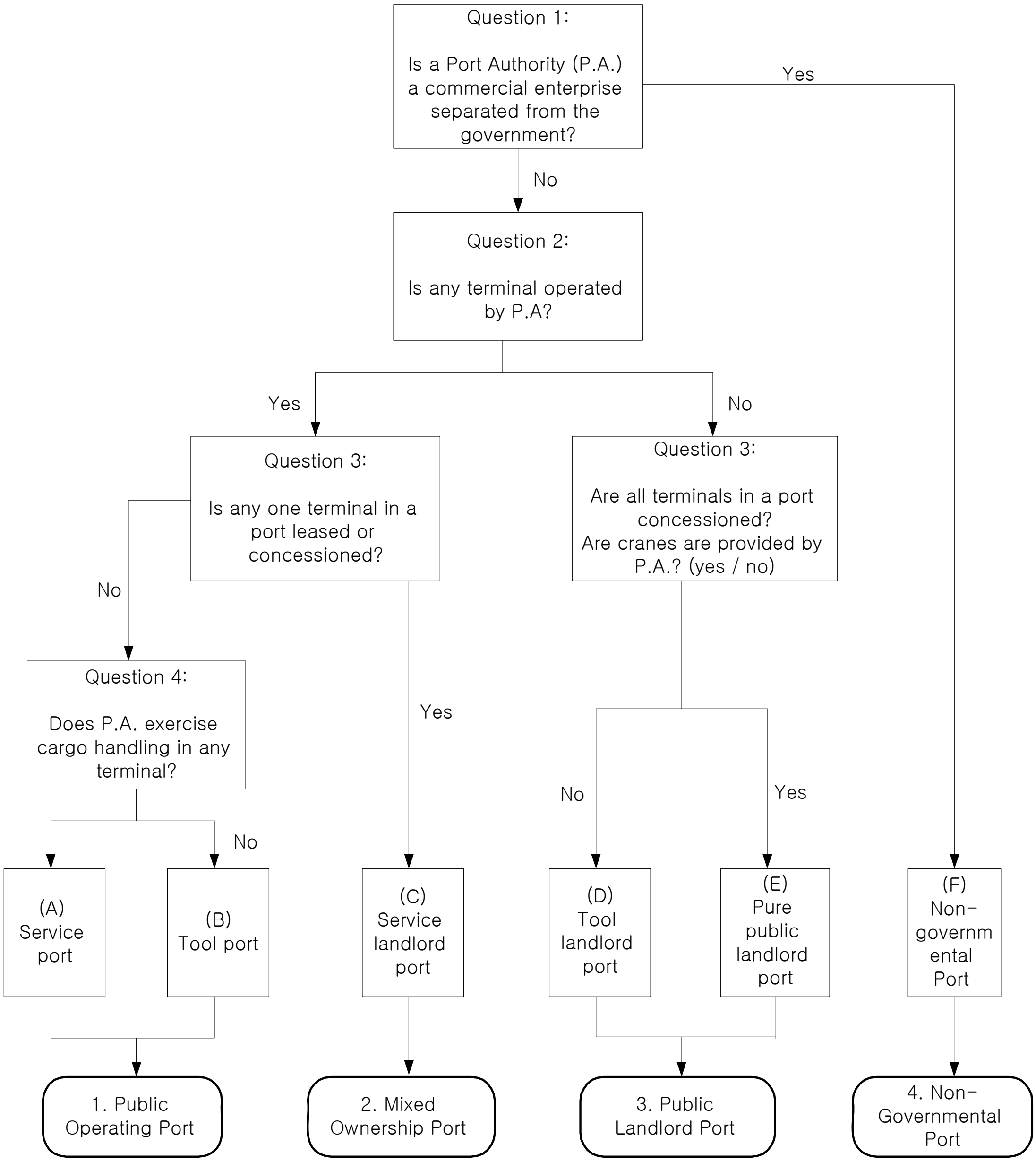
Type	Public Port Authority or Government	Institutionally Separated Private or Quasi-public Entity
(A) Public Service Port	Land Infrastructure (berth) Superstructure (crane) Cargo handling	None
(B) Public Tool Port	Land Infrastructure (berth) Superstructure (crane)	Cargo handling

(C) Service-Landlord Port	Land Infrastructure (berth) Superstructure (crane) Cargo handling	Infrastructure (berth) Superstructure (crane) Cargo handling
(D) Tool-landlord Port	Land Infrastructure (berth) Superstructure (crane)	Infrastructure (berth) Superstructure (crane) Cargo handling
(E) Public Landlord Port	Land	Infrastructure (berth) Superstructure (crane) Cargo handling
(F) Non-Governmental (Independent) Port		Land Infrastructure (berth) Superstructure (crane) Cargo handling

Since there are numerous assets for infrastructure and superstructure in a port, it is practically impossible for this study to track ownership information for all assets and institutional boundaries and organizations for all types of port function. Instead, information on ownership of berths and cranes is traced and used as proxies for the general structure of ownership for infrastructure and superstructure of ports, respectively. This approach is a simplified way of outlining the institutional structure of a port, but it is reasonably sought since berths, terminals, and cranes are representative infrastructure and superstructure assets for handling containers.

The application of more coherent criteria for all ports in the process of the institutional survey were achieved through designing and exploring a series of steps in decision making logic, described in Figure 4.3. According to the logic, if a port authority is involved in container terminal operation including terminal ownership and cargo handling activities, it is categorized as either a service port or a tool port, not being categorized as a landlord port. If the port authority owns all or almost all of its container berths and terminals in the port, handling container cargoes in any one of the terminals, the port is categorized as a (public) service port.

Figure 4.3. Decision Making Logic for Port Ownership Practice



Port authorities in some ports try to hold both their terminal operation function and container handling capacity, while they also act as landlords by leasing out parts of their container terminals and berths. These ports are classified as service landlord ports. As will be shown in the later discussion, relatively larger portions of container ports in the global port sector are currently organized this way. It is partly due to the fact that, in many countries, ports have multiple (and conflicting) economic and social objectives. Often they cannot fully transfer the production activities and handling services to private hands. Furthermore, this type of ownership can have a “politically effective” outcome in the sense of balancing out the multiple but conflicting roles of ports. In sum, in service landlord ports, the port authorities have mixed identities as both container and vessel service providers and landlords for port assets.

Public landlord port and tool-landlord port are the most decentralized systems of production and service in public sector-owned ports. They do not operate any container terminals and lease out or concession all of their terminals. In cases where container cranes are owned by port authorities and leased to the private operator or container handler, they can be called tool-landlord ports.

Finally, there are ports that are legally separated from national or local governments. They are managed and operated under either private or quasi-public port authorities that have enjoy quite higher levels of independence than the general public ports. Many of them are shaped as pure private entities. Sometimes, quasi-public corporate organizations are created to be separated from the public governments. The common factor is that public governments are not involved in operation and asset management of terminals.

In analyzing the institutional features of a port, many circumstantial differences exist in organizing ownership for port assets and responsibility for port functions. For example, who exercises greater control over budgeting, procurement, contracting, maintenance strategies and programming, salary scales and employment conditions, hiring and firing of labor and staff, setting performance targets and strategies? Who appoints the director of a port authority? Who constitutes the board members? Has the authority negotiated loans directly with a commercial bank? All this information may influence different arrangements of port institutions, shaping different nuances in port ownership and corporate structure.

However, the goal of this survey was to capture the underlying goals and intentions of port activities and services by focusing on the question of whether the port's main objective is to directly provide such services as terminal operation and container handling or just function as a landlord. Rather than focusing meticulously on the technical details of institutions, the survey had to focus on analyzing how terminal operation and container handling are institutionally separated from a port authority's roles for port management and regulation; specifically, whether port production and service have been provided by applying such models: management contract and outsourcing, leasehold, concession, and asset divestiture.

According to the empirical survey, the original six categories should be aggregated in the end to four types that have distinctive institutional characteristics, shown in Figure 4.2:

(1) Public Operating Port
(2) Mixed Ownership Port
(3) Public Landlord Port
(4) Non-Governmental Port

Public Operating Port

This category includes both service ports and tool ports. Service ports and tool ports are similar in sharing the characteristics that a main objective of port authorities is to be involved in terminal operation or cargo handling. Tool ports still operate container terminals although their cargo handling function can sometimes be contracted out to the private service providers. Yet, in general, the fundamental goals of tool ports are similar to that of (operating) service ports in the sense that port authorities officially exercise distribution of containers either through their own equipment or by renting equipment. Therefore, both service ports and tool ports are classified as *Public Operating Port*.

Mixed Ownership Port

Secondly, *Mixed Ownership Port* includes service landlord ports which can be qualitatively different than service ports or tool ports. It is so because parts of its container terminals are leased out so that the port authorities have to act as landlords. On the other hand, they still operate container terminals to handle containers directly, thereby having to act as terminal operators. From this point of view, the identity of port authorities in service landlord ports is qualitatively different than service ports and tool ports whose main role is achieved directly through terminal operation and container handling. Also, distribution of asset ownership for cargo handling and organization of port functions are mixed between port authorities and other private terminal operators.

Public Landlord Port

Thirdly, *Public Landlord Port* can also be a qualitatively different type of port than *Public Operating Port* and *Mixed-Ownership Port*. The port authorities for *Public Landlord Port* act mostly as landlords without having to function as a terminal operator. Both pure landlord port and tool landlord port are classified as the same type. While tool landlord ports, unlike pure landlord ports, own container cranes in terminals and rent them out, their role as a landlord is not fundamentally compensated by this practice. Therefore, pure landlord ports and tool landlord ports are classified as *Public Landlord Port*.

Non-Governmental Port

Finally, *Non-Government Port* includes (1) the ports where the private or quasi-public port authorities are legally and institutionally separated from the national or local governments or (2) the ports which are organized as a pure private entity rather than a public authority.

4.3 Temporal Trends in Port Institutional Reform

4.3.1 Corporate structure transformation of ports, 1991-2004

From 1991 to 2004, there were two major trends in the management practices of top ports in the world. There has been devolution of the management from national or state level to local or individual entity level. In 1991, 42% of the world's top 97 ports were managed by national or state governmental bodies; the percentage dropped to a mere 32% by 2004. The other major transformation is that corporatization has become a popular management practice. Corporatized ports (including statutory corporations) accounted for less than one third of the top ports in 1991, but by 2004, 45% of the ports were corporatized in one way or another. Ports governed under corporate law have increased likewise. In 1991, less than 10% of the ports were either government-owned corporations under corporate law or entirely private corporations; the percentage has increased to 18% by 2004.

Table 4.3: Corporate Structure of Port Management in the World, 1991-2004

Corporate Structure Categories	1991	(%)	2004*	(%)	2004	(%)
1.National level[4]	31	**32%**	25	26%	40	26%
2.State or Provincial level[5]	10	10%	6	6%	7	5%
3.Local Government Department	2	29%	22	23%	43	**28%**
4.Statutory Authority or Corporation	20	21%	28	**29%**	36	24%
5.Government-Owned Corporation	7	7%	12	12%	15	10%
6.Private Enterprise	1	1%	4	4%	10	7%
Total	97	100%	97	100%	151	100%

* The ports that have management type information in 1991 are included for analysis.

[4] National government or national-level port authority
[5] State or Provincial government or state-level port authority

4.3.2 Ownership transformations of ports, 1991-2004

The most remarkable trend in ownership practice of top ports in the world is the transfer of ownership from public hands to increasingly private hands. For instance, the majority of the world's top 98 ports were under full public ownership (61%) in 1991. However, in 2004, more than 40% of them practiced the landlord model along with 7% being under completely private ownership.

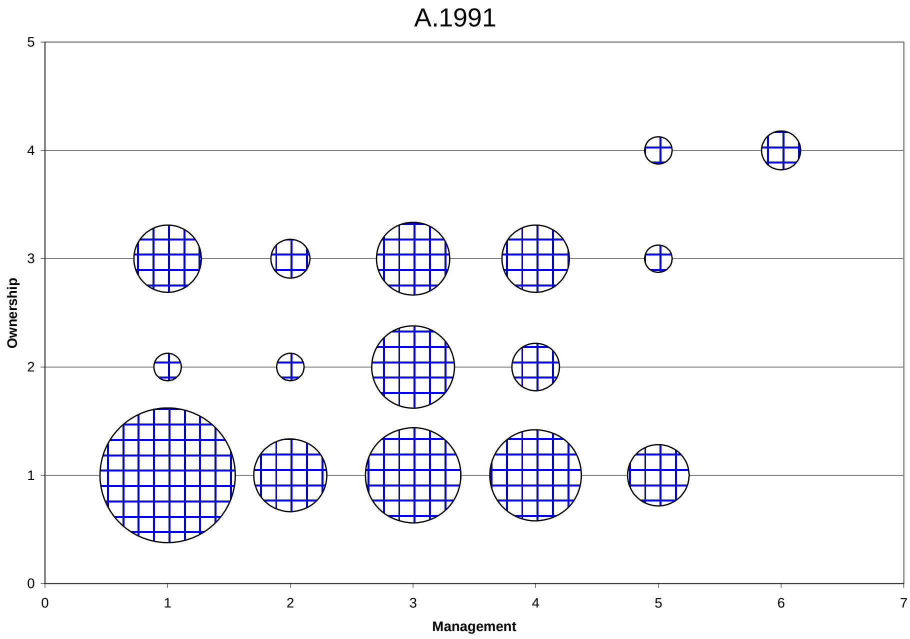
Table 4.4 Port Ownership Practice in the World, 1991-2004

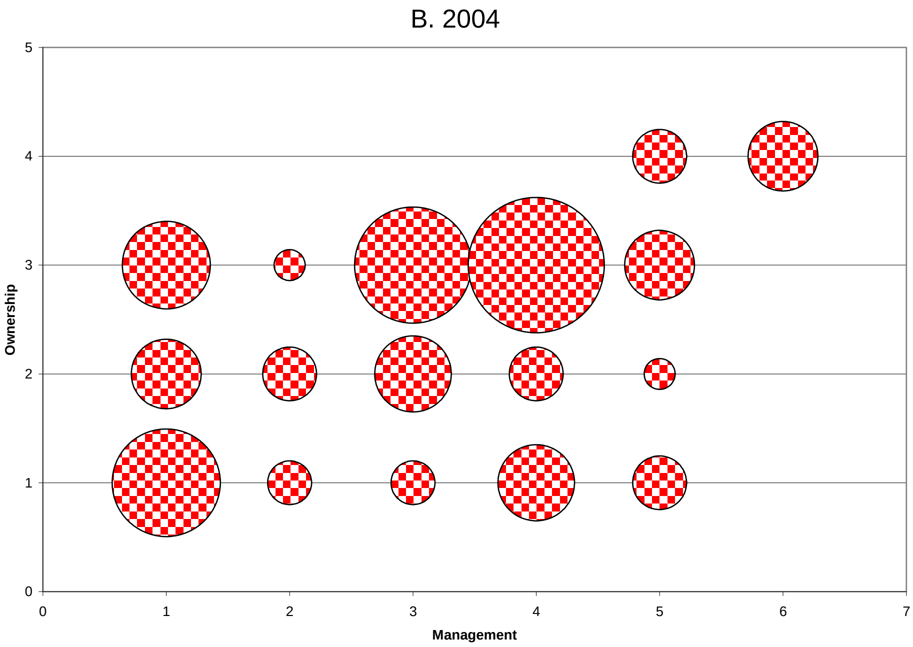
Ownership Categories	1991 Ports	%	2004 Ports*	%	2004 Ports	%
1.Public Operating Port	60	**61%**	25	26%	50	33%
2.Mixed Ownership Port	14	14%	19	19%	24	16%
3.Public Landlord Port	22	22%	47	**48%**	64	**42%**
4.Non-government Port	2	2%	7	7%	14	9%
Total	98	100%	98	100%	152	100%

* The ports that have management type information in 1991 are included for analysis.

Combined ownership and management matrices, Figure 4.4, confirm the trends revealed in Table 4.3 and Table 4.4. The conspicuous trend is an upward linear trajectory – that is, from a dominance of publicly owned, nationally managed ports to a system of (partially) privately owned and decentralized or corporatized ports. The detailed membership of ports in each category and trends of transformation are presented in Figure 4.5 and Appendix 4.1.

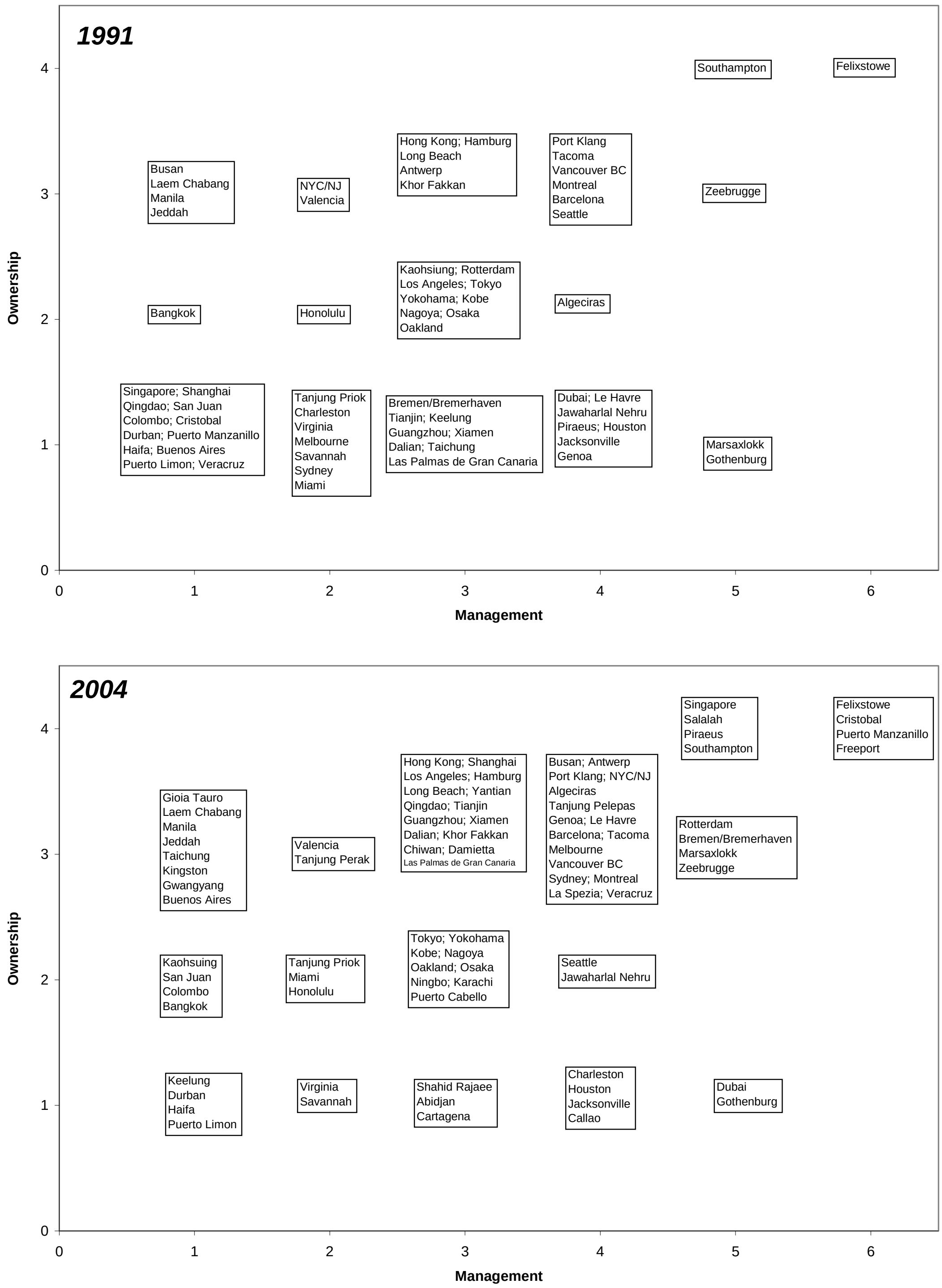
Figure 4.4: Ownership and Management Structure of Ports in the World





***Legend of Management Structure Categories**: (1) national government (or national port authority); (2) state or provincial government (or state port authority); (3) local government department; (4) statutory authority or corporation; (5) government owned corporation; (6) private enterprise*
***Legend of Ownership Categories**: (1) Public Operating Port; (2) Mixed Ownership Port; (3) Public Landlord Port; (4) Non-Government Port*

Figure 4.5: Ownership and Corporate Structure of Top 100 Ports in the World



***Management**: (1) national government; (2) state or provincial government; (3) local government; (4) statutory authority or corporation; (5) government owned corporation; (6) private enterprise*
***Ownership**: (1) public operating Port; (2) mixed ownership Port; (3) public landlord port; (4) non-government port*

4.3.3 Port size and institutional features of ports, 1991-2004

Table 4.5: Port Size and Institutional Features

Year 1991							Year 2004						
Group 1: Rank 1-26 (More than 800001 TEU)							***Group 1: Rank1-25 (More than 2300001 TEU)***						
Own / Corp	***1***	***2***	***3***	***4***	***N***	***%***	***Own / Corp***	***1***	***2***	***3***	***4***	***N***	***%***
1	1	1	2	0	4	15	***1***	0	1	2	0	3	12
2	2	0	1	0	3	12	***2***	0	1	9	0	10	**40**
3	2	8	4	0	14	**54**	***3***	0	2	5	0	7	**28**
4	2	0	2	0	4	15	***4***	0	0	2	0	2	8
5	0	0	0	0	0	0	***5***	1	0	0	1	2	8
6	0	0	0	1	1	4	***6***	0	0	0	1	1	4
N	7	9	9	1	26	100	***N***	1	4	18	2	25	100
%	27	**35**	**35**	4	100		%	4	16	**72**	8	100	
Group 2: Rank 27-50 (330001 ~800000 TEU)							***Group 2:Rank 26-49 (1500001-2300000 TEU)***						
Own / Corp	***1***	***2***	***3***	***4***	***N***	***%***	***Own / Corp***	***1***	***2***	***3***	***4***	***N***	***%***
1	5	0	1	0	6	25	***1***	1	2	1	0	4	17
2	5	1	1	0	7	**29**	***2***	2	0	1	0	3	13
3	0	1	0	0	1	4	***3***	1	4	2	0	7	**29**
4	2	1	4	0	7	**29**	***4***	0	2	6	0	8	**33**
5	1	0	0	1	2	8	***5***	0	0	0	1	1	4
6	0	0	0	0	0	0	***6***	0	0	0	0	0	0
n.a.	1	0	0	0	1	4	***n.a.***	0	1	0	0	1	4
N	14	3	6	1	24	100	***N***	4	9	10	1	24	100
%	**58**	13	25	4	100		%	17	38	**42**	4	100	
Group 3: Rank 51- 74 (130000-330000 TEU)							***Group 3: Rank 50-74 (550000-150000 TEU)***						
Own / Corp	***1***	***2***	***3***	***4***	***N***	***%***	***Own / Corp***	***1***	***2***	***3***	***4***	***N***	***%***
1	8	0	0	0	8	**33**	***1***	4	1	2	0	7	**28**
2	0	0	0	0	0	0	***2***	0	2	0	0	2	8
3	6	0	3	0	9	**38**	***3***	0	0	2	0	2	8
4	4	1	0	0	5	21	***4***	2	0	5	0	7	**28**
5	1	0	1	0	2	8	***5***	1	0	3	1	5	20
6	0	0	0	0	0	0	***6***	0	0	0	2	2	8
N	19	1	4	0	24	100	***N***	7	3	12	3	25	100
%	**79**	4	17	0	100		%	28	12	**48**	12	100	
Group 4: Rank 75-98 (Less than 130000 TEU)							***Group 4: Rank 75-98 (Less than 550000 TEU)***						
Own / Corp	***1***	***2***	***3***	***4***	***N***	***%***	***Own / Corp***	***1***	***2***	***3***	***4***	***N***	***%***
1	10	0	3	0	13	**54**	***1***	7	1	3	0	11	**46**
2	0	0	0	0	0	0	***2***	0	0	0	0	0	0
3	4	0	0	0	4	17	***3***	2	0	1	0	3	13
4	3	1	0	0	4	17	***4***	3	1	3	0	7	29
5	3	0	0	0	3	13	***5***	1	1	0	0	2	8
6	0	0	0	0	0	0	***6***	0	0	0	1	1	4
N	20	1	3	0	24	100	***N***	13	3	7	1	24	100
%	**83**	4	13	0	100		%	**54**	13	29	4	100	

Table 4.5 presents relationships between port institutions and port production scales. The 98 ports represent port ownership and corporate structure for 1991 and 2004 which are classified into four different groups based on their ranks of production scales in each year. Ports in *Group 1* have the largest scales of container production, while *Group 4* includes the smallest ports for both years.

In 1991, as sizes of port production were smaller, ports adopted more centralized ownership models – *public operating port*. For *Group 1*, the most popular ownership models were *mixed ownership* and *public landlord models*. However, for the other three groups, more than 50 percent of ports practiced a public operating model (*Group 2* = 58%, *Group 3* = 79%, and *Group 4* = 83%). On the contrary, in 2002, a public landlord model was the most popular way to organize port ownership for *Groups 1, 2,* and *3* (*Group 1* = 72%, *Group 2* = 42%, and *Group 3* = 48%). Yet many small ports in *Group 4* still adopted a public operating model (54%). In general, smaller ports are inclined to be organized based on more centralized ownership models for both years.

In terms of relationships between corporate structure and port size, in 1991, municipal management was a predominant model of port administration for larger ports in *Group 1* (54%). For ports in *Group 2,* state or provincial management was the popular way (29%), while statutory authority or corporation models were also equally popular for the group (29%). Smaller ports in *Group 3* were mostly managed by both national management (33%) and municipal management (38%), whereas national management is adopted as the most popular mode for the smallest ports in *Group 4* (54%). In 2004, for *Groups 2, 3,* and *4*, ports in larger-sized groups were inclined to adopt more decentralized ways of port management (i.e. municipal management and statutory corporation models for *Group 2*, national management and statutory corporation models for *Group 3*, national management for *Group 4*). However, for the largest ports in *Group 1*, more centralized approaches such as state and municipal management models were adopted than in the case of *Group 2*.

In general, I found that the larger the ports, the more decentralized structure of port management and ownership for both years, although the relationship between port size and corporate structure may not be very distinctive compared to the relationship between port size and port ownership.

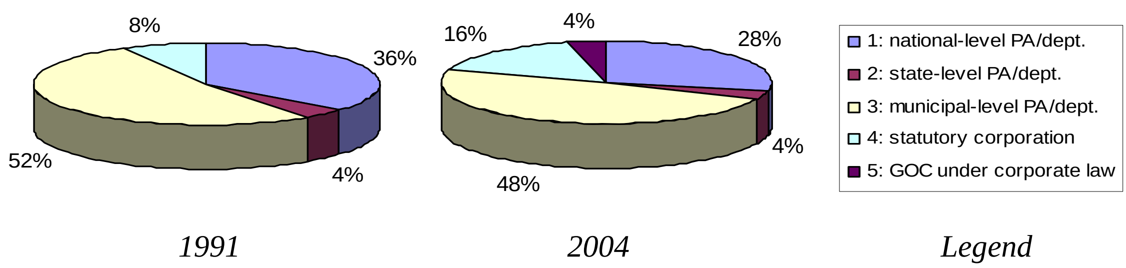
4.4 Continental and Regional Trends in Port Institution Reform[6]

4.4.1 Asia[7]

Management and Corporate Structure

In Asia, national management has a strong tradition. Municipal management has also been a popular way to manage ports in Japan and more recently in China, while their own mechanisms are unique. While national level management in Asia has decreased over the last decade, there is as yet no serious emergence of corporatized ports under corporate law, whether in the form of government-owned corporations or private corporations. As of 2004, only one port was a government-owned corporation under corporate law. The biggest trend in management structure of Asian ports is the shift away from nationally governed ports into statutory authority or corporations.

Figure 4.6 Corporate Structure System of Asian Ports (N=25)

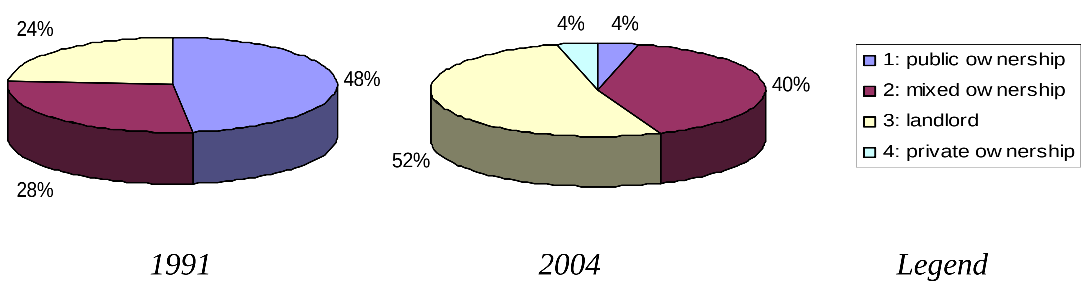


[6] For the analysis presented in this section, we use 98 ports that have institutional information for both years of 1991 and 2004.
[7] The definition of regions are mainly followed by the one by Containerisation International Yearbook 2005, while some regions are aggregated for a presentation purpose: Asia (East Asia, South Asia), Africa (North Africa and South Africa), Australasia, Europe (Northern Europe, Southern Europe, East Europe), Middle East, North America, Latin America (Central America and Latin America).

<u>Ownership</u>

Ownership practices of Asian ports in 1991 were distributed among three systems, public ownership, mixed ownership, and the landlord model, with public ownership associated with the most number of ports (48%). However, in a decade or so, the number of ports under public ownership decreased dramatically to a mere 4%, whereas the proportions of the other two increased. In 2004, 40% of the ports were under mixed ownership and 52% were practicing the landlord model. Interestingly, their landlord models vary depending on regions in many ways as the periods of development of the landlord model are different to each other.

Figure 4.7: Ownership System of Asian Ports (N=25)



4.4.1.1 East Asia

As a region, East Asia has the most complex, if not the "messiest," port system structures, exhibiting myriad trends from port reforms at the terminal level in China, lack of changes since the 70s in either management or ownership of ports in Japan, and recent corporatization schemes in Korea, to temporary re-centralization of ports in Taiwan during the late 1990s.

A nation-wide trend in China during its economic transition has been devolution of economic accountability and regulatory responsibilities to a local level. This has been the case in the port sector as well. The ports were formally under the control of the Ministry of Communication in the past, but most ports in China are now run as a municipal department or port authority. In the 1990s, China enacted a law that precipitated local municipal governments to act as both landlord and regulator of the ports in their jurisdiction. Port authorities were either created or transferred to municipal governments, and they were endowed with financial autonomy in the routine administration and operation of ports (Wang et al. 2004). These are generally known as Port Administrative Bureaus. With respect to terminal level reforms, terminals used to be owned and operated by port authorities themselves until the 1990s. Since the early 1990s, ports in China have made increasing use of joint ventures (Wang et al. 2004; ADB 2000), frequently with foreign companies, to establish separate private corporations that operate individual terminals. This was a strategic response to circumvent the strict ban on foreign companies from engaging in the construction and operation of Chinese ports, which was set out by the Maritime Code adopted in the 1990s. In other cases, the port authorities created spin-off state-owned enterprises (SOEs) (i.e., wholly-owned subsidiaries of the port authorities) to operate terminals. In theory, these joint venture enterprises and SOEs are severed from the port authorities. The only exception to this trend has been Hong Kong, whose port has historically always been managed by the municipal authority and has practiced a landlord model.

Shanghai is an example of this complex system. Until the early 1990s, Shanghai was under the direct jurisdiction of the Ministry of Communication, and the Ministry operated terminals directly (ADB 2000). In the 1990s the Shanghai Port Authority was created, which was subsequently converted into the Shanghai Port Administration Bureau in 2003. The Bureau was assigned as the regulator and manager of the port.[8] At the same time, Shanghai International Port Group Co., Ltd. (SIPG) was created as a spin-off enterprise of the Bureau. This firm is in charge of making joint ventures with other enterprises, usually foreign companies, and it is these joint venture firms that operate terminals in the port. For instance, SIPG and Hutchison Port Holdings (HPH) together set up Shanghai Port Container Co. (which is listed on the Shanghai stock exchange), the operator of the Shanghai Container Terminal.

Mirroring the slow structural changes in the national economy, the port sector in Japan has exhibited a strong resistance to institutional innovations. In the post-war years, Japanese ports have always been placed under a municipal department or port authority. The port authorities lease some of their terminals to private operating companies, but some terminals are also operated by the port authorities themselves.

The biggest reform in the Korean port sector has been the transfer of authority from a national government agency, the Ministry of Maritime Affairs and Fisheries, to a statutory corporation created under the decree of the Port Authority Law in 2003. This has occurred in both Busan and Incheon. Soon after the enactment of the Port Authority

---

[8] World Cargo News at: *http://www.worldcargonews.com/htm/n20030201.667580.htm*

Law, the Busan Port Authority was established later in the year. The Incheon Port Authority was launched after a couple of years of more planning in 2005. Terminals in both ports had been operated by private as well as government-owned companies even before the management reforms.

Perhaps the most surprising in the region is Taiwan's restructuring of their ports in recent years. From 1945 to 1999 its main ports were controlled by municipal level departments called Harbor Bureaus (ADB 2000). However, in 1999, ports in Kaohsuing, Keelung, Haulien, and Taichung were all transferred back to a national entity, the Ministry of Transportation and Communication (MOTC).The country's justification for its decision was to streamline the decision-making processes and to coordinate investment schemes by cutting down the number of decision-making entities. Private sector involvement in the operation of terminals has increased in ports in Taiwan. All stevedoring in Keelung was opened to private stevedoring companies in 1999. Kaohsuing has allowed private sector involvement in terminal operations in addition to its own operations. Taichung, on the other hand, has been transformed into a landlord port from a public operating port, according to the definition developed in Figure 4.3.

4.4.1.2 South Asia

As a region, there is as yet no serious emergence of corporatized ports that are governed under private corporate law in South Asia, whether in the form of government-owned corporations or private corporations. Ports in most countries are still under the jurisdiction and direct supervision of a national or regional government authority (e.g., Indonesia, Philippines, Thailand). Two countries are, however, challenging this general tendency of the region and paving the way for port reforms: Malaysia and Singapore.

Until 1990, the Malaysian ports were formally controlled by Port Commissions and Authorities, a national entity established under the Port Authorities Act in 1963 (ADB 2000). At the same time, the Authority was directly responsible for the provision of most port services. The passage of the Port Privatization Act in 1990 introduced both corporatization and privatization efforts (ADB 2000). In Port Kelang, for example, the administrative and regulatory functions of the port were transferred to a statutory port corporation (Port Kelang Authority, or LPK) (Meyrick & Associates and Tasman Asia Pacific. 1998). At the terminal level, all of the container terminals came to be operated entirely by private companies. The privatization schemes at the terminal level actually began in 1986 when a part of the container terminal facilities operated by the port authority was concessioned to Kelang Container Terminal Sdn Bhd (KCT), a joint venture enterprise between the port authority and private investors (Trujillo and Nombela 2000). The remaining facilities and services of the port were concessioned to Kelang Port Management Sdn Bhd (KPM) in 1992, guided by the legal framework of the Port Privatization Act of 1990.

In Juhor port, the whole port was concessioned to a single corporate entity in 1995, again under the guidance of the Privatization Act in 1990 (Meyrick & Associates and Tasman Asia Pacific. 1998). The port company was granted a long-term lease of 30 years initially to operate the port, with an option to extend it for an additional 30 years.

The Juhor Port Authority continues to exist but its responsibilities include only safety and environmental regulations.

Likewise, the port of Singapore used to be a publicly operated port under the control of a national government body, Port of Singapore Authority (PSA), which took over the responsibilities, assets, and liabilities of the Singapore Harbour Board in 1964. Since the 1970s the Singapore government has introduced the concept of "public administration reengineering" to use public resources more effectively in many areas of public service provision (Saxena 1996). Such restructuring reviews the role of the public sector in economic activities, moving away from direct provisions of goods and services through bureaucratized systems. Under these efforts, the national government has aggressively adopted new information technology and organizational design to increase levels of citizen participation.

Since international trade has been Singapore's main source of survival its strategy on the port sector has been designed to increase global openness and competitiveness at the national government level. Singapore, having a strategic vision, has aggressively invested in port and airport infrastructure through overprovision strategy at variance with cost-benefit analysis, capturing short-run financial efficiency (Phang 2003). While it was sometimes criticized as a reason for low factor productivity, Phang (2003) argues that the strategic investment has been evaluated as an effective way to maintain its position as the leading hub port in South Asia and to improve long run growth by sustaining Singapore's international competitiveness.

Since the 1990s, hampered by financial difficulties created partly by its historical aggressive investment, the government created the Maritime and Port Authority of Singapore to take over regulatory responsibilities from the PSA in 1996. The next year, the PSA was converted into a government-owned corporation, PSA Corp., Ltd. (the international arm of which is known as PSA International Pte., Ltd. in its global operations).[9] The company is a 100% state-owned company and runs under the general private corporate law and performs all of the operations in the port.

As the port of Singapore seeks to expand beyond the home markets, it has made a major financial commitment to acquire a number of concessions and to fund overseas expansion in order to compete with other international operators (e.g. bond issue of US$250 million; ADB 2000, 67). The port has been given the latitude to undertake direct marketing efforts by relaxing regulations on pricing and common-user access. The management of the port worked continuously to improve labor productivity. It was able to maintain labor peace due to an expanding labor market and an active coalition with port labor. Furthermore, the port boldly introduced innovative technology in port operation such as (a) application of Electronic Data Interchange (electronic message exchanges); (b) re-engineering of the trade clearance process; and (c) investment in high profile equipment such as Post-Panamax cranes (UNCTAD 1998).

After the corporatization was implemented, the Port of Singapore had a plan to sell some of the corporation's stock through IPO to fulfill the government's objective of

[9] PSA International Pte Ltd. Annual Report 2004: Financial Review.

broadening the public participation in the stock market. Yet this was not realized until 2005. Its reform effort during the last decade is still ongoing. Overall, Singapore has executed comprehensive and complete corporatization (Government-Owned Corporation) as well as terminal privatization reforms, in conjunction with strategic and risky long-term investment in port infrastructure at the government level.

Most of the institutional reforms in the port system in South Asia have occurred at the terminal level (i.e., terminal level privatization). In the past, public operation of terminals had been the dominant practice in the region (which was also the case in Malaysia and Singapore as detailed above). However, there are virtually no purely public operating ports in the region now. In the port of Jawaharlal Nehru in India, for instance, although the Jawaharlal Nehru Port Trust continues to be involved in some terminal operations, all of the container terminals were granted out to private companies under build-operate-transfer (BOT) contracts in 2000. The Mumbai Port Trust has licensed two of its berths to the shipping lines XCL/Orient and has allowed the private sector to provide all of the container-handling equipment except ship-to-shore gantry cranes (ADB 2000).

4.4.2 Oceania[10]

The port sectors in Australia and New Zealand have followed a rather similar progression.[11] In Australia, ports were under the control of state-level public entities

[10] Because the number of ports we have information for both years (1991 and 2004) is only six, I do not present the statistics here.

until the early 1990s while operating under a public service port model. The ports were within departments of the State Maritime Boards, and all services provided by the ports were rendered by the port authorities themselves. Reforms in the early 1990s transformed them into statutory port corporations owned by the government, operating under a landlord model. Under such important laws as *The Government-Owned Corporations Act* and *The Transport Infrastructure Act of 1994* in Queensland and the *Ports Corporation and Waterways Management Act of 1995* in New South Wales (NSW), major ports were established as individual corporations, and their services turned over to separate private enterprises. Ports in South Australian ports were initially corporatized and subsequently privatized. The original objective of port corporatization in Australia mainly aimed at public sector reform, which is a bit different from that of port privatization in the United Kingdom or the corporatization policy in New Zealand. They were much driven to resolve the problem of public debts and depletion on the recurrent budget.

Everette (2005a) illustrates that, in pursuing the scheme of corporatization, Australia predominantly adopted the model of Statutory State Owned Corporations (SSOCs), while each state enacted legislation for its own model of corporatization. During the process of designing corporatization, “there was agreement that efficiency improvements in the public sector were necessary but not on what was the effective mechanism for achieving this (p.8).” As a result, disputes occurred on the issue of what

[11] This paragraph is reorganized from information based on the Port of Melbourne Corporation Website, Meyrick and Associates and Tasman Asia Pacific (1998, 52-60), Asian Development Bank (2000, Appendix 1), Everette (2005a; 2005b), etc.

the appropriate model is: Government Owned Companies (GOCs) or Statutory State Owned Corporations (SSOCs). While the early discussion on the corporatization scheme was directed to the model of GOCs, and in fact, the legislation for the corporatization of NSW ports was drafted as GOCs, before enactment in 1995 the newly elected Labor government in the state amended the legislation based on the belief that vital economic infrastructure should be directly controlled by government. Therefore, launched by corporatization in NSW, the SSOCs model was implemented in all other mainland states in Australia.

The port of Melbourne is a prime example of this reform process.[12] After a long negotiation process, Melbourne Port Corporation was established in 1996 under the *Port Services Act of 1995* (which was later transformed into Port of Melbourne Corporation in 2003). The Victorian State government transferred its functions as the strategic port manager to the corporation, such as powers to undertake the integrated management and development of the land and waterside of the port. In addition, services previously provided by the port authority were subsequently privatized to private operating companies.

Meanwhile, at the time that the reform was implemented, conflicts between strong port labor unions and container handling companies created considerable work stoppages in many Australian ports in 1998. Despite the original endeavor to increase port

[12] This paragraph is reorganized from information based on the Port of Melbourne Corporation Website, Meyrick and Associates and Tasman Asia Pacific (1998, 52-60), Asian Development Bank (2000, Appendix 1), Everette (2005a; 2005b), etc.

productivity, poor labor productivity was a continuous problem. After the settlement of the labor problems, some indicators showed the improvement in port efficiencies, while total throughput increase was not impressive. For example, UNCTAD (2002, 69) shows that average stevedoring productivity in five major Australian ports in 2001 increased, while port performance deteriorated during the same period in most other ports in the world except Singapore and Rotterdam: (a) container movements per crane per hour: 26.3 containers (increased by 11.9 % in 2001); (b) productivity per vessel: 40.9 containers per ship per hour (increased by 11.4 % in 2001); and (c) total throughput increased by less than 1%.

However, it has been argued that, while corporatization adopted in Australia may have recently improved some efficiency at container terminal level, it does not fully reap the original goals of private sector participation and corporatization.[13] A study by the Australian Department of Industry claims that it is partly due to the failure of creating a high degree institutional independence, an ignorance of strategic issues, and constrained funding for public investment (ADOI 2001, 4). With this dilemma, further reform was implemented in NSW based on legislation enacted in 2003. The 1995 legislation had created the Melbourne Port Corporation strictly as a landlord and the responsibility for the landside and seaside had been separated. Port of Melbourne Corporation now provides the land, waters, and infrastructure necessary for the development and

[13] This paragraph is organized from information based on the Port of Melbourne Corporation Website, Department of Infrastructure (2001), Meyrick and Associates and Tasman Asia Pacific (1998, 52-60), Asian Development Bank (2000, Appendix 1), Everette (2005a; 2005b), etc.

operation of the port of Melbourne since the 2003 legislation supported the restructuring to integrate the responsibility for both landside and seaside assets (ADOI 2001, 11).

While it is unclear yet whether the new legislation will create a better institutional environment for increasing port efficiency in Australia, Everette (2005a; 2005b) recently significantly criticized the current direction of port reform and corporatization, attributing a reason of the failure to the legislation created under the SSRC model:

> The legislation and corporatized artifacts in Australian mainland ports have failed, in general… the legislation has, in fact, created a model with inherent flaws and serious contradictions. The legislation enacted is such that while it has set in place a model which articulates commercial objectives the model in fact created is one in which political objectives may override commercial ones; where strategy may be determined by a bureaucratic elite without the requisite skills and insights and the resultant strategy appears *ad hoc*; and a corporate culture that frequently has failed to transcend that of the statutory authority and public utility model (Everette 2005a: p.1)…With the SSOC model, political and ministerial input is pivotal to the day-to-day operation of the ports. Ministers determine prices…the model differs considerably from the planned market oriented business anticipated when the policy of corporatisation was initially adopted (Everette 2005b: p.4).

In general, Australia has been quick to move toward where the global port sector is directed since it implemented port reforms in the 1990s. Since the first creation of the statutory authority a century ago in the country, corporatization has been an endeavor to address the issue of making government business efficient. In the last decade, within the industry, academia, and government there has been serious conversation around the issues to find better models for restructuring the country's port sector.

Institutional reform in New Zealand started earlier than in Australia. As New Zealand has undergone structural reforms in its government sector since the mid 1980s, the public sector has rearranged its role for the provision of public services, in an attempt to improve the efficiency of service provision. New Zealand's government-owned enterprises involving energy, transport, banking, construction, air traffic, and communications have continuously restructured or corporatized to ensure managerial accountability for profitable operations.

Likewise, the New Zealand ports were once managed by public entities—but at the local/municipal level—until the late 1980s. Until that time, the ports were subject to the power of relatively autonomous local Harbor Boards, which were locally elected and reported to a National Port Authority. New Zealand turned its ports into corporations as well, but unlike Australian ports, they were to be governed under private corporate law and hence were allowed to sell their shares on the stock exchange. Therefore, New Zealand's decentralization and corporatization schemes were a bit more extensive than those in Australia. Like their Australian counterparts, the New Zealand ports began operating under a landlord model beginning in the late 1980s. Until 1988, the ports were under the control of the locally elected Harbor Boards of New Zealand, which in turn reported to a National Port Authority.[14] The passage of the Port Companies Act in 1988 "transformed the centralized system of port administration into a fully decentralized one (Meyrick and Associates and Tasman Asia Pacific 1998, 41)." Under the terms of the Port Companies Act of 1988, "the centralized control on key decisions such as capital

[14] The Port of Auckland website

investment came to an end (42)." "New port companies were established for each of the major ports, and the ownership of these companies placed in the hands of the local regional council (42)." "The new port companies took over the commercial activities of the previous Harbour Boards." "Each company has responsibility for an entire port." "Port companies assumed all port operations, related debts, stock, bank balances and balance sheet liabilities of the Harbour Boards. When the transfer of assets and liabilities was complete, the Harbour Boards were dissolved (42)."

The Port Companies Act allowed the company shares traded on the stock exchange. Initially the shares were 100% owned by the Board according to the original legislation. the legislation required Regional Councils to keep a minimum holding of 51 percent. However, in August 1990, *the Port Companies Amendment Act* allowed full privatization (i.e., sale of all of the shares to the public) of the ports (Meyrick and Associates and Tasman Asia Pacific 1998, 42). In Tauranga, for instance, 45 percent of the port company's shares were sold to the public in the initial IPO, but now more than 55% of the shares are held by the public.[15] In contrast, only 20 percent of the shares in the Auckland port company are freely traded on the New Zealand Stock Exchange.[16]

[15] The Port of Tauranga website
[16] The Port of Auckland website

4.4.3 Middle East[17]

Ports in Bahrain and Israel are steadfastly placed under the governance of a national-level public entity that owns and operates terminals on its own than other countries (Kuwait and Saudi Arabia) in the region. Saudi Arabia differs distinctively from Israel in its ownership structure, however: its ports are landlord ports whose terminals have been managed and operated by the private sector through lease and concession contracts since 1997. On March 15, 1997, royal approval was granted to pass the responsibility of all operations and maintenance of berths and equipment owned by the Ports Authority to the private sector, to be managed on a commercial basis.[18] Under this new guideline, terminals in the Saudi ports (e.g., Dammam, Jeddah) were put to public bidding during the year 1997, and contracts were granted to the party who offered the highest percentage of share of revenue to the government. Today, all terminals in the country's ports are managed and operated by the private sector.

Port reforms have been also implemented in Oman and UAE. In the case of Oman, a unique transformation has occurred at the port of Salalah (i.e., Mina Raysut). Until 2000, as in many other countries in the region, the port was administered by a national-level government entity, the Ministry of Communications. In 2000, Salalah Port Services Company (SAOG) was created, and the government gave the enterprise a 30-year concession to manage and operate the port as its port authority as well as its

[17] Because the number of ports we have information for both years (1991 and 2004) is only seven, I do not present the statistics here.
[18] The website for the Saudi Port Authority

operator.[19] Hence, it was not merely a concession of terminals, but a concession of the entire port. The company operates the sole container terminal of the port; therefore, the port is a private operating port. This restructuring has largely been hailed as a successful public-private partnership in the region.

UAE's biggest change has been the corporatization of Dubai port from a statutory corporation to a government-owned corporation under the general private corporate law, enabling it to increase its overseas business operations. In 2001, Dubai Port Authority, Jebel Ali Free Zone, and Customs were merged to form the Ports, Customs, and Free Zone Corporation.[20] Since then, the company has become world's sixth largest port operator around the globe, including the Dubai port. The recent attempt to purchase P&O's terminals located in the US in 2006 turned out to be a failure due to the extreme political pressure and hurdles created by the US Government and politicians.

4.4.4 Europe

Original Model of Port Institution

There had been a few distinctive views on the role of ports in the past but this tradition has become more diluted as institutional reform has been implemented throughout Europe. Chlomoudis and Pallis (2002, 22-23) and TFE (Technum Flanders Engineering) (2002, 22-23) claim that: Ports under the Anglo-Saxon principle are regarded as business enterprises that should earn sufficient returns to allow them to

[19] The Salalah port website.
[20] The Dubai port corporation website

upgrade and renew their assets. One responsibility for the ports under this principle is to make profits, not being able to usually appeal to a central authority for assistance against the coverage of possible deficits. Yet making a substantial profit may not always happen since ports may just strive to recover costs, including those of capital expenditure.

On the other hand, TFE (2002), and Chlomoudis and Pallis (2002, 22-23) claim that, in the Continental European doctrine, there have been two port management models in the past: The Municipal Hanseatic Model and the Latin Model. Under the view of both models, ports are part of a country's general infrastructure that play a crucial role in trade and industry, but this view is more strongly reflected in the Latin Model. The Municipal Hanseatic Model is characterized by relatively semi-autonomous port authorities that have applied in Belgium, Germany, and the Netherlands. The Latin Model often involves more centralized governance of ports by which ports try to promote trade and regional development as a critical social benefit. Costs yielded do not have to be recovered directly from users, but are rather recovered from a larger population of beneficiaries through taxation. Therefore, the ports "do not have to break even in a strictly financial sense as the costs can be borne by the states directly in their various manifestations (TFE 2002, 23)." And, "in some cases, it is even pointless to try to assess the financial balance of a particular port, since depreciation of assets is not included in the general accounts (23)." Table 4.6 summarizes institutional features in the different models in Europe.

Table 4.6: European Port Administration Model[21]

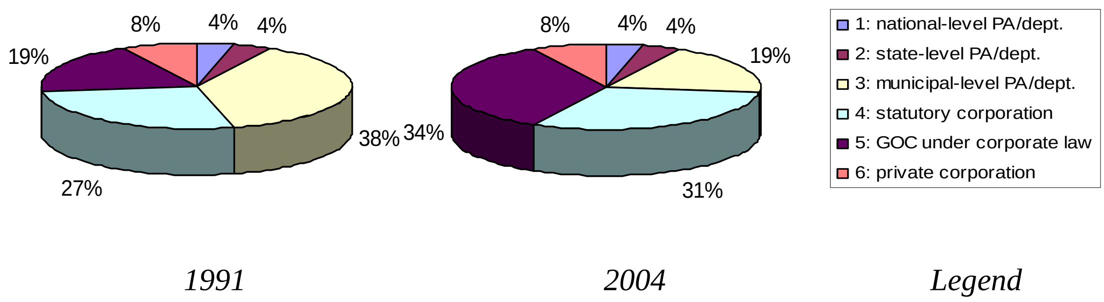
Model	Characteristics	Examples
Local Hanseatic Model	• The ports follow the "Hanseatic" tradition, i.e. municipal interest with the powerful managerial and economic presence of the local authorities. • This model is similar to the U.S. West Coast model (California; Washington) in the sense that they are administratively and financially semi-autonomous agencies, armed with strong city charter protections and powers.	• Typical in North-Western Europe (e.g. Scandinavia, Hamburg, Rotterdam, Antwerp), except in the UK and the Baltic countries that were under Soviet influence. • All ports located in the area between Hamburg and Belgium, and the Scandinavian ports.
Latin Model	• This model supports major intervention of central government while its degree varies.	• Typical in the Mediterranean countries in which the responsible body of port management is the state.
Port Trust Model	• The ports are institutionalized as Trusts. • This model tends to be abandoned or transformed as the implementation of a privatization process has progressed over the last decade.	• Mainly observed in the UK.

Management trends since the 1990s

During the last decade, in Figure 4.8, management structure of ports by a national or state level public entity has not been a dominant *modus operandi* in Europe. Since the 1990s, management structure of ports at the municipal level has taken the largest share in general for a substantial share of European ports (38% in such a category in 1991), but over the past decade or so, some have become government-owned corporations (34% in such a category in 2004).

[21] Table 4.5 is reorganized information from Chlomoudis and Pallis (2002), Technum Flanders Engineering (2002), World Bank (2001), etc.

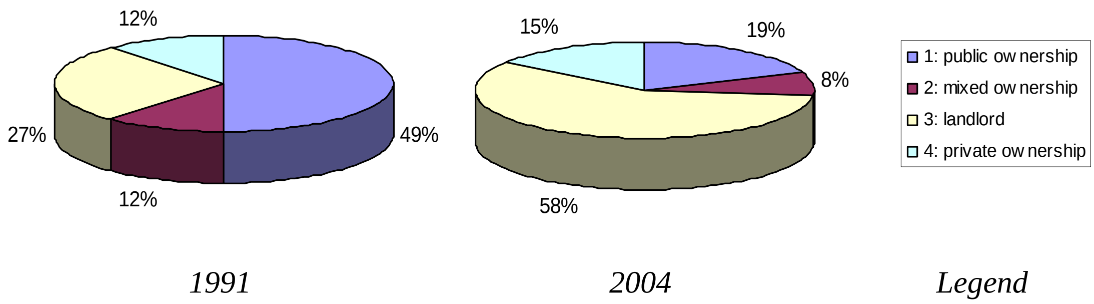
Figure 4.8: Corporate Structure System of European Ports (N=26)



Ownership

The public sector involvement in the terminal ownership and operation of ports was strong in Europe in 1991: 62% of the ports were under either public or mixed ownership, while the share was relatively lower than that of Asia (76%) in general. By 2004, however, these two forms of ownership had declined dramatically, and most of the ports assumed the landlord model or entirely private ownership (73% combined). More specific trends in institutional reform may vary depending on the regions in Europe.

Figure 4.9: Ownership System of European Ports (N=26)



4.4.4.1 Northern Europe

Management structure of ports by a national or state level public entity has never been popular in northern Europe. Historically, managing ports at the municipal level has been the dominant modus operandi for most ports in the region for a long time. Such an attribute started to change in the 1980s, which gained momentum in the ensuing decade. The overall trend has been to corporatize city-level port governing bodies into mainly government-owned enterprises operating under general corporate law, or sometimes into statutory corporations. A few exceptions include Aarhus in Denmark and Hamburg in Germany who have not thus far adopted such corporatization schemes. On the other hand, private sector participation in the operation of terminals has been historically strong in the region, and the trends in the past decade or so have been to increase such participation even more. As such, a few more ports have adopted a landlord model.

The United Kingdom, for instance, has been extremely aggressive in its privatization schemes in the port sector. Most of the commonly used ports used to be placed under the control of either independent port authorities or port trusts. Starting in the 1980s, however, ports were reorganized as corporations under private corporate law to reduce public sector involvement in port investment and operations. Ports like Felixstowe, for example, have undergone a full privatization process. Felixstowe is now owned by HPH on a freehold basis and operated as the Port of Felixstowe, Ltd (ADB 2000). All the port activities are handled by the company itself. In other words, it is a private service port (Baird 1999). Southampton is likewise a private service port (although the majority shareholder of the port company is the government). Such changes are consistent with the current dominant discourse in the country to view ports as business enterprises that should have their own responsibility to be profitable and to earn enough returns to be able to replace their assets over time.

A case of a transformation of a port from being operated as a municipal authority to a corporation under private corporate law at the same time as it shifted its ownership practice to a landlord model is the port of Bremen/Bremerhaven in Germany. Until 2002, ports in Germany were owned and operated by municipalities as a part of their government apparatus. There was no autonomous public body, such as a port authority, for the ports, and they were neither legally nor economically independent. As a result of port reforms in the late 1990s, Bremenports GmbH & Co. KG, a limited company, was formed in 2002 to manage the ports of Bremen and Bremerhaven on behalf of the Free Hanseatic City of Bremen.[22] The municipality is a limited partner in the company with a 50% stake. Furthermore, devolution of responsibilities has occurred in the operation of terminals as well. All terminals are now operated by private companies, whereas the municipality itself used to be engaged in all of the activities at the terminal level in the past.

4.4.4.2 Southern Europe

In southern Europe, the most popular corporatization scheme in the port sector reform has been conversion of public entities as the port manager into statutory corporations to be governed by a separate statute, thus devolving a high degree of autonomy and

[22] The Bremenport website: www.bremenports.de

accountability downwards. This was extremely popular in countries such as Italy, Spain, and Portugal in the late 1980s and early 1990s. After such transformations, no further corporate changes for the management structure occurred in these countries. A few countries more proximate to the Mediterranean went further by turning their statutory corporations into a corporation operating under private corporate law. This was the case in Greece and Malta. Along with such corporatization reforms, most of the ports in the region simultaneously switched from historically being a public operating port to a landlord port. Many ports are advised and encouraged by their governments to seek private sector involvement in the operation of terminals. In some countries, the port authorities even came to be explicitly banned by law from getting involved in terminal-level activities. Hardly any port is operating terminals on its own nowadays in the region.

Italy is typical of these institutional reforms. A major port reform in Italy was introduced with law number 84 of January 1994 (TFE 2002). Previous to the introduction of the law, ports were managed by public entities and placed strictly within the public domain. Furthermore, private undertakings in the port were seldom allowed and incessantly hindered by many restrictive practices coming down from above. The reform law established statutory corporations called Port Authorities in major ports to take over the place of the previous institutions, consortiums, provincial education offices, mechanical equipment companies, or other public bodies involved in the control and management of port properties. In addition, the port authorities were to act as a landlord and allow private enterprises to carry out terminal-level activities such as cargo handling business. In fact, the port authorities are strictly forbidden from carrying out cargo handling services either directly or indirectly via holding shares in stevedoring companies.

Port of Genoa, for instance, had been placed under the directorship of Consorzio Autonome del Porto (Autonomous Consortium of the Port), or CAP, since 1984 (TFE 2002, 48). In 1992, the CAP began granting concessions to private companies for cargo handling activities on designated port areas, but some of the activities were still conducted by the port company itself. The 1994 port reform law number 84 then commanded the establishment of a port authority responsible for comprehensive planning and control of the port, and dictated concessionary contracts to be used as a means of transferring the management of operational activities from the public body to private operators.[23] The reform process in Genoa was completed in December 1994 with the annual concession of the Multi-purpose Terminal wholly assigned to a private company and the establishment of the new Port Authority on January 1, 1995.[24]

4.4.5. North America

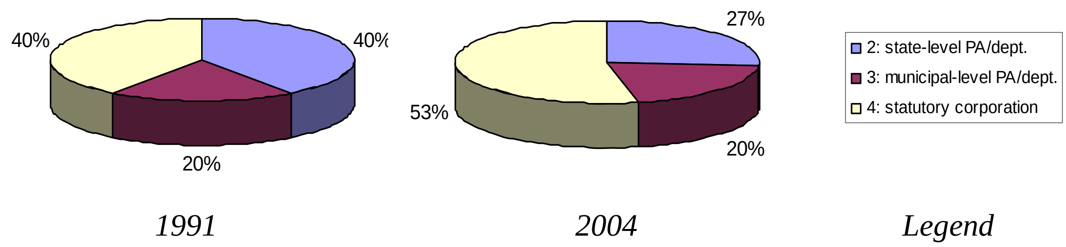
Corporate Structure and Management

Management of ports by national level public bodies has seldom been practiced in the context of North America (i.e., the US and Canada); even in 1991, no ports were

[23] Port of Genoa Website: http://www.porto.genova.it/uk/ap/intro/ap.htm
[24] Source: international port information provider: *Informare* website at *http://www.informare.it/news/forum/capoc1uk.htm*

governed in such a way. Management at the state level and statutory authority were two predominant practices in 1991, each with 40% of the ports, but some ports were overtaken by the statutory authority or corporation model by 2004. Management of 13% of the ports has been transformed from state-level governance to statutory corporation.

Figure 4.10: Corporate Structure System of North American Ports (N=15)

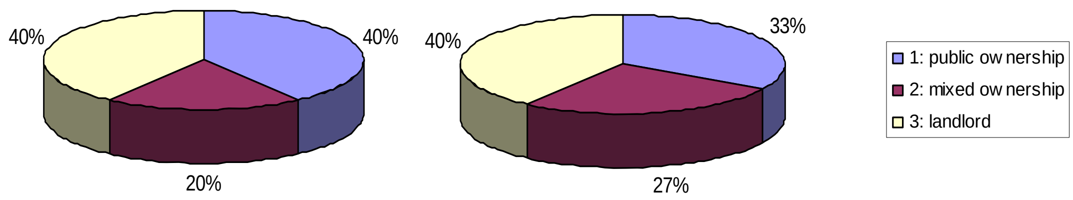


Ownership

There is no significant transformation in ownership structure of North American ports. The slight difference between the years 1991 and 2004 is a small shift from public ownership to mixed ownership, a mere 7% shift. This is partly due to the US port system that had primarily used a mixture of public landlord model and privately operated terminals before the early 1990s. In the late 1800s and early 1900s, when they were established, many port authorities focused more on developing the ports in conjunction with the private sector. They now emphasize more regulating private sector activity (private terminals) within the port. Moreover, many North American ports have not faced a similar level of intensity of competition to the ports as in Europe and Asia.

Rather, the regional and national gateway ports still operate as a regional monopoly by sharing the fairly large size of hinterlands.

Figure 4.11: Ownership System of North American Ports (N=15)



1991 *2004* *Legend*

In spite of the general historical direction that the US system has taken, different port administration models have taken hold between the East and the West. While many Eastern states have taken the approach of regional public authorities for their services, the West rejected the idea for theirs. The most visible example has been ports in South California which enjoyed the extensive development powers granted to “home rule” cities under the California constitution. Los Angeles created powerful municipal proprietary departments to develop and manage the region's early harbor facilities. These powerful semi-autonomous public enterprises created strong incentives for public entrepreneurs to engage in long-range strategic planning and devise innovative development and financing policies. Municipal "home rule" charters historically provided the proprietary departments with considerable autonomy and powers to ensure their ambitious capital improvement programs. Voter-approved local constitutional protections once limited the ability of the mayor, city council, or the city manager to micro-manage their affairs (Erie & Kim 2002).

The situation became gradually and increasingly different since the implementation of Proposition 13 in 1978. Erie and Kim (2002) show critical points about the changes:

> Local politicians have had strong incentives to rewrite the rules to funnel agency revenues into the city's general fund and enhance their control over port authorities. From 1977 to 1999 a series of voter-approved L.A charter amendments restricted powers of the citizen commissions overseeing these once-independent agencies. The boards lost their authority to appoint and remove general managers, set departmental salaries, and act independently of city council review and possibly override their decision-making.
>
> (p.13)

Canada and the United States have differed in their recent port system reforms. Canada has given a uniform treatment to all of their ports, whereas in the United States, patterns of changes have differed from one state to another, probably reflecting the historic autonomy of states vis-à-vis the federal government—or rather the continual conflict to gain such an autonomy—with respect to many decision-making processes.

In Canada, both Montreal and Vancouver went through the same progression of institutional changes. Originally, both ports were governed by the National Harbor Board for almost half a century until 1983, when Montreal Port Corporation and Vancouver Port Corporation were created for the respective ports. The corporations received a greater autonomy, but as a public agency they still reported to the Federal Transport Department. The management structure changed once again in 1999, when a statute called the Canada Marine Act C-9 created Montreal Port Authority and Vancouver Port Authority for the respective ports. The port authorities are a corporate entity (i.e., statutory corporation) and completely autonomous from the government in their business decisions. In terms of terminal operations, the port authorities have always leased them to private companies to operate them without partaking in the activities themselves.

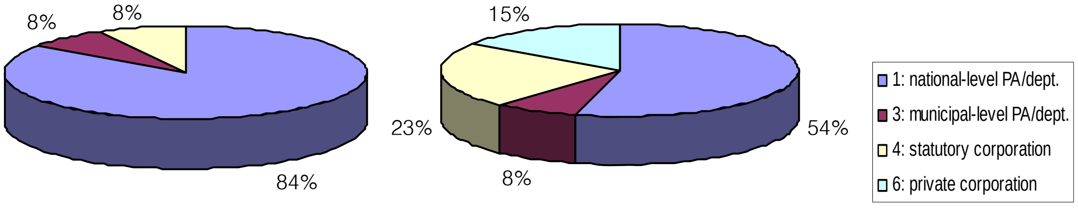
In the United States, states have exhibited different patterns from one another, as mentioned above. However, the most striking feature of the port system in the country has been the lack of institutional changes across the states, apart from a few exceptions. Changes in both management and ownership have been few and slow in virtually every state as historically engrained practices have continued to live on. In terms of management practices, for instance, Californian ports have historically been governed by municipal governments and continue to be so. In Georgia, Hawaii, and Virginia, ports have been under the state government apparatus. Yet, in Washington State, ports have been running as a statutory corporation since the early 20th century. New York/ New Jersey and South Carolina are two of the very few cases that have undergone some transformation in management structure since the middle of 1900s. The state-level port authorities have been transformed into statutory corporations in both cases (i.e., South Carolina Ports Authority, Port Authority of New York and New Jersey). However, it is unclear whether these statutory corporations are financially and managerially autonomous entities that are fully separated from state or local governments, as partly shown in the case that politicians recently enhanced their control over municipal ports such as the port of Los Angeles (Erie 2004).

Likewise, terminal ownership and operation practices have lingered in most states. Port authorities in states such as Georgia, South Carolina, Virginia, and Texas are still operating their terminals on their own. In contrast, such states as New York/New Jersey, California, and Washington have always sought private sector participation in the ownership practice and operation of terminals. A small change has occurred in Florida, as the Port of Miami (a Miami-Dade County Government department) began allowing a private company, Port of Miami Terminal Operating Company—50% of whose shares are owned by P&O as of 2005—to operate some of its container terminals in 1994. Nevertheless, the department is still actively involved in the operation of other terminals.

4.4.6 Latin America

Latin America has an eclectic group of ports in terms of management and ownership practices. However, most of the region's large ports fall into one of two categories: a progression from the public operating port model governed by a federal-level public department/agency to a landlord or service-landlord model (albeit mostly still managed at the federal level) or entirely private free port.

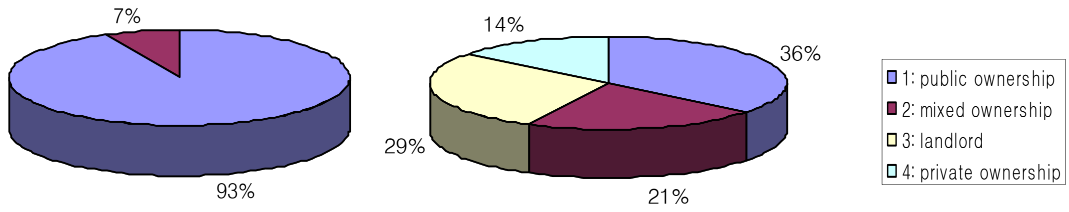
Figure 4.12: Corporate Structure System of Latin American Ports (N=13)



1991 *2004* *Legend*

Out of the 14 Latin American ports on which we have data for both 1991 and 2004, 11 ports were controlled directly by a public entity at the national level and all save one practiced the public service model in 1991 (Figure 4.13). In 2004, half of the Latin American ports were still managed by a national public entity (Figure 4.12), but only five ports still operated all of their terminals on their own (Figure 4.13). The rest of the ports introduced private sector involvement in the operation of their terminals in one way or another. The transformation has largely been achieved via a means of concession, which has become increasingly popular since the late 1980s in the region.

Figure 4.13: Ownership System of Latin American Ports (N=14)



1991 *2004* *Legend*

Archetypal of this transformation are ports in Brazil such as Santos. The process of reform started in 1990 with the dismantling of the national public agency Portobras and the ensuing decentralization of the port governance system. Following this, Brazil passed a law, Law 8630, to establish the general framework of the newly reformed port system in 1993. The law granted autonomy to all seaports and allowed private participation in cargo handling services. It also paved the way for plans to privatize 36 state ports, some of which are well advanced for small ports. In the main ports of the country, such as Santos and Rio de Janeiro, important reforms were put into action, and substantial private participation has been introduced through concession of terminals. It is estimated that about 75% of the infrastructure in these ports has been passed over to the private sector through concessions (Trujillo & Nombela 2000, 150).

In Santos, for instance, a 25-year concession for the main container terminal, TECON, was bid for in a live public auction in 1997. The winner of the bid, Santos Brasil Consortium, was a consortium of pension funds, investment banks, and a terminal operating company, Multi-terminal. A smaller terminal, T37, had also been concessioned (ADB 2000, Appendix 4 16-17). These were all conducted under the general auspices of Project Santos 2000, with which the authorities have been striving to create a port operated by private entrepreneurs by means of leasing and partnerships. Through the project's core program, Port of Santos' Leasing and Partnership Program (SPLPP), by the end of 1997, 71.21% of the port had been already leased or was in a bidding process.[25]

Examples of free private ports in the region are Freeport in Bahamas, at which Hutchson Port Holdings (HPH) owns a new terminal on a freehold basis, and Bridgetown in Barbados whose port is managed and operated by the Barbados Port Inc. Likewise, most of the ports in Panama are now fully private ports, after initial flirtations—and huge successes—with concessions (e.g., Puerto Manzanillo and Cristobal).

[25] The website for the port authority of the city of Santos

4.4.7 Africa[26]

Institutional reforms and changes in the port sector in Africa have not been a major trend in general. In North Africa, there have been few institutional changes in the port sector. Most of the ports have always been directly managed by a national government authority, and the authorities themselves have been operating the daily business of the ports under their jurisdiction. Examples are Djibouti (port of Djibouti), Morocco (port of Casablanca), and Sudan (Port Sudan).

Southern Africa has been obstinately against reforms in the port sector, as major ports are still governed by a national-level government entity, and their container terminals operated by the port authorities themselves. Durban in South Africa and Mombasa in Kenya are prime examples of such a continued dominance of national government in the port sector in the region.

[26] Because the number of ports we have information for both years (1991 and 2004) is only six, I do not present the statistics here.

4.5 Findings and Conclusions

This chapter makes an extensive survey of and performs analysis on world port institutions and their changes over the last decade or so. For most world scale ports and national gateway ports, port institutions mirror the historical development of national and regional political structures and economic systems. From this point of view, port managing institutions have developed uniquely in each country, having a close relationship with the historical trajectories that each port has gone through and clearly illustrating path dependence characteristics of port institutions.

However, not all ports have stayed on their own historical paths with organizational inertia. While some have been languid in updating their port institutions such as corporate structure and asset ownership, port policy in different countries has interacted with and influenced other ports and therefore ports have adapted to the external environment, thereby assimilating their port managing institutions. In particular since the early 1980s, as new ages of globalization have risen and the rationale for ports reforms has developed, port management and ownership models have been newly designed, developed and implemented, assimilating with each other in some parts of the world. Often some port authorities with strategic vision have aggressively moved toward new models of management and technology so that they can capture the higher ground of competition. This strategic movement could also create new orders and hierarchies of hub and spoke in world shipping and facilitate the speed of institutional change, making speed faster than it ever has been in the past.

Since the 1990s there have been two distinctive trends in general. In terms of port management and corporate structure, more decentralized corporate structure and administration increasingly gain momentum. Corporatization has recently been particularly popular on the continents of Asia, Oceania, and Europe, while the mechanisms have not been always the same in all of the countries adopting it. The specific models have been influenced by the countries' political contexts and traditional port governing models. In terms of port ownership, increasing cases of contracting, leasing, and concessions have continuously occurred for container terminal levels and other cargo and vessel services in almost all regions. It has thereby transformed many public service ports to landlord models. Privatization through full asset divestiture may separate macro-level regulatory functions such as navigation, customs procedure, and investment in nautical infrastructure from port management and terminal operation functions.

The models of corporatized ports vary depending on the implementation and legislation schemes. Some models still have not "unbundled" different functions such as regulation, port planning and management functions, and terminal operation with cargo handling functions. It may not achieved the increasing levels of intra-port competition that some partial privatization models intend to achieve, while it may be possible to partly exclude politics from port management at a port level. Many previous port studies have not clearly examined whether or not the corporatized structures of port authorities have in fact increased the level of efficiency at a port level and whether or not terminal level private sector participation can actually increase port efficiency. There is much work to be done in this area.

What this chapter clearly shows is that while boundaries for the adaptation of port institutions have expanded in the past decade, there are still different levels of vigilance, strategy, and flexibility on institutional reform and innovation in differing parts of the world. Such regions and countries as South Asia (Singapore, Malaysia), Oceania (New Zealand, Australia), East Asia (China), and some Latin American countries are more enthusiastic about innovation in port institutions. While their reasons and models are different, the speed of institutional change and the levels of consideration in the public and private sectors on the issue are considerable.

Several northern European countries, southern European countries, and Korea have actually tried to follow the predecessors after some periods of testing the models by examining the cases of other countries and discourses on the issue. They have at least more than medium high levels of vigilance on institutional reform. Finally, US, Japan, and many countries in the African continent so far show only low levels of interest in reforming their port managing and operating models.

The US and Japan achieved some institutional innovation by adopting decentralized landlord models or municipal management in the earlier period of the twentieth century. Yet this fact has inhibited them in the last years from moving strategically forward to new institutional models. Certainly, it seems that organizational inertia and path dependent characteristics do play some roles here rather than making a decision after systematically assessing the merits and the demerits of the newly discussed models. Finally, many African countries still show very low levels of vigilance on the issue and very low levels of decentralization and private sector participation in the port sector.

The next few chapters will systematically analyze how the different institutional characteristics, flexibility, and vigilance on institutional changes will influence port efficiency. This further analysis thereby tries to identify the critical role of port institutions in creating productive port efficiency.

CHAPTER 5

Benchmarking of World Port Productivity: Relative Port Efficiency and Temporal and Regional Trends

5.1 Introduction

This chapter evaluates productive efficiency of world seaports based mainly on the concept of total factor productivity. The evaluation can be done by a non-parametric mathematical programming technique, Data Envelopment Analysis (DEA). The analysis examines relative efficiency based on inputs and outputs of ports that were selected for the survey of institutional analysis in Chapter 3. The analysis in this chapter specifically measures the relative productive efficiency that was achieved by the ports in 1991 and 2004 in the process of port production and service. In addition, the analyses for the two years also allow us to directly measure amounts of change in productive efficiency and analyze what factors contributed to the change in efficiency between 1991 and 2004. In order to systematically investigate levels of shift or change in port efficiency during the period, this chapter estimates the models to create the Malmquist Total Factor Productivity Index (MPI), evolved from the basic DEA model.

The objective of this chapter in the context of the whole dissertation can be summarized by the following: This chapter thoroughly analyzes productive efficiency of world scale hub and national gateway ports in most countries in the world. By doing so, it becomes a foundational chapter for the analysis that will be conducted in Chapter 5 and Chapter

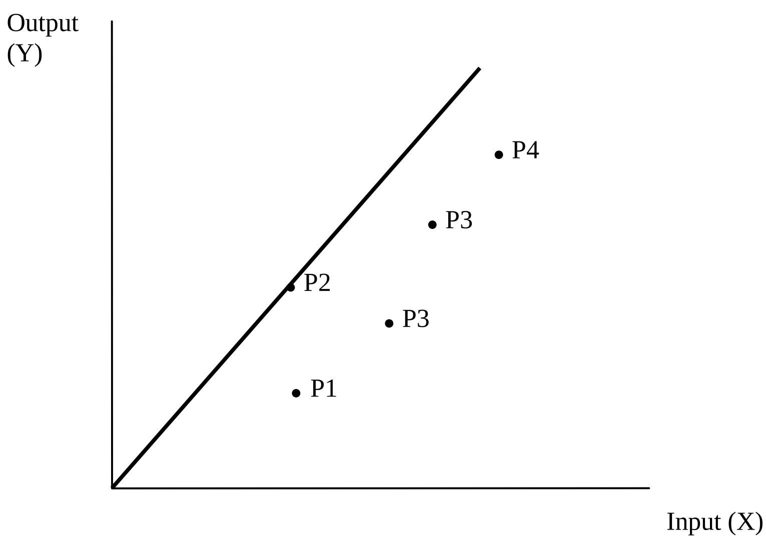
6. In order to systematically analyze the influence of port institutional characteristics on port productivity, the quantitative results of analysis in this chapter such as DEA scores and the Malmquist Productivity Index are designed to turn into the dependent variables that will be used in the following chapters.

5.2 Port Efficiency Measurement Framework

5.2.1 Concept of efficiency

The process of production is ways of converting certain inputs into outputs. The relationship between the quantity of inputs and outputs is usually expressed by a production function, $Y = f(K, L)$. It basically illustrates the maximum amount of the product that can be produced by utilizing alternative combinations of inputs such as labor, capital, and land (Nicholson 2004). The maximum amount of the product given the inputs can define a production frontier that sets a limit to the range of possible productivity (Figure 5.1).

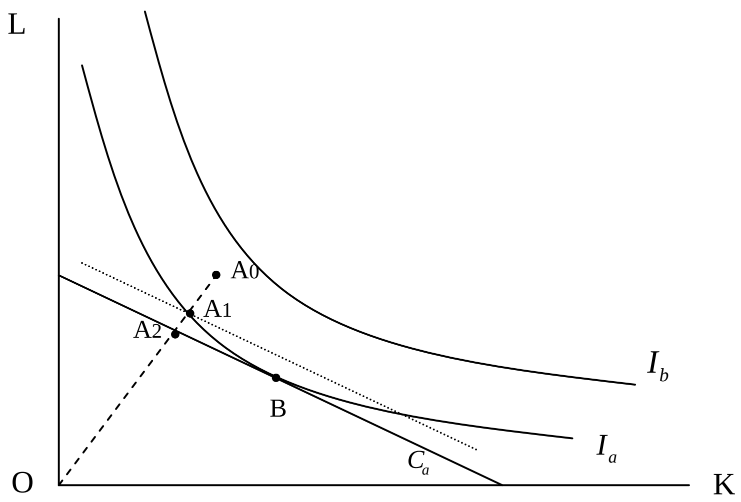
Figure 5.1: Production Function and Frontier



Firms operating below the production frontier are observable and numerous, in fact, in the real world, while a firm and an industry's productivity cannot exceed the limits set by the frontier. Therefore, a firm or an industry that lies below its production frontier can be regarded as inefficient and the divergence of productivity could have a few causes: e.g. (a) differences in the environment in which production occurs, (b) differences in the efficiency of the production process, and (c) differences in production technology.

Farrell (1957) defines two different concepts of efficiency in production: technical efficiency and allocative efficiency. Technical efficiency is the conversion of physical inputs into outputs, which is also noted as productive efficiency by Nicholson (2004). In order to be technically efficient given current levels of technology, there should be no wastage of inputs in producing a certain quantity of output. Therefore, the failure to produce the maximum amount of output from a set of inputs results in technical inefficiency.

Figure 5.2: Different Efficiency Concepts



This can be illustrated by Figure 5.2. Assume that there is only one isoquant for each level of output, given a current level of technology. An isoquant is a curve that shows minimum amounts of inputs, capital (K), and labor (L), to produce a given output quantity. The isoquants of firm A (I_a) and firm B (I_b) illustrate different combinations of inputs for firm A and B, respectively, that produce a same level of output. They also show the efficient frontiers of production for the two firms. If a firm is producing at a point on the isoquant then it is technically efficient. As firm B uses more inputs, both K and L, than firm A to produce the same level of outputs, firm B is technically less efficient than firm A.

Allocative efficiency depends on whether the amounts of inputs are chosen to minimize the cost of production. Let us assume that firms are already fully technically efficient. If a firm is producing at a point on the isoquant, it is then operating at a technically efficient level. In order for firm A to maintain the same level of output along the isoquant (I_a), L has to be increased to compensate for the decrease in K. The amount by which L has to be increased to compensate for a one unit decrease in K can be shown as the slope of the isoquant. It is the ratio of the marginal products of K and L, which is termed as the marginal rate of technical substitution between K and L. Marginal rate of technical substitution can simply be illustrated as the following equation:

$$MRTS = -\frac{MPL}{MPK}$$

where MPL is the marginal product of labor and MPK is the marginal product of capital.

The straight line, C_a, is an budget line, illustrating combinations of input K and L that have the same expenditure level. It is thus called an isocost line. The slope of the budget line denotes the negative ratio of the price of K to the price of L ($-\frac{P_L}{P_K}$). Isocost lines closer to the origin (O) show a lower total cost. The cost of producing a given output quantity can be minimized at the point where the isocost line is tangent to the isoquant. This defines allocative efficiency requiring the following condition:

$$\frac{MPL}{MPK} = \frac{P_L}{P_K}$$

When it is both technically and allocatively efficient, a firm can be regarded as cost efficient. In Figure 5.2, the point A_0 is both technically and allocatively inefficient. A firm uses more inputs than it needs to produce the level of output, I_a. The ratio of $\frac{OA_1}{OA_0}$ can define the firm's level of technical efficiency. And, technical inefficiency can be denoted as 1-$\frac{OA_1}{OA_0}$, which implies the proportion of probable cost reduction in producing the level of output, I_a when the input ratio (K/L) is held constant. Inversely, if constant returns to scale are assumed, it can also be translated into the proportion by which output can be expanded when the firm operates at 100 % technical efficiency. Technical efficiency is usually determined by measuring whether and how many inputs need to be reduced in equal proportions to reach the frontier. This is known as a "radial contraction" of inputs because the point of operation moves along the line from the origin to where the firm is now (OA_0 in Figure 5.2) (SCRCSP 1997).

The point A_1 is technically efficient, but not cost efficient because the same level of output is produced at less cost at point B. The level of allocative efficiency can be measured by $\frac{OA_2}{OA_1}$. The proportional increase in costs can occur by $1-\frac{OA_2}{OA_1}$, due to allocative inefficiency. Consequently, if a firm moved from point A_0 to point B its cost efficiency would increase by $\frac{OA_0 - OA_2}{OA_0}$. This increase is comprised by (i) an increase in technical efficiency shown by $\frac{OA_0 - OA_1}{OA_0}$ and (ii) increase in allocative efficiency measured by $\frac{OA_1 - OA_2}{OA_1}$.

5.2.2 Concept of data envelopment analysis (DEA)

5.2.2.1 Definition of efficiency in DEA

As claimed in the section 3.3 in Chapter 3, DEA is one of the strongest methodologies to estimate total factor productivity based on the concept of relative efficiency. DEA stems from the concept that the efficiency of a Decision Making Unit (DMU) is determined by its capability to convert inputs into intended outputs. The term, Decision Making Unit, refers to any entity that should be evaluated in terms of its conversion abilities. Based on single or multiple inputs and outputs, DEA optimizes individual data and creates a single “virtual” input and “virtual” output. DEA then approximates a discrete piece-wise frontier by a group of “Pareto efficient,” or technically efficient, DMUs. Because the theoretically possible levels of efficiency are not known in most social science cases, the concept of Pareto efficiency has to be converted to that of the relative efficiency represented in DEA. DMUs on the efficient frontier have an efficiency score (called a DEA score) equal to 1. Efficiency scores of inefficient DMUs are measured relative to the efficient DMUs.

In sum, according to Cooper et al. (2004), DEA uses the following two definitions: (a) Extended Pareto-Koopmans Definition and (b) Relative Efficiency Definition:

> (a) Extended Pareto-Koopmans Definition: Full efficiency is attained by any DMU if, and only if, none of its inputs or outputs can be improved without worsening some of its other inputs or outputs.
>
> (b) Relative efficiency Definition: A DMU is to be rated as fully efficient on the basis of available evidence if, and only if, the performances of other DMUs do not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs.
>
> (p. 3)

Because the efficiency of each DMU is measured with respect to all the other DMUs chosen for evaluation, the term "relative efficiency" is used in DEA. All DMUs on the efficient frontier, or the envelopment surface, have a DEA score of 1 and are considered DEA efficient.

5.2.2.2 Formalization: two-stage process for CRS[1] input-oriented model

Let us assume that *n* DMUs need to be evaluated. Each DMU uses various amounts of *m* different inputs to produce *s* different outputs. For example,[2] DMU_j consumes

[1] CRS: Constant Returns to Scale

$\{X_j = x_{ij}\}$ of inputs (i = 1, 2…m) and produces $Y_j = \{y_{rj}\}$ of outputs (r = 1, 2….s). The *(s x n)* matrix of output is denoted by Y and *(m x n)* matrix of input is denoted by X. We also assume that $x_{ij} > 0$ and $y_{rj} > 0$, meaning that each DMU has at least one positive input and one positive output value.

Consider the problem of evaluating the relative efficiency for DMUo, any one of the *n* DMUs. The relative efficiency of DMUo can be measured by the ratio of outputs to inputs, subject to the constraint that no DMU can have a relative efficiency score greater than unity:

$$\max_{u,v} \frac{\sum_r u_r y_{r0}}{\sum_i v_i x_{i0}}, \textit{where } u_r, v_i = \text{weight assigned to output r and input i.}$$

$$\textit{subject to}$$
$$\frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1 \quad \textit{for } j = 1, \ldots n$$
$$u_r, v_i \geq 0 \quad \textit{for all } i \textit{ and } r.$$

Without additional constraints, this fractional programming problem is unbounded, generating infinite numbers of optimal solutions. If (u*, v*) is optimal, then $(\alpha u^*, \alpha v^*)$ is also optimal for $\alpha > 0$. Charnes and Cooper (1962) developed a transformation to resolve this issue. The transformation allows us to have a representative solution by having a solution (u, v) for which $\sum_{i=1}^{m} v_i x_{i0} = 1$. The result of

[2] The examples and paragraphs in the following are drawn from Tonzon (2001)

the Charnes-Cooper transformation changes variables from (u, v) to (μ, ν), yielding the following equivalent linear programming problem:

$$
\begin{aligned}
&\max_{u,v} \sum_{r=1}^{s} \mu_r y_{r0} \\
&\textit{subject to} \\
&\sum_{r=1}^{s} \mu_r y_{r0} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \\
&\sum_{i=1}^{m} v_i x_{ij} = 1 \\
&\mu_{r,}\ v_i \ge 0
\end{aligned}
$$

For which the linear programming dual problem is

$$
\begin{aligned}
&\theta^* = \min \theta \\
&\textit{subject to} \\
&\sum_{j=1}^{n} x_{ij}\lambda_j \le \theta x_{i0} \qquad i = 1, 2, \ldots m; \qquad \qquad \ldots\ldots..(1) \\
&\sum_{j=1}^{n} y_{rj}\lambda_j \le y_{r0} \qquad r = 1, 2, \ldots s; \\
&\lambda_j \ge 0 \qquad \qquad j = 1, 2, \ldots n.
\end{aligned}
$$

Farrell (1957) develops the above model, the “Farrell Model.” The model assumes a so-called “strong disposal,” ignoring the presence of non-zero slacks of inputs. It is often referred to as a “weak DEA efficiency” in operations research (Cooper et al. 2004).

Since $\theta = 1$ is a feasible solution to (1), the optimal value to (1), $\theta^* \le 1$. If $\theta^* = 1$, then the current input levels cannot be reduced proportionally, indicating that DMUo is on the frontier. If $\theta^* < 1$, then DMUo is dominated by the frontier. The optimal solution to

θ^* yields an input-oriented efficiency score for a particular DMU. The process is repeated for each DMU_j to have efficiency scores. At this stage, DMUs for which $\theta^* < 1$ are inefficient. DMUs for which $\theta^*=1$ are boundary points. After calculating (1), some boundary points have non-zero input and output slacks:

$$\begin{cases} s_i^- = \theta^* x_{i0} - \sum_{j=1}^{n} \lambda_j x_{ij} & i = 1, 2, \ldots m \\ s_r^+ = \sum_{j=1}^{n} \lambda_j y_{rj} - y_{ro} & r = 1, 2, \ldots s \end{cases}$$

Where s_i^- = input slack and s_r^+ = output slack.

Therefore, we use the following linear programming model to determine the possible non-zero slack after (1) is solved:

$$\begin{aligned} &\max \sum_{j=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+ \\ &\textit{subject to} \\ &\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta^* x_{i0} \qquad i = 1, 2, \ldots m; \\ &\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro} \qquad r = 1, 2, \ldots s; \\ &\lambda_j, s_i^-, s_r^+ \geq 0 \ \ \forall i, j, r \end{aligned} \qquad \ldots\ldots (2)$$

DMUo is efficient if and only if $\theta^*=1$ and $s_i^-{*} = s_r^+{*} = 0$ for all *i* and *r*. This refers to the condition of "DEA Efficiency." DMUo is weakly efficient if $\theta^*=1$ and $s_i^-{*} \neq 0$ *and / or* $s_r^+{*} \neq 0$ for some *i* and *r*. The slacks are obtained by (2). This defines the condition of "Weak DEA efficiency."

In general, Models (1) and (2) have shown a two-stage process that can solve the following DEA model:

$$
\begin{aligned}
&\min \theta - \varepsilon\left(\sum_{j=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
&\textit{subject to} \\
&\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{i0} \qquad i = 1, 2, \ldots m; \qquad\qquad \ldots\ldots (3) \\
&\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro} \qquad r = 1, 2, \ldots s; \\
&\lambda_j, s_i^-, s_r^+ \geq 0 \quad \forall i, j, r
\end{aligned}
$$

ε is a so-called non-Archimedean element that should be smaller than any positive real number. This allows solving (1) in two steps: first, the minimization over θ; second, fixing $\theta = \theta^*$. The slacks then have to be maximized without changing the pre-determined value of $\theta = \theta^*$.

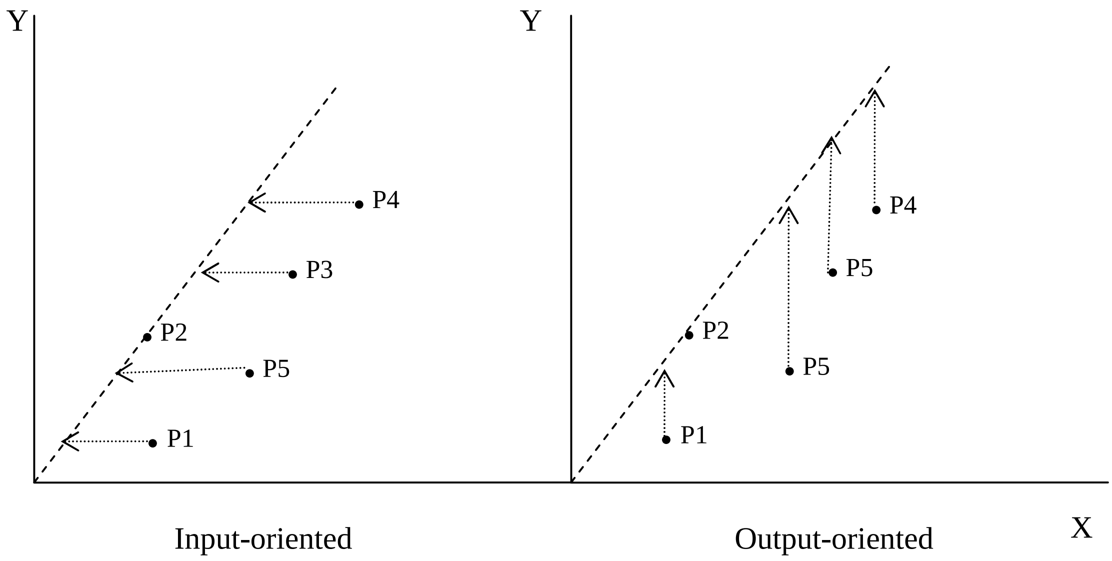
5.2.2.3 Envelopment surface orientation: input vs. output

Note that the model (3) is an input-oriented constant returns to scale (CRS) envelopment model. In the concept of input orientation, a DMU can improve efficiency through proportional reductions of inputs. On the other hand, output orientation improves efficiency through proportional increases of outputs. The following diagram simply conceptualizes the different approaches based on methods of orientation.

As shown in Figure 5.3, inefficient DMUs are projected to different points on the frontier based on the two methods of orientation. Formally, the input-oriented model can be modified to conceptualize the output-oriented model, as shown in the following:

$$\begin{aligned}
&\max \phi - \varepsilon(\sum_{j=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+) \\
&\textit{subject to} \\
&\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{i0} \qquad i = 1, 2, \ldots m; \qquad \ldots\ldots (4) \\
&\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \phi y_{ro} \qquad r = 1, 2, \ldots s; \\
&\lambda_j, s_i^-, s_r^+ \geq 0 \quad \forall i, j, r
\end{aligned}$$

Figure 5.3: Projection to frontier for the input- and output-oriented CCR Model[3]



[3] Source: Cooper et al. (2004, 16)

Model (4) also first calculates ϕ^* by disregarding slacks, and then optimizes the slacks by fixing $\phi = \phi^*$ in the following linear programming problem:

$$\max \sum_{j=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$
$$subject \;\; to$$
$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{i0} \qquad i = 1, 2, ...m; \qquad \text{...... (5)}$$
$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \phi^* y_{ro} \qquad r = 1, 2, ...s;$$
$$\lambda_j, s_i^-, s_r^+ \geq 0 \;\; \forall i, j, r$$

Therefore, DMUo is efficient if and only if $\phi^*=1$ and $s_i^-{}^* = s_r^+{}^* = 0$ for all *i* and *r*. DMUo is weakly efficient if $\phi^*=1$ and $s_i^-{}^* \neq 0 \;\; and/or \;\; s_r^+{}^* \neq 0$ for all *i* and *r*. Finally, DMUo is relatively inefficient if $\phi^*>1$.

The above models are based on the assumption of constant returns to scale, known as the CCR models, named for the original designers of the model, Charnes, Cooper, and Rhodes (1978).

5.2.2.4 Application of model orientation to container port industry

Both input- and output-oriented models have some areas that are useful given the contexts of global container port industry. The input-oriented model is closely related to the operational and managerial point of view. It is so because the concept implies that efficiency can be achieved through proportional reduction of inputs. In other words, given the fixed amount of output, the emphasis is placed on how a firm can minimize the inputs utilized for production. In contrast, the output oriented model can be related to a more strategic role of ports. The role of long-term planning and strategies can be appreciated for the purpose of growth of port production, since the model focuses more on how a firm can maximize output given the amount of resources available (Cullinane et al. 2004; Cullinane et al. 2005).

The input-oriented model, on the one hand, follows inherently the static view on the role of strategies and planning since it accepts the concept that the port industry and port output levels are mostly shaped by long-lived infrastructure, the nature of lumpy investment in facilities, and external factors such as port regulations and market conditions. Thereby, port efficiency can mostly be achieved by rationalizing input factor choice. In other words, the view emphasizes that port outputs are already fixed within a certain period range given the external conditions. Furthermore, container ports have a fairly stable number of clients – shipping lines so that ports are usually able to easily predict their container throughputs for the next several years. If this is the case, the key to port management is, and should be, directed to saving costs through efficient utilization of production factors upheld by inner-organizational managerial practices of container production.

On the other hand, by adopting the output-orientation envelopment we can appreciate a more dynamic view on, and expanded roles of, port managers, authorities, and policies that are sometimes able to influence external markets and conditions. Considering the magnitude and flow of international trade and the speed of technological development in the port sector, port institutions should have room for strategically designing timely investment schedules for cutting edge technology, and to frequently upgrade their output capacity to both respond to and shape changing environments. To do so, certain levels of port policy, strategic planning, and capital management should be well embedded in port organizations and implemented in practice. Ports' substantial knowledge of their pre-existing facilities and labors (factor inputs) is needed to eventually monitor how many output levels have been reached given the levels of inputs. The input factors should be also "rationally" chosen in order to maximize outputs to face the current external forces, and to shape the future conditions in favor of ports themselves. In this view, the input choice in the contemporary port business is more likely a necessary precondition decided in advance, while ports try to design, develop, and outlay strategies and policies aiming to increase port throughputs in the end.

This chapter takes the view that, in order for ports to compete under the umbrella of contemporary global port sector, the roles of port management do not necessarily stay within the inner-organizational practice of rationalizing input factors. Rather than narrowly focusing on the ability of port authorities to adjust input factors, the analysis of this chapter attempts to examine whether differing levels of external and internal institutions of ports – markets (hinterland economies), technology, strategy, and ability to keep up with the best practice – can influence port efficiency and how these institutional factors and capacities interplay to consequently determine port efficiency.

In order to investigate the idea more clearly, the analysis starts with the roles of differing institutions that are equally appreciated at first, rather than presuming that one is mainly shaped by the others. Therefore, taking into account the roles of port policy and port authorities that can, at least partly determine output levels, is meaningful. Yet the concept does not necessarily reject the importance of input factor choice; it implicitly embraces the concept that efficient utilization of factors can influence outputs to some degree, as shown in the analysis of MPI later. Furthermore, while focusing more on managerial efficiency in input choice can mainly produce implications for business management for the level of individual port organizations, the output-oriented model adopted in this chapter is able to both evaluate and inform policies and decision-makings at national, regional, or local levels. From this perspective, the output-oriented surface envelopment is chosen to benchmark productive efficiency of world container ports. The analysis makes it possible to investigate the mechanisms that differing levels of port institutions can interplay, thereby shaping port efficiency.

5.2.2.5 Returns to scale and extension of models

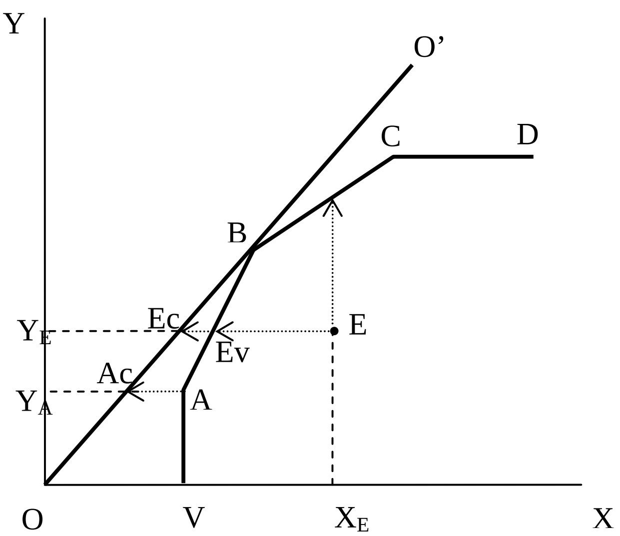
In estimating relative efficiency under the assumption of constant returns to scale (CRS), the size of DMUs is not considered as one of the factors that cause ports to operate efficiently or inefficiently. In order for small DMUs to be considered as efficient under the CRS model, they must produce outputs with the same ratios of input to output as can larger DMUs or vice versa. It can be partly adopted due to the logic that no economies of scale are present at the industry level. Normatively, all ports should enjoy the point where doubling inputs will lead to a doubling in all outputs ($f(ka, kb) = kf(a,b)$) since it is the most efficient point for ports to operate.

This may be a strong assumption as compared to the real feature of the port sector if economies of scale are present in the port sector (e.g. Turner et al. 2004). If port organizations can be subject to economies of scale or increasing returns to scale, ports can operate more efficiently by intentionally increasing their production scales. For these cases, doubling all inputs would lead to more than a doubling of outputs ($f(ka, kb) > kf(a, b)$). This is generally possible as producers take advantage of some managerial and external market advantages such as stronger purchasing powers, and spreading their overheads over time and over different types of products. However, in some cases, ports may become too large and operate under decreasing returns to scale, or diseconomies of scale. If this is the case, doubling of all inputs will lead to less than a doubling of all outputs ($f(ka, kb) < kf(a, b)$), producing diseconomies of scale at that port production scale.

In contrast to the CRS assumption, in general, the DEA model under VRS is less restrictive in assessing relative efficiency by allowing the best practice (measuring the ratio of outputs to inputs) to vary with the size of the organizations in the sample. The different implication between the two approaches is illustrated in detail in Figure 5.4. The frontier line under CRS, OBO', is based on the highest ratio of outputs and inputs that can be achieved, irrespective of size. In contrast, the frontier under VRS, VABCD, passes through the points where DMUs can achieve the highest ratios of outputs to inputs, given their relative size, and some parts of the frontier runs parallel (VA and CD) to the respective axes beyond the extreme points.

The distance from a constant returns frontier to a DMU illustrates technical efficiency under CRS while the distance from a variable returns frontier to a DMU illustrates technical efficiency under VRS. When technical efficiency is calculated under the assumption of VRS, efficiency scores indicate technical inefficiency for each DMU that results from factors other than production scale. It is therefore typical that technical efficiency scores under VRS will be higher than those calculated under CRS, thereby port representing a port as more efficient under VRS.

Figure 5.4: Returns to Scale and the Production Frontiers[4]



The distance between frontiers under CRS and VRS determines the scale efficiency component. If a port operates where the CRS frontiers meet VRS frontiers, it operates with the optimal scale within the sample. In Figure 5.4, B is the only DMU that operates without having both scale and non-scale inefficiency under each assumption. A, C, and

4 Source: adapted from (SCRCSP 1997: 17)

D are subject to scale inefficiency but do not have any non-scale inefficiency, or 'pure' technical inefficiency, since they are on the production frontiers under VRS. The scale efficiency score of DMU A can be determined by the ratio of distances Y_AA_C to Y_AA (Y_AA_C / Y_AA). As is shown in this case, if the scale efficiency score is less than 1, the DMU has increasing returns to scale. It implies that if the DMU increased its size, it would approach the optimal production scale within the sample selected. The other two DMUs, C and D, operate with decreasing returns to scale. Their production scales are too large so that they cannot achieve scale efficiency under CRS, while they are efficient under VRS. Finally, the technical efficiency of E under CRS can be represented as Y_EE_C / Y_EE, which are comprised by (a) scale inefficiency (Y_EE_C / Y_EE_V) and (b) non-scale technical inefficiency (or 'pure' technical inefficiency) (Y_EE_V / Y_EE).

In order to formally transform the DEA model under CRS to the DEA model under VRS, a simple condition can be added to the original CCR model, or the model with the CRS assumption (Banker et al. 1984) (Table 5.1). If the constraint $\sum_{j=1}^{n} \lambda_j = 1$ is added to Model (3) and (4), making the implicit weights add up to 1, it relaxes the constant returns to scale assumption. This model is known as a BCC model which allows the assumption that ports can operate at the production scales where the variable returns to scale exist, such as increasing, constant and decreasing. The following table summarizes different DEA models based on surface orientation of envelopment and return-to-scale.

Since the early work of Charnes, Cooper, and Rhodes (CCR) (1978) and Banker, Charnes, and Cooper (BCC) (1984), there have been continuous extensions of the models associated with the DEA methodology including the Additive model (e.g. Charnes et al. 1985). The Additive model is similar to the BCC model, based on VRS in the sense that it uses a piece-wise linear, variable returns-to-scale property. The difference comes from its projection path. For surface orientation, the Additive model is based on the concept of a Pareto minimum function, while the BCC model has both input and output orientations (Figure 5.3).

Table 5.1: DEA Models based on Surface Orientation and Returns to Scale Assumption

Frontier type	Input-Oriented	Output-Oriented
Constant Returns-to-Scale	$\min \theta - \varepsilon(\sum_{j=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+)$ *subject to* $\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{i0} \quad i = 1, 2, \ldots m;$ $\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro} \quad r = 1, 2, \ldots s;$ $\lambda_j, s_i^-, s_r^+ \geq 0 \ \ \forall i, j, r$	$\max \phi - \varepsilon(\sum_{j=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+)$ *subject to* $\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{i0} \quad i = 1, 2, \ldots m;$ $\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \phi y_{ro} \quad r = 1, 2, \ldots s;$ $\lambda_j, s_i^-, s_r^+ \geq 0 \ \ \forall i, j, r$
Variable Returns-to-Scale	Add $\sum_{j=1}^{n} \lambda_j = 1$	
Non-increasing Returns-to-Scale	Add $\sum_{j=1}^{n} \lambda_j \leq 1$	
Non-decreasing Returns-to-Scale	Add $\sum_{j=1}^{n} \lambda_j \geq 1$	
Efficient Target	$\begin{cases} \hat{x}_{i0} = \theta^* x_{i0} - s_i^{-*} & i = 1, 2, \ldots m \\ \hat{y}_{r0} = y_{ro} + s_r^{+*} & j = 1, 2, \ldots s \end{cases}$	$\begin{cases} \hat{x}_{i0} = x_{i0} - s_i^{-*} & i = 1, 2, \ldots m \\ \hat{y}_{r0} = \phi^* y_{ro} + s_r^{+*} & r = 1, 2, \ldots s \end{cases}$

Source: (Zhu 2003, 13)

In addition to the basic models, Charnes et al. (1985) introduced *DEA Window Analysis* to handle panel data involving pooled cross section and times series observation. This model was most recently applied to a study of efficiency comparison for the 30 largest ports by Cullinane et al. (2002) and Cullinane et al. (2005). The analysis in this chapter adopts two specific cases of *DEA Window Analysis*: *Contemporaneous Analysis and Intertemporal Analysis* with panel data of two years, 1991 and 2004. The specific models will be further discussed in the later sections.

There have thus far been many cases that have applied DEA to various conditions and sectors. Some applications have involved evaluation of efficiency in such infrastructure managing organizations as hospitals (Banker et al. 1986), schools (Ray 1991), courts (Lewin et al. 1982), post offices (Deprins et al. 1984), and air force maintenance units (Charnes et al. 1985). DEA has also been applied in the transportation sector to airlines (Banker and Johnston 1994; Charnes et al. 1996) and railways (Oum and Yu 1994).[5]

5.2.3 Evaluation of container port efficiency through DEA

In the past, it has been popular to evaluate port efficiency by measuring single factor productivity such as cargo handling productivity at berth (Bendall and Stent 1987; Tabernacle 1995; Ashar 1997; De Monie 1987). It had been also done by comparing actual throughput with optimum throughput over a specific time period (Talley 1988).

[5] A detailed bibliography related to DEA (1978-1992) can be found in Charnes et al. (1995, chapter 2).

As noted however, port efficiency cannot be effectively measured on the basis of a single value. DEA is thus one of the most powerful approaches to assess port efficiency.

Roll and Hayuth (1993) originally suggested DEA as a way to measure port efficiency by exploring a theoretical potential to apply DEA to the port sector. Until recently, efforts have been made in studies with relatively small number of ports and container terminals. For instance, Martiniez-Budria et al. (1999) use DEA-BCC models to measure the efficiency of 26 ports. Tongzon (2001) uses both DEA-CCR and DEA-additive models to analyze port efficiency of 4 Australian and 12 other international container terminals for the year of 1996. Valentine and Gray (2001) apply the DEA-CCR model to evaluate 31 container ports out of the world's top 100 container ports for the year of 1998. The model has been continuously applied for measuring port efficiency with an argument that DEA is a superior method of port performance measurement (Marlow and Paixao 2004) and its appropriateness to benchmark different ports (Wang et al. 2002). The majority of the studies adopting DEA have used standard CCR and BCC models with cross-sectional data, or sometimes, panel data with the limited number of ports.

The previous studies can be characterized as follows. Firstly, many studies that measure relative port efficiency usually carry such objectives as benchmarking of efficiency in different ports or evaluating the relationship between port efficiency and other port characteristics (e.g. port size, port function, and sometimes, organizational structure). However, secondly, most of the studies suffer from the lack of available data, and so their analyses are mostly done with very limited numbers of sample sizes, when they evaluate productive efficiency of ports and terminals. The lack of data critically forced many previous studies to limit the scope of analysis to several ports, in particular a country or region. It was oftentimes one of the barriers in laying out statistical frameworks to identify factors of port efficiency and systematically investigating the relationship between port efficiency and other organizational and social features.

Along the similar lines, Kumbhakar and Lovell (2000) point out the limitation of cross-sectional data in analyzing factors of port efficiency. They claim that, while “cross-sectional data provide a snapshot of producers’ efficiency panel data provide more reliable evidence on their performance.” This issue has not resolved until recently. In their 2004 publication, Cullinane et al. (2004) still present criticism against the studies using DEA with cross-sectional data. According to them, the previous studies do not take into account effects of time on change in port efficiency. Analyzing 25 container ports for 8 years, their DEA window analysis shows that container port efficiency fluctuates over time and more careful design of studies should be carried out to capture long-term increased efficiency and competitiveness that accrue from significant investments. Although they adopted 25 major container ports for their analysis, it was a beginning point to use panel data with relatively large number of ports and years.

5.2.4 Model specification: window, contemporaneous, and intertemporal analysis for time-series data

When data is cross-sectional, DEA compares one DMU with all other DMU in the data. Yet when the panel data is involved in the analysis, the impact of time should be considered by only choosing alternative subsets that are called reference observations subsets (Tulkens and van den Eeckaut 1995; Cooper et al. 2004). The time dependent general model of DEA is called "Window Analysis." The general concept of Windows Analysis is as follows:

Let us write t as the time when the observation is made and let T stand for the total number of time periods observed. The input variables (x) and the output variables (y) of DMU k can then be represented as the following vectors:

$$(x_{kt}) = (x_{1,kt,}x_{2,kt}, ...x_{M,kt}) \in R^M,$$
$$(y_{kt}) = (y_{1,kt,}y_{2,kt}, ...y_{n,kt}) \in R^N$$

The basic idea of Window Analysis is to deem each DMU as if it were a different DMU in each of time periods t. Each DMU is then not compared with the whole data set but only with alternative subsets of panel data – reference observations subsets. Let us consider w to be the width of window. If the window width represents the time duration for the reference observations subsets, a single window reference observations subset can be expressed as below:

$$\{(x_{kt}, y_{kt}) \mid k = 1, 2, ..., K; \quad h = t,\ t+1, ...,\ t+w;\ t \le T - w\}$$

A sequence of reference observations subsets can be generated by successive windows defined for t=1, 2,…, T-w.

It is known that two extreme cases of *Window Analysis* are *contemporaneous analysis* (when w=1) and *intertemporal analysis* (when w=T) (Cullinane et al. 2005). In other words, *contemporaneous analysis* constructs a reference observations subset at each point in time, with all the observations made at that time only. As denoted in the following, a sequence of T reference observation subsets are constructed (one for each time t) over the whole observation period:

$$\left\{ \left(x_{kt}, y_{kt} \right) \mid k = 1, 2, ..., K \right\} \; for \;\; t = 1, 2, ..., T.$$

Intertemporal analysis constructs a single reference observations set from the observations made throughout the whole period. The only one reference observations subset can be written as the following:

$$\left\{ \left(x_{kt}, y_{kt} \right) \mid k = 1, 2, ..., K; \; t = 1, 2, ..., T \right\}.$$

One possible disadvantage of *DEA Window Analysis* is related to the basic assumption of Window Analysis: Some conditions faced by DMUs in the past stay relatively constant in the future, in particular within the period of window width (Cooper et al. 2004). By accepting the assumption, part of the past should be ignored in the modeling process (Tulkens & van den Deckaut 1995). Along a slightly different angle, there has been lack of discussion about the size of window width. According to Cullinane et al.

(2005), “it is difficult to find more than an ad hoc justification for the size of the window,” (12).

One of the objectives for this chapter is to estimate temporal change in efficiency of ports from 1991 to 2004. If efficiency change has occurred over the long period, the impacts of time (window width) on productive efficiency can be attributed to two different components: technological progress and changes in total technical (managerial) efficiency. According to economic theory, technological progress is explained by the shift of the production frontier over time, while technical efficiency implies the capacity of ports to follow managerial best-practices in order to operate on the frontier at any point in time. When window width (w) is small, it can be assumed that technological levels remain same. If this is the case, productive efficiency estimated from DEA measures the managerial capacity that ports can follow the best practice at that time.

However, the period this chapter interested in measures change in port efficiency is from 1991 to 2004. Over the time the global port sector has experienced huge amounts of port reform and private sector participation efforts. This chapter tries finally to evaluate the influence of changing port organization on port efficiency. The width of window for intertemporal analysis in this chapter is larger than 10 years. Given the rapid technological development in the port and container handling industry, it is unreasonable to assume that technological levels remain the same over the period. Therefore, it should be regarded that productive efficiency measured from DEA consists of both the capacity to keep up with the latest technology based on both strategic and large scale capital investment, and managerial capacity to follow the best practice.

The differentiation between the two has greatly different policy implications because it identifies the sources of inefficiency of ports. For example, the result would be the design and creation of unreasonable policy, if a port could not efficiently utilize its existing technological assets and facilities, but attributed its inefficiency to levels of technology and the corresponding capital investment.

5.2.5 Port output and input variables and software

5.2.5.1 Objectives and issues

Port input and output data variables should achieve two conflicting objectives at the same time. On the one hand, they have to reflect actual processes of container port production accurately. On the other hand, they have to capture the essence of these processes with the simple design of models, since it is certainly impossible to include all of the factor variables used and output variables generated in the production processes. The reality of port production is that ports have complex and multiple lists of input (e.g. capital; labor; land) and output (e.g. cargo handled; warehousing; vessel services such as repair). Their combination can be different depending on the main objectives of ports. The existence of different major goals sought by ports introduces us to the consideration that port input and output may have endogenous relationships. Cullinane et al. (2004) raise the following interesting point. If the port objective is to maximize profits, employment or port labor can be regarded as port input. Yet, if the objective is to increase employment, labor should be one of the output variables. There should certainly be endogenous relationships in the port production process. While port labor is certainly used as one of input variables in production (port labor influences production), as ports expand and reduce their sizes, the size of port labor can be also changed (production scales influence the size of labor).

The core of this study is, however, to observe production behaviors and their change in container ports by measuring technical efficiency in container handling, rather than investigating the size of external impacts or benchmarking the amounts of profits created. We can here reasonably assume that, at the first stage, efficient utilization of resources in seeking to have larger port throughputs is best-sought by the container ports as a prerequisite. Ports can then implicitly try to achieve larger external impacts through revenue and job growth. Moreover, the importance of labor, in the essence of port production, has recently decreased more and more.[6]

Another issue is that, for benchmarking port efficiency, terminal level investigations on port efficiency are more proper for one-on-one comparisons since each terminal has closer characteristics to fit a comparative study. However, the original purpose of this dissertation is to compare the influence on port efficiency by differing management structures and ownership at a port level. In other words, the focus of this study is placed

[6] Most of the modern world-scale ports and national gateway ports, in general, attempt to utilize state-of-the-art equipment in handling containers rather than deploying many dockworkers. This tendency has become stronger given the increasingly fierce competition faced by world-scale container hub and gateway ports.

on how port governing or managing agencies such as port authorities and government departments are able to achieve better efficiency in their production and service. Therefore, the port level data are used for investigation in this study.

5.2.5.2 Port input variables

In order to design port input and output variables more clearly, we should consider what determines the essence of container port production in the contemporary world. While recent interest has been directed to logistical capacity of ports, the main activity of large scale container ports is increasingly organized around handling as much container volumes as possible with efficient utilization of port capital infrastructures such as container cranes; container berths; and other equipment.

Economic theory implies that effective handling of container volumes depends largely on efficient use of port land, labor, and capital (Dowd and Leschine 1990). Container handling productivity is directly associated with the land-sea interface that container transfer functions are constantly carried out. The efficiency of the land-sea interface is mainly influenced by conditions of container berth, movement rates of quayside cranes and yard equipment, the productivity of gang workers employed in terminals, and the use of ground space. In terms of terminal engineering, physical conditions and layouts of berths and container cranes are the most critical factors to determine the efficiency of the land-sea interface. Moreover, an efficient utilization of ground space typically reduces frequencies of operational access to containers. Therefore, container terminals' operational targets are achieved through conditions of access to containers shaped by berths, cranes and yard equipment, and land areas (Le-Griffin and Murphy 2006, 3).

Information on port labor, out of the major factor inputs, does not have reliable sources of data generally in the port sector. It is partly due to the fact that the structure of port labor is particularly complex, consisting of different types of full time jobs, part time positions, and contracted jobs, that are not managed and administered by port authorities but by each individual terminal operator and service provider. It is thus very difficult to trace all the information even in one port authority level. Currently, no commercial, government, or non-profit data providers supply this sort of information at an aggregated port level. Especially when a study like this chapter deploys large scale benchmarking frameworks (total, 236 ports including 138 ports for 2004; 98 ports for 1991) across many regions, it is not possible to acquire reliable sources of labor information.

However, it has been recently claimed that port land and capital input such as berth and quay length, terminal area, and capacity of container cranes, directly affects container terminal efficiency (Notteboom et al. 2000) while labor can be measured through other capital input variables. Due to the considerable amount of collinearity, the number of workers in a dock can be proxied by the number of container cranes at a container terminal (Marconsult 1994; Tongzon 2005). In this view, given the difficulty of acquiring reliable sources of information, port labor should be measured based on the relationship with other capital input data. Yet, Cullinane et al. (2004) states that, with the rapid development of manufacturing and transportation technology, new equipment, such as automated guided vehicle and automatic stacking cranes deployed at the container terminal yard, advanced ports are able to use lower numbers of port labor. Therefore, collinearity, or predetermined relationship, between port labor and container cranes observed in the past will not be necessarily static and continuously linear in the future. In spite of their intuition on the newly emerging relationship, they cannot successfully suggest new ways of measuring labor deployed in ports.

More detailed input factors and conditions may possibly influence the efficiency of port infrastructure: berth occupancy rate, crane operating hours, different handling speeds of cranes, equipment age and maintenance conditions, etc. However, as the number of input variables increases, an issue of multi-collinearity becomes significant (Cullinane 2005, 14). Especially given that the relative importance of different factor inputs cannot be clearly known in the complex production processes, the multi-collinearity problem may shape the model to capture a distorted reality of container production. Moreover, there are practical problems which arise in obtaining data on large numbers of variables across the vast number of samples.

There has been thus far a lack of study discussing the relative importance of different factor input variables in shaping efficiency of the land-sea interface. From the perspective of container terminal engineering, however, different scales of impacts of berth, cranes, ground area, and workers on port efficiency should be fine-grained in the future. This limitation allows DEA to become a more appropriate methodology in evaluating port infrastructure productivity, because the DEA analysis does not require the setting of a priori weight for the various input variables to produce an overall efficiency measure –DEA scores (Tongzon 2001, 109).

Given the characteristics of container port production and the limitation of available information, ***total container berth length*** (meter); ***container terminal area*** (square meters); ***capacity of container cranes*** (tonnage) including large quayside cranes and mobile cranes in container terminals, are selected for the proxies of factor input for container port production. The descriptive statistics of major input variables are summarized in Table 5.2.

5.2.5.3 Port output variable

There are also multiple outputs produced in a port. While contemporary ports diversify their production activities by integrating more logistics ability like manufacturing, packaging, and delivery into traditional cargo and vessel services, the main focus of large scale container ports is still organized around handling container volumes as much as possible. Moreover, the emphasis on efficient container handling has not weakened as ports seek diversification of their production but are strengthened more and more by trying to become a regional transshipment hub. In other words, the volume of containers handled may be a precondition that ports can develop other types of production activities by integrating new concepts of logistical capacity. Considering the focus of this study to benchmark world-scale and national gateway container ports,[7] this study regards ***container volumes handled*** (total throughputs) at a port level as port output, with a unit of TEU (Twenty Foot Equivalent Unit) handled. Most studies have taken this variable as port output, since it is the most directly associated variable with port capital input.

By including both intertemporal and contemporaneous analyses with observation for two years, 1991 and 2004, this study is designed to increase the validity for analyses and trace changes of port efficiency and sources of inefficiency. Furthermore, in order to reduce the impacts of severe output fluctuation that may be caused by unexpected external shock, we use the averages of three years for outputs to come up with throughput values for the two observation years, 1991 and 2004, respectively. In detail, to come up with the values of throughputs of 1991 for the ports in the sample, we use the average values of 1989, 1990, and 1991 for each port. For the values of throughputs of 2004, the averages of 2002, 2003, and 2004 were used. By adopting this average approach, it is possible to reduce the impact of fluctuation that can be generated by such external shock as port shutdown that is due partly to labor dispute or severe weather conditions and so on.

[7] The ports surveyed in Chapter 4 are the main samples to gather port input and output data, since the final objective in this dissertation is to identify a relationship between the institutional characteristics (Chapter 4) and the port efficiency examined in Chapter 5. Basically, the samples are in line with the world scale hub and national gateway ports selected for Chapter 4. Information for a total of 138 ports is gathered for 2004 and 100 ports for 1991. Some ports surveyed in Chapter 4 are excluded for the analysis in this chapter since they are relatively unreliable as regards the information required for this analysis. In order to trace the change of port efficiency, we construct a time series database, basically including two years of information for each port: 1991 and 2004. Yet since some ports that existed in 2004 did not exist in 1991, their input and output data for 1991 cannot be included in the analysis. In tracing the change of port efficiency, these ports are excluded. The analyses in this chapter utilize time dependent DEA methods including intertemporal and contemporaneous analyses in order to use the analytical concepts with the panel data.

The secondary data on port input and output are generally acquired from three different sources and were confirmed by cross-checking. The main source is acquired from *Containerisation International-Online (CIO)*[8] for the year of 2004 data, and *Container International Yearbook (CIY) 1992* for the year of 1991 data. The data are basically disaggregated into terminal levels in a port. In the aggregation process to a port level data, data for certain ports are organized differently in a way that the ports use different levels of aggregation (terminal vs. port) and definitions of input and output categories.

An attempt at confirming the data was thus made by examining another source of data from *Ports and Terminals Guide (PTG) 2005*. The PTG 2005 gives qualitative information on port regulation, terminals, and equipment as well as some quantitative information on those. When there are unreasonable or missing figures in the CIY and CIO data, they were crosschecked with the PTG data. If the PTG data did not provide information needed to confirm the data, individual port websites were visited to confirm the validity of information regarding port inputs and outputs. Many port websites provide at least the most recent information on their terminals and equipment while the past information is offered only by certain ports. It is not unusual to have discrepancy on information among these three sources. When this is the case, the majority opinions are usually followed. If the majority opinions do not exist, showing a large scale of gaps among the three sources, the final data takes the median values of the three sources. The statistics of major input and output variables are summarized in Table 5.2.

---

[8] This research thanks Containerisation International for providing the data.

Table 5.2: Descriptive Statistics of Input and Output Variables

		Output	Inputs		
		Container Throughput (TEU)	Berth Length (m)	Terminal Area (sq. meters)	Container Crane (Tonnage)
1991	Mean	679132	1906	694016	467
	Standard Error	100334	228	82225	54
	Median	328809	1068	362000	267
	Standard Deviation	993258	2258	813982	533
	Kurtosis	9.33	8.31	5.33	6.47
	Skewness	2.85	2.56	2.15	2.36
	Minimum	606	92	4500	31
	Maximum	5313900	13799	4441284	2925
	Sum	66554927	186748	68013564	45729
	Total N	98	98	98	98
2004	Mean	1837835	2485	1057178	874
	Standard Error	247519	208	105871	73
	Median	1000095	1800	580000	631
	Standard Deviation	2907686	2442	1243703	858
	Kurtosis	20.22	4.46	5.06	4.05
	Skewness	4.04	2.03	2.19	1.95
	Minimum	8875	91	15000	45
	Maximum	20508333	13329	6834710	4254
	Sum	253621251	342956	145890534	120561
	Total N	138	138	138	138

5.2.5.4 Software

The DEA software programs used for the analyses are DEA Frontier Premium developed by Cook and Zhu (2005), and DEA Excel Solver developed by Zhu (2003). In these programs, the output-oriented DEA scores for relatively inefficient ports are represented as larger than 1 (DEA efficiency).

5.2.6 Port capital input and technology changes

Table 5.2 illuminates the rate of technological changes in port infrastructure capital over the last decade. The mean length of container berths was 1906 meters per port in 1991.

It has increased by more than 30% over the last decade and become 2485 meters per port in 2004. The net increase from 1991 to 2004 was 579 meters for each port in the sample of this study. In other words, all the ports have expanded their berth lengths by 45 meters per year. For a benchmarking perspective, the Port of Los Angeles Container Terminal (LACT) has a total of 665 meters comprised by three berths. Berths that are similar in length to the LACT have been added to all major container ports during the period.

Regarding terminal areas, container ports have expanded their areas by 363162 square meters (90 acres) over the last 13 years. The figure is exactly matched to the size of land areas of the LACT, implying that major hub or gateway container ports in the world have expanded their areas by the size of the terminal. Overall, they have increased their terminal areas by more than 52 percent during the last decade.

Finally, the container crane capacity average was 467 tons per port in 1991. It dramatically increased by almost 90 percent and become 874 tons per port in 2004. The net increase of crane capacity is 407 tons per port during this period. Currently, the capacity of container cranes that are most popularly used in leading container ports ranges from 30 to 75 tons.[9] Based on a simple calculation, it becomes clear that a port has added approximately seven to ten quayside container handling cranes from 1991 to 2004. It is also confirmed by my data showing that the average number of quayside

[9] For example, one of the top producers of ship-to shore container cranes, Konercranes produces Super Post-Panamax (lift load more than 65 tons, outreach 60 meters), Post-Panamax (lift load 50-65 tons, outreach 50 meters), and Panamax gantry cranes (lift load 35-45 tons, outreach 40 meters). (Source: www.konecranes.com).

container cranes was 11 per port in 1991; it became 18 cranes per port in 2004 (with ratios of 6 to 8 cranes per 1000 berth meters). In other words, at the industry level, in order to accommodate natural increases of container cargoes during the period, each port has had to order one new container crane every other year (0.5 per year) from equipment makers such as Kalmar (Cargotec Corporations), Liebherr, and Gottwald.

According to the Cargotec Corporations, the average lifetime of container handling equipment including ship-to-shore cranes, reach stackers, and straddle carriers is between 10 and 30 years.[10] However, in my view, the economic lifetime can be much more limited because of the rapid development of more efficient container handling technologies. For example, the current international norm about the average age of container cranes is 20 years (Roux 2006). One of the top terminal operators, Hutchison Whampoa Limited, operates 21 tugs in the port of Hong Kong, which have an average age less than seven years.[11] Given that "the average age of the world fleet fell marginally to 12.2 years (UNCTAD 2006, 4)," container cranes may keep up with this rate of technological change in order to handle containers that are being carried by mega and super-mega ships.

The costs of container cranes are currently about US$ 7 to 8 million for Post-Panamax cranes. In 2002, Ports of New Orleans purchased two Post-Panamax container cranes (65 tons of lifting capacity, 52 meters of outreach) at a cost of US$ 12.3 million (about US$ 6.5 million per crane). However, given the recent increasing demand for ship-to-

[10] See the "Business Environment" section at www.cargotec.com
[11] See the "Ports and Related Service" section at www. hutchison-whampoa.com

shore gantry cranes, "crane prices have risen sharply in the last three years."[12] In October 2006, the port of Portland Commission approved the order of a US$ 7.8 million Post-Panamax cranes.[13]

Based on the information discussed above, the costs that an average-sized port having about 20 cranes in 2004 has to expend can be estimated by the following:

$$TC = \left[\text{NC+RC} \right] \times C$$

Where
- TC = Total yearly investment to purchase container cranes by an average-sized port
- NC = Number of new cranes added to accommodate natural increases of containers
- RC = Number of cranes that need to be replaced
- C = Cost of one container crane

The direct costs for ship-to-shore cranes are incurred to purchase new cranes (NC) and replace old cranes (RC). The number of cranes newly added to a port (NC) is 0.5 per year per port by using the industry average discussed above. The number of cranes being replaced (RC) is calculated as follows:

$$RC = \left[Crane\ numbers \times Depreciation\ rate \right]$$

Where
- Number of cranes = 20 per port
- Depreciation rate = $\frac{1}{20}$ per year, i.e. inverse of an average crane lifetime (20 years is assumed based on the mean value of lifetime suggested by Cargotec Corporation)

Therefore, $NC + RC = 0.5 + \left(20 \times \frac{1}{20} \right) = 1.5$ cranes per year for an average-sized port. If 1.5 cranes need to be ordered by all ports, a total of 210 cranes are ordered by 138 ports

[12] *WorldCargo News*, "Crane price surge – demand pull and supply push" November, 2005, p. 44
[13] See the *Newsroom* (press release) section of Port of Portland

in my data for the year 2004. Since approximately 85 percent of total world container throughputs are handled by the ports in my dataset, the total numbers of crane orders are approximately 247 $\left(=\frac{210}{0.85}\right)$ at the global port industry level. The World Cargo News Annual Ship-to-Shore Crane Survey confirms that approximately 250 cranes per year were newly delivered in 2004 and 2005.[14] In 2006, a total of 325 cranes were delivered in 2006. The survey also estimates that 335 cranes will be delivered in 2007. These figures are approximately matched to the numbers of yearly crane orders estimated above.

Since the price of a new Post-Panamax crane is approximately $US 7 to 8 million, the total yearly investment to purchase ship-to-shore container cranes by an average-sized port (TC) is approximately US$ 11 to 12 million in 2004. Based on a same logic, by replacing the values of NC and RC proportionally, ports with 80 container cranes (e.g. Hong Kong: 89, Rotterdam: 71, Los Angeles 63) should expend approximately $US 40 million in a recent year.

While ports have to spend US$ 10 to 40 million to purchase ship-to-shore cranes in a year, lifetime costs of cranes are more important than purchasing costs. According to Kalmar owned by Cargotec Corporation,[15] a lifetime cost for owning a ship-to-shore crane is about EUR 70-90 million during 30 years lifetime (Table 5.3). It is US$ 26-34 million over 30 years excluding labor cost. While the yearly capital investments for

[14] *World Cargo News Online*, “WCN's 13th Annual Ship-to-Shore Crane Survey” March 17, 2007
[15] “Capital Markets Day,” Kalmar Presentation by Granskog, Christer. March 21. 2006. New York.

purchasing container cranes range from US$ 10 to 40 million per port, the total costs incurred over the lifetime amount to three times of these values without considering labor costs.

Table 5.3 Lifetime Cost of Container Crane Ownership[16]

Item	Percent	Lifetime cost (EUR)	Lifetime cost (US $)
Capital investment	10 %	7-9 million	8-11 million
Interest	3-4 %	2-3.5 million	2.5-4.5 million
Maintenance	7-8 %	5-7 million	6.5-9 million
Energy	4 %	3-3.5 million	4-4.5 million
Labor cost	70 %	49-63 million	64-82 million
Cost of non-availability	5 %	4 million	5 million
Total (Total except labor cost)	100% (30%)	70-90 million (21-27 million)	90-116 million (26-34 million)

[16] Reorganized from "Capital Markets Day," Kalmar Presentation by Granskog, Christer. March 21. 2006. New York.

5.3 Analysis and Results

5.3.1 Intertemporal analysis, 1991-2004

As discussed previously, the variable returns to scale (VRS) model is less restrictive, in comparison to the CRS model, by allowing the best practice (measured by the ratio of outputs to inputs) to vary with the size of the organizations in the sample. The analyses in this chapter implement both the CRS assumption approach and the VRS assumption approach in order to confirm the validity of this assumption and consider that the concept of economies of scale may prevail in the port sector (Turner et al. 2004). Furthermore, even though the framework of analysis in this chapter includes world scale hub and national gateway ports, as mentioned before, their sizes are quite different; from a few dozen thousand TEUs to a dozen million TEUs. Relaxing the assumptions of CRS makes it possible to acknowledge that smaller ports may face disadvantages caused by production scale effect and the DEA scores from the analysis with VRS assumption can only reflect efficiency results from factors other than production scale economies.

As shown in Appendix 5.1, the results of the two approaches, in general, are most likely similar. Therefore, the result and the discussion of the analysis in the later section are presented based on the VRS model. One difference is, however, found in the following sense: Some ports categorized as very or relatively inefficient ports under the CRS assumption are classified as quite efficient ports under the VRS assumption (e.g. port of

Belize City for the years of 1991 and 2004; port of Corinto for the year of 2004; port of Xiamen for the year of 1991; port of Salalah for the year of 1991; port of Puerto Limon for the year of 1991; port of Veracruz for the year of 1991; port of Montevideo for the year of 1991). Since relaxing the CRS assumption considers that smaller ports may have inherent limitations in production scale that keep them from functioning equally effectively as larger scale ports, the analysis allows the relatively smaller ports to be closed to efficient frontiers when they are effectively and strategically managed despite their disadvantages in size.

In order to examine the impact of port size on relative efficiency of ports more clearly, Pearson's correlations between DEA efficiency scores and volumes of container throughput with a two-tailed t-test are estimated with a null hypothesis: the size of port does not influence port efficiency. In order to confirm another alternative hypothesis that, as has been claimed by policy makers and practitioners, the direction of influence on efficiency by the size of port were certain – as if smaller ports were more inefficient – one-tailed t tests should be conducted. DEA scores acquired from both the CRS model and the VRS model are compared against port throughput.

According to Table 5.3, the correlation between DEA scores under VRS and port size shows -0.328. It is statistically significant at the 5 percent confidence level. The t-statistics, 8.756, are much larger than t-critical values for both one-tailed (1.651) and two-tailed tests (1.970). Therefore it is possible that, even without considering the concept of scale economies, the larger the ports, the smaller the DEA scores (more efficient) acquired from intertemporal analysis. This analysis implies that larger ports organize their strategies and management more effectively to become efficient in container production even without having the advantages of economies of scale. This may reasonably reflect the popular conception, in the sense that most of larger ports in the world container-port sector are leaders in technology (the effects of technological progress) and strategies and management skills or they have significant locational advantages to increase outputs given the amount of inputs.[17] However, we have to be careful in interpreting the results as it could actually measure the impact of time, rather than the actual size of ports, on port efficiency, since the inter-temporal analysis has a feature that regards ports over the different years as if they exist and operate at the same period. Thus, in order to confirm the implication that the larger ports move more strategically and managerially to become more efficient ports, similar results should be demonstrated in the contemporaneous analysis.

When considering the effect of scale economies on port efficiency, the correlation between DEA scores under CRS and the scales of port production is -0.344 (Table 5.4). The analysis is done without including one outlier (Port of Salalah in 1991) that shows a tremendously higher DEA score than the average of other ports. It is also statistically significant at the 5 percent confidence level for both one-tailed and two-tailed tests. Again, the analysis demonstrates that the larger the ports the smaller the DEA scores (more efficient). The scatter plot in Figure 5.5 illustrates the relationship between the two variables.

[17] The relationship among these factors (location, institutions, production scales, and efficiency) is systematically examined in Chapter 7.

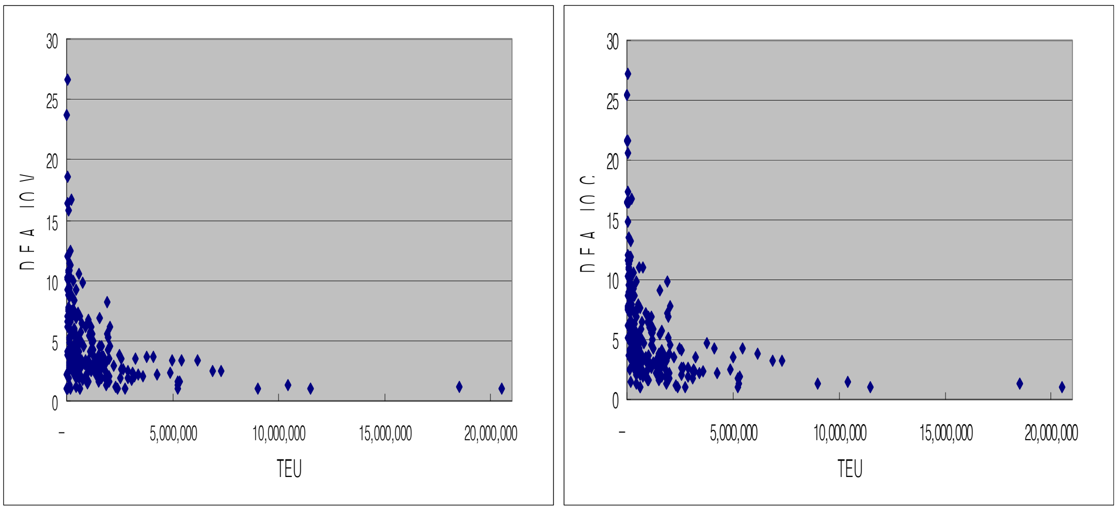
Table 5.4: Correlation Analysis between Intertemporal DEA scores and Port Size

	TEUAVE	DEAIOV	DEAIOC*
Mean	1346519.42	4.888	5.682
Variance	5.62793E+12	13.309	18.419
Observations	238	238	237
Pearson Correlation		-0.328	-0.344
Hypothesized Mean Difference		0	0
Degree of freedom		237	236
t Stat		8.756	8.762
P(T<=t) one-tail		1.943E-16	1.902E-16
t Critical one-tail		1.651	1.651
P(T<=t) two-tail		3.886E-16	3.806E-16
t Critical two-tail		1.970	1.970

- *TEUAVE: total volume of container throughputs (TEU)*
- *DEAIOV: Output-oriented DEA scores based on VRS*
- *DEAIOC: Output-oriented DEA scores based on CRS*

** The statistics are calculated without including one outlier in DEA scores*

Figure 5.5: Relationship between port efficiency and production scales



A. DEA Scores (VRS) vs. Throughput **B. DEA Scores (CRS) vs. Throughput**

- *TEU: total volume of container throughputs (Twenty-foot Equivalent Units)*
- *DEA_IOV: Output-oriented DEA scores based on VRS*
- *DEA_IOC: Output-oriented DEA scores based on CRS*

However, it should be also noted that, according to Appendix 5.1 and 5.2, while they are relatively efficient than smaller ports in general, according to the CRS model, many large scale ports are operated under decreasing returns to scale (DRS) at each port level. It may imply that, if higher levels of inter-port competition are introduced into the regional markets where these ports are located, the higher efficiency can be achieved at the regional level. In other words, by breaking a port operated under DRS into same total scales of multiple ports operated under IRS or CRS, the region may be able to achieve higher port efficiency at an aggregate level.

Table 5.5 shows DEA efficient ports and four other quartiles of ports classified by standard deviation of DEA scores. In addition, efficiency scores are cross-tabled based on the relationship between efficiency quartiles of ports and production scales of ports. In general, smaller ports are inclined to be categorized into inefficient quartiles, while there are also many small ports showing high levels of efficiency such as Salalah, Chittagong, Puerto Limon, and Belize City. 23 out of 38 ports in *Class 1* (the largest production scales) are classified into two high efficiency quartiles (DEA efficient or First quartiles). Three Japanese ports are the least efficient ports among the ports in *Class 1*: Yokohama, Nagoya, and Kobe. 44 out of 78 ports in *Class 4* (the smallest production scales) are classified into the least efficient quartile, or the fourth quartile. However, 9 ports in *Class 4* are still classified as quite efficient ports. In Table 5.5, since the cases of ports observed for multiple years (here, 1991 and 2004) are treated as if they were two different ports, in the intertemporal analysis, they are differentiated by using the symbols: ‘*’ for 1991 and ‘+’ for 2004.

Table 5.5: DEA Efficiency of Ports: Intertemporal, VRS

DEA scores / Size	**Efficient ←---→ Inefficient**				
	DEA efficient DEA=1 (N= 12)	First Quartile 1<DEA<2.48 (N=48)	Second Quartile 2.48<DEA<3.75 (N=59)	Third Quartile 3.75<DEA<6.36 (N=59)	Fourth Quartile DEA>6.36 (N=60)
Class 1: Larger than 2 million TEU (N=38)	Hong Kong+ Busan* Shanghai+ Yantian+ Guangzhou+	Hong Kong* Singapore*+ Busan+ Kaohsiung*+ Los Angeles+ Dubai+ Tokyo+ Manila+ Port Klang+ Qingdao+ Tanjung Pelepas+ Laem Chabang+ Gioia Tauro+ Tianjin+ Ningbo+ Xiamen+	Rotterdam*+ Los Angeles* Hamburg+ Long Beach+ Antwerp+ NY/NJ+ Bremen/BH+ Felixstowe+ Kobe* Tanjung Priok+ Algeciras+	Yokohama+ Nagoya+ Kobe+	
Class 2: Smaller than 2 million and Larger than 1 million TEU (N=51)		Keelung*+ Colombo+ Salalah+ Chiwan+ Tanjung Perak+ Santos+ Khor Fakkan+ Southampton+ Puerto Manzanillo+ Manila* J. Nehru+	Dalian+ Charleston+ Tacoma+ Barcelona+ Yokohama* Virginia+ Osaka+ Tokyo* Genoa+ Melbourne+ Piraeus+ Vancouver+ Durban+ Felixstowe* Marsaxlokk+ Taichung+ Bangkok* La Spezia+ Jeddah+ Valencia+	Hamburg* Le Havre+ Oakland+ Long Beach* Seattle*+ Savannah+ Houston+ Gwangyang+ Bremen/BH* Bangkok+ Kingston+ Sydney+ Oakland* Montreal+ Zeebrugge+	NY/NJ* Antwerp* Miami+
Class 3 Smaller than 1 million and Larger than 300000 TEU (N=71)	Puerto Limon+ Chittagong+	Haifa+ Honolulu+ Shahid Rajaee+ Karachi+ Izmir+ Abidjan+ Veracruz+ Houston* Guayaquil+ Piraeus* Santos* La Spezia* Casablanca+ Aqaba+	Dubai* Damietta+ Nagoya* Saigon Newport+ Inchon+ Las Palmas+ Tanjung Priok* Cartagena+ Colombo* Honolulu* Jeddah* Algeciras* Shanghai* Puerto Cabello+ Dublin+ Rio Haina+ Tauranga+ Mombasa+	Le Havre* Charleston* Gothenburg+ St Petersburg+ Auckland+ Brisbane+ San Antonio+ Durban* Lisbon+ Haifa* Port Klang* Helsinki+ Barcelona* Fremantle+ Puerto Cortes+ Valencia* Miami* Southampton*	Tacoma* Buenos Aires+ Jacksonville+ Melbourne* Montreal* Osaka* Sydney* Aarhus+ Savannah* Jurong+ Gothenburg* Tianjin* Zeebrugge*

			Santo Tomas+	Montevideo+ Port of Spain+ Vancouver* Port Louis+ Gdynia+	
Class 4 Smaller than 300000 TEU (N=78)	Reykjavik* Xiamen* Belize City+ Corinto+ Salalah*	Puerto Limon* Veracruz* Montevideo* Belize City*	Doha+ Douala+ Taichung* Dalian* Izmir* Fremantle* Tauranga* Lisbon*	Limassol+ Helsinki* Havana+ Auckland* Buenos Aires* Khor Fakkan* Djibouti+ Mina Sulman+ Dar-es-Salaam*+ Port Sudan+ Puerto Cortes* Riga+ Lome+ Cristobal* Aqaba* Oranjestad+	Genoa* Aden+ Constantza*+ Dublin* Jacksonville* Las Palmas* Dakar+ Aarhus* Oslo+ Brisbane* Damietta* Shuaiba*+ Guayaquil* Casablanca* Copenhagen*+ Mombasa* Klaipeda+ Koper*+ Gdynia* Pointe-a-Pitre*+ Marsaxlokk* Tallinn+ Santo Tomas* Guangzhou* Muara+ St Petersburg* Mina Sulman* Bridgetown*+ Toamasina+ Varna+ Rijeka*+ Walvis Bay+ Port Sudan* J. Nehru* Djibouti* Oranjestad* San Antonio*

Note: 1. Bremen/BH=>Bremen / Bremerhaven; 2. J. Nehru=> Jawaharlal Nehru; 3. Las Palmas=>Las Palmas de Gran Canaria; 4. Saigon Newport => Saigon Newport: Cat Lai & Tan Cang Terminal; 5. Santo Tomas => Santo Tomas de Castilla; 6. Ports for the year of 1991 are represented by "*", those for the year of 2004 represented by"+"

Out of a total of 238 ports included in the intertemporal analysis, 12 ports are categorized as DEA efficient ports showing DEA scores equal to 1: Busan (1991); Salalah (1991); Reykjavik (1991); Xiamen (1991); Belize City (2004); Chittagong (2004); Corinto (2004); Guangzhou (2004); Hong Kong (2004); Shanghai (2004); Yantian (2004). This result is in line with a well known idea that some of the most efficiently managed ports in the world can be found among those in China that are recently emerging and physically well-structured (e.g. Shanghai and Guangzhou) and some other Asian ports that have traditionally been managed quite efficiently (e.g. Hong Kong and Busan).

The ports falling in the first quartile have DEA scores from 1.05 to 2.481. While 1 as a DEA score means the most efficient DMUs in the sample, the relatively inefficient ports have scores larger than 1 in the output-oriented DEA model developed by Zhu (2003). A port with a DEA score of 2.48, given the current input level, should increase output by 2.48 times in order to sustain the same levels of productive efficiency achieved by the DEA efficient ports that are more close to the efficient frontiers shown in Figure 4.2.

Relatively speaking, while they are less efficiently operating than the DEA efficient ports, ports in the first quartile operate more efficiently than those in the other three quartiles. Here again, some ports in this category are well known international or regional hub ports such as Singapore (1991, 2004); Port Klang (2004); La Spezia (1991); Piraeus (1991); Veracruz (1991, 2004); and Los Angeles (2004); and emerging Chinese ports such as Tianjin (2004) and Ningbo (2004). Interestingly, some newly emerging ports are also classified in this group, showing their recent conspicuous achievement in efficiency: e.g. Dubai (2004); Gioia Tauro (2004); Laem Chabang (2004); Jawaharlal Nehru (2004).

The DEA scores in the second quartile are in general larger than 2.48 but smaller than 3.75, showing medium or medium-high levels of productive efficiency. They need to increase their output by 2.5 to 3.8 times to achieve the same level of efficiency as the DEA efficient ports in the sample. The examples include many ports with relatively long histories such as Felixstowe (1991, 2004); Algeciras (1991, 2004); Piraeus (2004); Rotterdam (1991; 2004); Hamburg (2004); Antwerp (2004); Bremen / Bremerhaven (2004); Long Beach (2004); New York / New Jersey (2004); Tacoma (2004); Melbourne (2004); Vancouver (2004); Tauranga (1991, 2004); Los Angeles (1991); Dubai(1991); Tokyo (1991); Yokohama (1991); and Bangkok (1991).

The third quartile includes ports with DEA scores from 3.75 to 6.36. They operate under the medium-low levels of efficiency in comparison to other ports in the sample. In order to catch up to the best practice, they have to expand their outputs by 3.8 to 6.4 times given the current levels of resource utilization. The examples are Auckland (1991, 2004); Barcelona (1991); Yokohama (2004); Nagoya (2004); Oakland (1991, 2004); Le Havre (1991, 2004); Seattle (1991; 2004); Sydney (2004); Lisbon (2004); Fremantle (2004); Hamburg (1991); Long Beach (1991); Charleston (1991); Miami (1991); and Kobe (2004). As we can reasonably project that ports can improve their efficiency over time due to a few reasons such as technical progress and improvement in management, most of the 1991 ports are classified into less efficient groups such as third or fourth quartiles. Yet it is interesting to note that many 2004 Japanese ports also fall into these groups, showing their recent troubles in improving port efficiency.

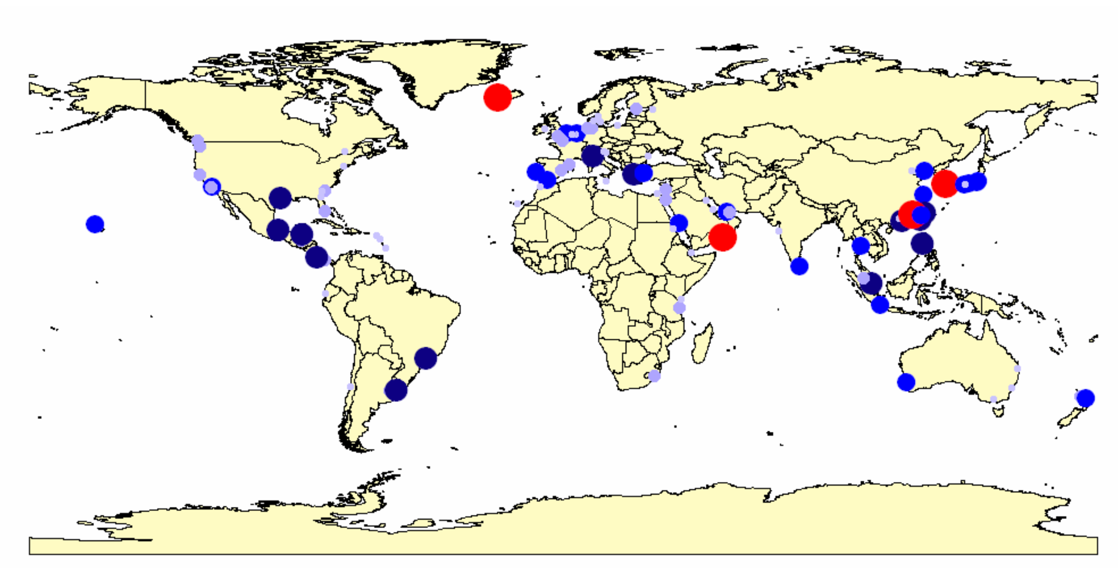
Finally, the fourth quartile has DEA scores bigger than 6.36, so they need to increase their outputs by more than 6.4 times to compete with the DEA efficient ports. The examples include many 1991 ports and smaller ports, and some of them are located remotely from the world main shipping activities and trading regions: Jacksonville (1991, 2004); Buenos Aires (2004); Oslo (2004); Zeebrugge (1991); St. Petersburg (1991); Miami (2004); and Casablanca (1991).

As is illustrated in Figure 5.6, most of the DEA efficient ports can be found in Asia and Central America in 2004, when comparing all ports in 1991 and 2004 as if all the ports in the two years existed at the same point of time: Overall, port efficiency in most continents has improved since 1991. Especially, with their highest relative efficiency in 2004, many South Asian and East Asian ports show their continuous dominance in efficiency since 1991. There was in general little difference between North American ports and European ports in 1991, but it seems that the difference in efficiency has enlarged over the last decade. Furthermore, the gap in efficiency between North American ports and Asian ports has also become larger. It is partly because many Chinese ports equipped with contemporary cargo handling and management technology and well-organized terminal layouts have emerged over time, while North American ports have shown relatively little improvement in efficiency.

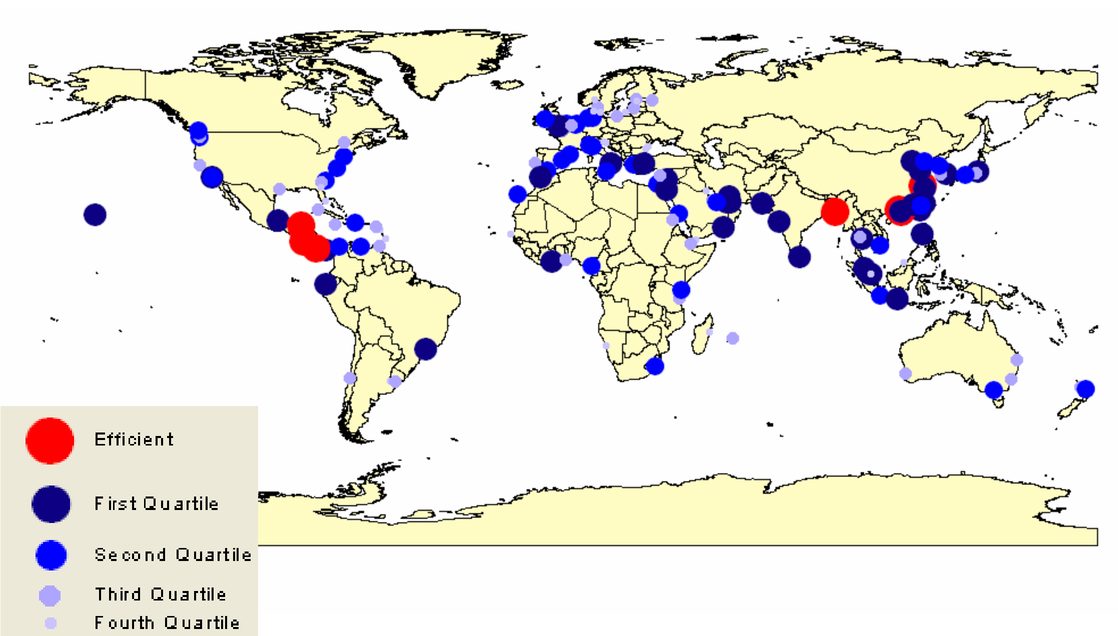
While there have been substantial levels of reform efforts in New Zealand and Australia, their levels of efficiency in relative perspective (not absolute levels of efficiency) have not improved impressively. As noted in Chapter 4, there were signs that their levels of efficiency in absolute terms have improved, which can also be confirmed by the analysis of MPI later; but the speed of the improvement may not yet outpace that of leading ports in other regions. It partly reflects the geographical disadvantages faced by the two countries located remotely from the major regional industrial clusters in the North.

Figure 5.6: DEA Efficiency in Intertemporal, Output-oriented, VRS

A. Ports in 1991



B. Ports in 2004



Legend

Table 5.6 shows movement of efficiency quartiles of each port based on the DEA relative efficiency scores. Again, we have to remember that this intertemporal analysis regards all the ports in different years as if they existed at the same point in time. Therefore, many ports in 2004 should inherently show better efficiency in relative terms if the overall efficiency in port industry has improved since 1991.

Table 5.6: DEA Efficiency Change: Intertemporal, VRS

Move from a less efficient quartile in 1991 to a more efficient quartile in 2004 (53 ports)		Stay at the same quartile of efficiency (30 ports)	Move from a more efficient quartile in 1991 to a less efficient quartile in 2004 (15 ports)
[4th to DEA=1]	[4th to 2nd, cont.]	Singapore	[DEA=1 to 1st]
Guangzhou	Marsaxlokk	Kaohsiung	Salalah
[2nd to DEA=1]	Damietta	Manila	Busan
Shanghai	Las Palmas	Keelung	Xiamen
[1st to DEA=1]	Dublin	Santos	[1st to 2nd]
Hong Kong	Santo Tomas	Veracruz	Piraeus
Puerto Limon	Mombasa	Felixstowe	La Spezia
Belize City	[3rd to 2nd]	Tanjung Priok	[1st to 3rd]
[4th to 1st]	Durban	Algeciras	Houston
Tianjin	Hamburg	Rotterdam	Montevideo
J. Nehru	Long Beach	Dalian	[2nd to 3rd]
Guayaquil	Bremen/BH	Jeddah	Lisbon
Casablanca	Charleston	Taichung	Kobe
[3rd to 1st]	Valencia	Tauranga	Nagoya
Port Klang	Barcelona	Auckland	Bangkok
Southampton	Vancouver	Puerto Cortes	Fremantle
Khor Fakkan	[4th to 3rd]	Oakland	Yokohama
Haifa	Savannah	Le Havre	[3rd to 4th]
Aqaba	Sydney	Seattle	Buenos Aires
[2nd to 1st]	Montreal	Helsinki	Miami
Dubai	Zeebrugge	Dar-es-Salaam	
Tokyo	Gothenburg	Jacksonville	
Colombo	St Petersburg	Aarhus	
Honolulu	Brisbane	Shuaiba	
Izmir	San Antonio	Pointe-a-Pitre	
Los Angeles	Gdynia	Constantza	
Melbourne	Djibouti	Koper	
[4th to 2nd]	Mina Sulman	Bridgetown	
Antwerp	Port Sudan	Rijeka	
NY/NJ	Oranjestad	Copenhagen	
Genoa			
Osaka			
Tacoma			

Among the 98 cases for which we have data for both years, 54 ports move to the upward quartiles. While it does not necessarily mean that these ports improved their port efficiency in absolute terms, it can be at least seen that they follow the efficiency increasing trends in the container port industry. Given this method of interpretation, if some ports move from a more efficient quartile to less efficient one, it can seriously signal that the ports have lost their past status of efficiency and competitiveness over the last decades.

5.3.2 Contemporaneous analysis, 1991 & 2004

The contemporaneous analysis in this section has two reference observations sets: (1) t = 1991; and (2) t = 2004. The 98 ports for which we have data for both years are included in the analysis and compared within each observations-set, thereby producing two different DEA scores for each year, respectively. Appendix 5.2 shows the DEA scores for each port for the two years.

The results of the two approaches under the CRS and the VRS assumptions are again most likely similar for most ports. The discussion of the analysis is presented based on the VRS model, allowing the possibility for smaller ports to be regarded as efficient if they are managed strategically. The framework of this analysis includes world-scale hub and national gateway ports, and their sizes are different. Little difference exists in overall rankings and the values of DEA scores of each port from the two approaches.

Yet several ports show some difference in their efficiency rankings between the two approaches: Antwerp, Rotterdam, Hamburg, Los Angeles, Long Beach, New York / New Jersey, Xiamen, Salalah, Fremantle, Montevideo, Tauranga, Djibouti, and Belize City in 1991; Bridgetown, Oranjestad, and Belize City in 2004. These ports are in general evaluated as less efficient under the CRS assumption but are classified as more efficient under the VRS assumption.

Again, these ports can possibly be presented as relatively less efficient if we do not allow that the impact of port production scale on efficiency can vary based on the VRS assumption. This is partly due to the fact that efficiency in those ports are relatively strongly influenced by port production scale by being subject to either increasing returns to scale or decreasing returns to scale. For example, the port of Hamburg in 1991 is more efficient under VRS (DEA Score = 2.70 with benchmarking to one of DEA efficient ports, Singapore) but becomes less efficient under CRS (DEA Score = 6.30 with benchmarking to one of DEA efficient ports, Busan). The port was subject to decreasing returns to scale at that point.

From the contemporaneous analysis, the impact of port size on efficiency can be reexamined, since the previous inter-temporal analysis has the limitations as discussed. Here, we use the averages of the two years, 1991 and 2004, for the two variables of port throughputs and DEA scores in order to have implications on whether there has been a serious relationship between port size and efficiency over the last decade.

According to Table 5.7, for both VRS and CRS, the correlation between DEA scores and port size shows similar strength of negative associations: -0.368 and -0.309, respectively. They are statistically significant at the 5 percent confidence level as the t-statistics are much higher than t-critical values for both one-tailed (1.661) and two-tailed tests (1.985).

Table 5.7: Correlation Analysis between DEA scores and Port Size

	TEUAVE2	AVEDEACOV	AVEDEACOC
Mean	1428638.854	4.016	5.215
Variance	4.37804E+12	6.711	14.724
Observations	98	98	98
Pearson Correlation		-0.368	-0.309
Hypothesized Mean Difference		0	0
Degree of freedom		97	97
t Stat		6.759	6.759
P(T<=t) one-tail		5.19611E-10	5.19627E-10
t Critical one-tail		1.661	1.661
P(T<=t) two-tail		1.03922E-09	1.03925E-09
t Critical two-tail		1.985	1.985

- *TEUAVE2: Averages of throughputs in 1991 and 2004 for each port;*
- *AVEDEACOV: Averages of DEA scores for the year of 1991 and 2004 from the VRS assumption*
- *AVEDEACOC: Averages of DEA scores for the year of 1991 and 2004 from the CRS assumption*

No matter whether economies of scale are considered or not, it is possible to understand that the larger the ports, the smaller the DEA scores (more efficient) over the last decade in general. This analysis result suggests that the former examination on the relationship between the port scales and DEA scores from intertemporal analysis does not reflect a spurious relationship between time and port efficiency. Therefore, again, a similar interpretation to the case of intertemporal analysis can be applied to this case: In general, most of larger ports in the container port industry have been leaders in technology development and strategies for port development and management.

Tables 5.8 and 5.9 illustrate DEA efficient ports and four other quartiles of ports in 1991 and 2004 respectively. The efficiency quartiles are also presented in combination with different classes of port production scales. Among the total of 98 ports included in the contemporaneous analysis for 1991, 9 ports are categorized as DEA efficient ports: Busan; Keelung; Hong Kong; Singapore; Veracruz; Fremantle; Xiamen; Salalah; and Belize City.

The ports in the first quartile have DEA scores ranging from 1.03 to 2.03. While they operated less efficiently than the DEA efficient ports in 1991, the ports overall operated quite efficiently comparing to the three other quartiles. For example, the port of Rotterdam had a score of 1.40, needing to increase its output by 1.40 times in order to have a same level of efficiency to one of the DEA efficient ports. The port of Los Angeles also needed to increase output by 1.84 times to compete with the DEA efficient ports. In the second quartile, port efficiency is larger than 2.03 but smaller than 3.42. The category includes ports that are world-widely located: e.g. Felixstowe in UK, Tokyo in Japan, Barcelona in Spain, Charleston in US, and Tauranga in Australia. The range of port efficiency in the third quartile is 3.42 to 5.62. They need to at least improve their output by more than 3.42 times to compete with other DEA efficient ports. Finally, the fourth quartile's DEA scores are larger than 5.62 indicating the need to increase their outputs at least more than 5.6 times by using the current amounts of input.

Table 5.8: DEA Efficiency of Ports: Contemporaneous, 1991, VRS

DEA scores Size	**Efficient ←--------------------------------1991 Ports ----------------------------→ Inefficient**				
	DEA efficient DEA=1 (N=9)	First Quartile 1<DEA<2.03 (N=16)	Second Quartile 2.03<DEA<3.41 (N=24)	Third Quartile 3.41<DEA<5.67 (N=24)	Fourth Quartile DEA>5.67 (N=25)
Class 1: Larger than 800000 TEU (N=25)	Hong Kong Singapore Busan Keelung	Manila Kaohsiung Rotterdam Los Angeles	Felixstowe Dubai Tokyo Nagoya Yokohama Long Beach Kobe Bangkok Charleston Hamburg Bremen/BH NY / NJ	Seattle Le Havre Tacoma Oakland Antwerp	
Class 2: Smaller than 800000 and Larger than 330000 TEU (N=24)		Colombo Piraeus Houston Santos La Spezia	Tanjung Priok Barcelona Shanghai Algeciras Jeddah Honolulu Haifa	Port Klang Valencia Durban Southampton Vancouver BC Melbourne Montreal	Osaka Miami Savannah Sydney Gothenburg
Class 3 Smaller than 330000 and Larger than 130000 TEU (N=23)	Xiamen	Buenos Aires Puerto Limon Lisbon Puerto Cortes	Khor Fakkan Dalian Taichung Helsinki	Auckland Las Palmas Casablanca Guayaquil Copenhagen Mombasa	Tianjin Jacksonville Zeebrugge Dublin Genoa Brisbane Aarhus Damietta
Class 4 Smaller than 130000 TEU (N=26)	Veracruz Fremantle Salalah Belize City	Izmir Montevideo Djibouti	Tauranga	Marsaxlokk St Petersburg Dar-es-Salaam Bridgetown Port Sudan Aqaba	Guangzhou Jawaharlal Nehru San Antonio Santo Tomas Shuaiba Mina Sulman Pointe-a-Pitre Koper Oranjestad Rijeka Gdynia Constantza

Table 5.9 DEA Efficiency of Ports: Contemporaneous, 2004, VRS

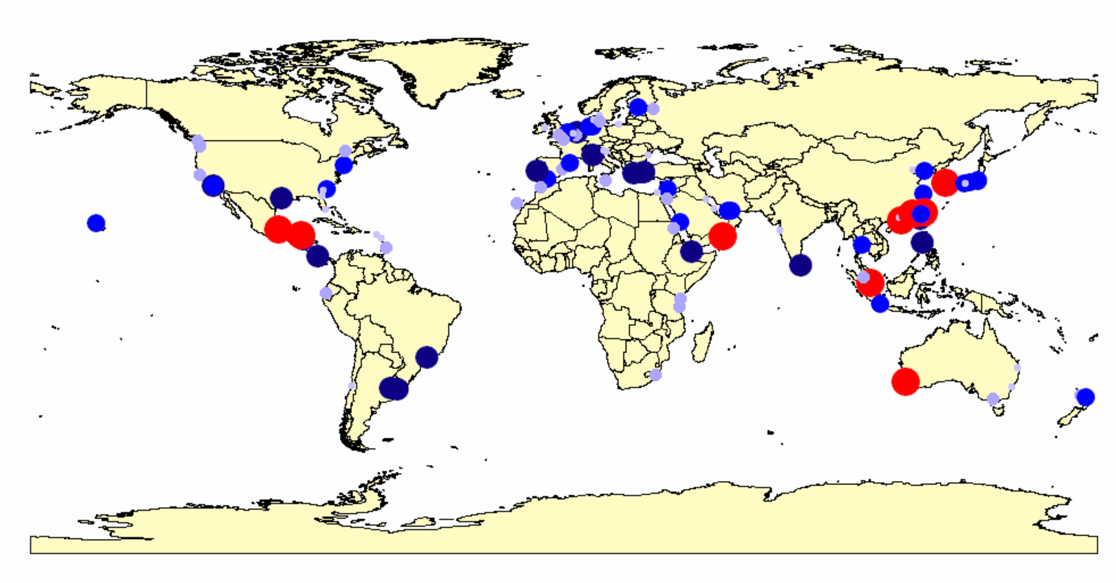
DEA scores / Size	**Efficient ←-------------------------------2004 Ports ----------------------------→ Inefficient**				
	DEA efficient 2004: DEA=1 (N=9)	First Quartile 1<DEA<2.19 (N=16)	Second Quartile 2.19<DEA<3.19 (N=24)	Third Quartile 3.19<DEA<4.36 (N=24)	Fourth Quartile DEA>4.356 (N=25)
Class 1: Larger than 2300000 TEU (N=23)	Hong Kong Guangzhou Shanghai	Singapore Busan Kaohsiung Dubai Tokyo Manila Tianjin Xiamen	Port Klang Rotterdam Los Angeles Felixstowe Tanjung Priok Algeciras	Long Beach Bremen/BH Hamburg Antwerp NY / NJ Yokohama	
Class 2: Smaller than 2300000 and Larger than 1500000 TEU (N=23)		Keelung Colombo Jawaharlal Nehru Khor Fakkan Salalah	Genoa Osaka Piraeus Santos Barcelona Vancouver BC	Jeddah Melbourne Charleston Valencia Tacoma Dalian Savannah Le Havre Seattle	Nagoya Kobe Oakland
Class 3 Smaller than 1500000 and Larger than 550000 TEU (N=24)	Haifa Puerto Limon	Southampton Veracruz Izmir	Honolulu Durban Marsaxlokk Taichung La Spezia Damietta	Houston Montreal Las Palmas Auckland	Bangkok Gothenburg Brisbane Sydney Miami Zeebrugge Jacksonville Buenos Aires St Petersburg
Class 4 Smaller than 550000 TEU (N=28)	Casablanca Belize City Bridgetown Oranjestad		Dublin Guayaquil Puerto Cortes Tauranga Aqaba Santo Tomas	Mombasa Montevideo Gdynia Djibouti Port Sudan	Helsinki Dar-es-Salaam Lisbon Aarhus San Antonio Fremantle Shuaiba Mina Sulman Pointe-a-Pitre Constantza Koper Rijeka Copenhagen

The result of analysis from the DEA scores also shows, in general, that many Asian ports operated efficiently in comparison to the ports in other continents in 1991. Some European and Central American ports could compete with the Asian ports in terms of efficiency. The regional features of port efficiency can also be confirmed by Figure 5.7. The overall relative efficiency levels in the Asian ports have continuously improved and maintained their dominance in 2004. While the number of DEA efficient ports in Asia reduces to three: Hong Kong, Guangzhou, and Shanghai, most ports in the first quartile are comprised by the East Asian and South Asian ports (10 out of 16 ports).

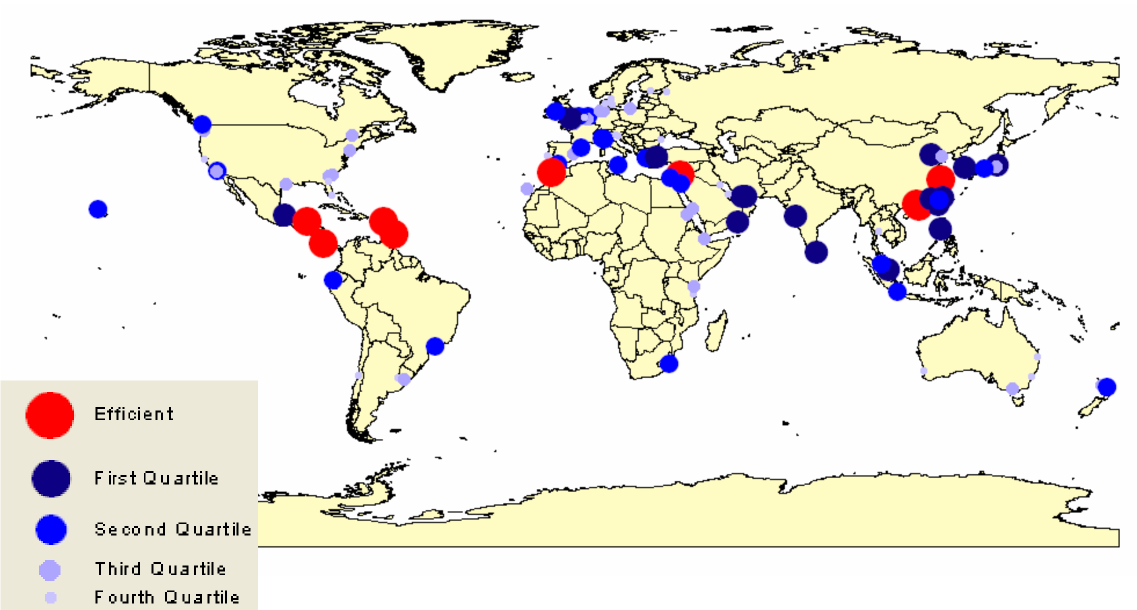
It is also impressive to observe that some Middle Eastern ports improve their relative efficiency: e.g. Dubai and Khor Fakkan. One of the DEA efficient ports located in the Middle East, the port of Salalah, has maintained its efficiency level (the first quartile) in 2004. Both European ports and African ports have shown little change in relative efficiency since 1991. While a few ports are classified within the first quartile, most of the European ports stay within the second and the third quartile. Many African and Australian ports are still categorized as either the third quartile or the fourth quartile. Finally, the relative efficiency in the North American and South American ports has become lower in 2004 than in 1991 overall, while two of the Central American ports (Oranjestad; Bridgetown) improved their productive efficiency.

Figure 5.7: DEA Efficiency in Contemporaneous, Output-oriented, VRS

A. DEA efficiency among ports in1991 (t=1991)



B. DEA efficiency among ports in 2004 (t=2004)



Legend

Table 5.10: DEA Efficiency Change: Contemporaneous, 1991-2004, VRS

Move from a less efficient quartile in 1991 to a more efficient quartile in 2004 (26 ports)		Stay at the same efficiency quartile (38 ports)	Move from a more efficient quartile in 1991 to a less efficient quartile in 2004 (34 ports)	
[4th to DEA=1]	[4th to Second]	Hong Kong	[DEA=1 to 1st]	[2nd to 3rd]
Guangzhou	Osaka	Belize City	Busan	Yokohama
Oranjestad	Dublin	Kaohsiung	Keelung	Charleston
	Genoa	Manila	Singapore	Dalian
[3rd to DEA=1]	Damietta	Colombo	Veracruz	Jeddah
Casablanca	Santo Tomas	Izmir	Xiamen	Hamburg
Bridgetown		Felixstowe	Salalah	Long Beach
	[3rd to Second]	Tanjung Priok		Bremen / BH
[2nd to DEA=1]	Port Klang	Barcelona	[DEA=1 to 4th]	NY / NJ
Shanghai	Durban	Algeciras	**Fremantle**	
Haifa	Vancouver BC	Taichung		[2nd to 4th]
	Marsaxlokk	Honolulu	[1st to 2nd]	Nagoya
[1st to DEA=1]	Guayaquil	Tauranga	Piraeus	Bangkok
Puerto Limon	Aqaba	Valencia	Santos	Kobe
		Seattle	La Spezia	Helsinki
[4th to First]	[4th to Third]	Auckland	Puerto Cortes	
Tianjin	Savannah	Le Havre	Rotterdam	[3rd to 4th]
Jawaharlal	Gdynia	Tacoma	Los Angeles	Oakland
Nehru		Melbourne		St Petersburg
		Montreal	[1st to 3rd]	Dar-es-Salaam
[3rd to First]		Las Palmas	Houston	Copenhagen
Southampton		Mombasa	Montevideo	
		Antwerp	Djibouti	
[2nd to First]		Port Sudan		
Dubai		Miami	[1st to 4th]	
Tokyo		Zeebrugge	**Buenos Aires**	
Khor Fakkan		Jacksonville	**Lisbon**	
		Sydney		
		Gothenburg		
		Brisbane		
		Aarhus		
		San Antonio		
		Shuaiba		
		Mina Sulman		
		Pointe-a-Pitre		
		Constantza		
		Koper		
		Rijeka		

According to Table 5.10, a total of 26 ports moved from the less efficient quartiles of relative efficiency in 1991 to more efficient ones in 2004. The most conspicuous examples are the ports of Guangzhou, Tianjin, Jawaharlal Nehru, and Oranjestad, which moved from the fourth quartile in 1991 to either DEA efficiency status or the first quartile in 2004.

There are also 38 ports that maintained the same efficiency level by staying in the same quartile during the period. While ports like Hong Kong and Kaohsiung maintained their high level of productive efficiency over time, others like the port of Le Havre and the port of Sydney have not caught up the leading ports, staying within either the third or fourth efficiency quartile during that time. Finally, a total of 34 ports moved from the more efficient quartiles in 1991 to less efficient ones in 2004. For instance, the port of Fremantle moved from DEA efficiency in 1991 to the fourth efficiency quartile in 2004. The port of Buenos Aires and the port of Lisbon reduced their relative efficiency from the first quartile in 1991 to the fourth quartile in 2004.

In particular, a few Japanese ports and several large US ports such as Los Angeles, Long Beach, New York / New Jersey, Oakland, and Houston have relatively decreased their levels of efficiency and been categorized into less efficient quartiles in 2004. As discussed in Chapter 4, Japan and the US are two of the regions where there has been a lack of momentum in port reform efforts. Larger portions of container terminals in the regions than South Asia and Northern Europe are directly operated under the government hands, while the exception can be the West in the US. In addition, the region is relatively strongly influenced by regional monopolistic characteristics of market structure, as will be formally presented in Chapter 7. For example, the US ports having larger scale of hinterlands (e.g. the three largest Californian ports in the sample –

LA, Long Beach, and Oakland – which handle 50% of cargoes traded into the US). In contrast, unlike the US ports, the Japanese ports have struggled to enlarge their markets. It is partly due to the sluggish Japanese economy over the last decade and the loss of their regional hub status to the Korean and the Chinese ports in the East Asian market. From these examples, it seems that the lack of vigilance in port reform efforts in those regions, playing together with other factors, may influence decreasing relative efficiency of the regions' ports.

In contrast to some Japanese ports and US ports, ports in China, UK, and UAE move to more efficient quartiles during the same period. Appendix 5.3 shows, summarized by a country level, how the quartiles of ports have changed over time. The changes in port efficiency qualitatively presented in this section are quantitatively examined in Chapter 6 through Malmquist Productivity Index (MPI).

CHAPTER 6

Malmquist Total Factor Productivity Index: Estimating Temporal Change in Port Efficiency and Sources of Efficiency Change

6.1 Objectives to Examine Port Efficiency Change

Few studies have thus far tried to quantitatively estimate changes in efficiency of world seaports during the last decades during which time substantial institutional changes have been realized in the global container port industry. Moreover, it has not been discussed thus far what the sources of efficiency gains or losses can be attributed to. This chapter attempts to systematically estimate efficiency changes of world seaports from 1991 to 2004 that have been sampled for this dissertation and used in the DEA contemporaneous analysis in the previous chapter.

Measuring changes in port efficiency and identifying sources of efficiency gains and losses is possible by using the concept of the Malmquist Total Factor Productivity Index, or Malmquist Productivity Index (MPI). In short, MPI can be estimated based on multiple applications of DEA models to benchmark port efficiency between two different time periods. The basic idea is that if efficiency change has occurred over the long period, temporal changes in efficiency can be attributed to two different sources related to port conditions, planning, and management. These are: (a) *frontier shift effects* and (b) *catch-up effects* (Nishimizu & Page 1982; Grifell & Lovell 1993; Estache et al. 2004):

On the one hand, the *frontier shift effects*, represented by the shift of the productive efficiency frontier in Figure 5.2 in Chapter 5, can occur because of such significant change as technological progress. Port efficiency gains from the frontier shift effects can come from the capacity to keep up with latest technologies that are possibly driven by institutional reforms to increase (or by increasing) market competition. To keep abreast with new technology requires quite effective long-term strategic planning and timely capital investment at a port and policy making level.

The *catch-up effect*, on the other hand, is also referred to as technical efficiency change that can be represented by a port's movement along the production frontiers, which is possible even within a relatively short period of time. The catch-up effect is so termed since the concept implies the capacity of ports to managerially follow best practices in order to operate on the frontiers at any point in time. The efficiency gains caused by the catch-up effect can be mainly attributed to managerial capacity of ports to (a) respond to port demand by flexibly adjusting production scales (changes in scale efficiency) and to (b) adjust input factors timely (changes in 'pure' technical efficiency). Not only incentive changing policies but also many other management systems and conditions could possibly promote this sort of behavioral change.

Given the discussion on the rate of changes in port capital and technologies in Chapter 5, the period this chapter is interested in measuring efficiency change is quite a long term (1991 to 2004). It is thus reasonable to consider the decomposition of efficiency change into the different major sources above stated. The global seaport sector during this period has experienced huge sums of port reform and rapid technological development. Therefore, in order to closely investigate the relationship between the institutional changes of port planning and efficiency in Chapter 7, it is meaningful to adopt MPI to separate temporal changes in productive efficiency into (a) technological progress and (b) change in technical (managerial) efficiency. The differentiation produces different policy implications as it identifies the sources of inefficiency of ports. For example, if a port does not efficiently utilize its existing assets and input factors, but tries to attribute its inefficiency to its level of technology and lack of long term capital investment, the result of these courses of actions would be creations of ineffective and unreasonable policies. In this perspective, examining the sources of inefficiency not only enriches the efficiency analysis in the previous section but also eventually helps to examine the influence of port institutions on port efficiency in the later chapters.

6.2 Formal Concept of Index

The MPI index formally measures the total factor productivity (TFP) change between the two time periods. It calculates the ratio of the distances of data in each time period relative to a common technology. If technology in period t1 is regarded as the reference technology and the base year for the comparison is period t0, the Malmquist TFP change index between period t0 and t1 is represented as the following:

$$\frac{TFP_{t1}}{TFP_{t0}} = \frac{d_{t1}(x_{t0}, y_{t0})}{d_{t1}(x_{t1}, y_{t1})}, \quad \text{--- (1)}$$

where $d_{t1}(x_a, y_a)$ represents the distance from the observation in period a to the period t1 technology. A value of the above index greater than 1 indicates a percentage improvement in TFP during the two time periods, t0 and t1.

Fare et al. (1994) refines this index suggesting the alternative practice to avoid having to choose between technologies in periods t0 and t1. The alternative concept is based on the geometric mean of two indices that are comprised by two times of benchmarking of one period in comparison to another. The first is evaluated with respect to period t1 technology and the second with respect to period t0 technology:

$$\frac{TFP_{t1}}{TFP_{t0}} = \left[\frac{d_{t1}(x_{t0}, y_{t0})}{d_{t1}(x_{t1}, y_{t1})} \frac{d_{t0}(x_{t0}, y_{t0})}{d_{t0}(x_{t1}, y_{t1})} \right]^{\frac{1}{2}}$$

$$= \frac{d_{t0}(x_{t0}, y_{t0})}{d_{t1}(x_{t1}, y_{t1})} \left[\frac{d_{t1}(x_{t1}, y_{t1})}{d_{t0}(x_{t1}, y_{t1})} \frac{d_{t1}(x_0^t, y_0^t)}{d_{t0}(x_{t0}, y_{t0})} \right]^{\frac{1}{2}} \text{--- (2)}$$

Equation (2), represented by distance functions, can be mathematically rewritten as the following; that is represented by output-oriented efficiency scores (ϕ), since the efficiency scores are the ratios of distance in the production frontiers:

$$\underbrace{\frac{\phi_{t0}(x_{t0}, y_{t0})}{\phi_{t1}(x_{t1}, y_{t1})}}_{A} \times \underbrace{\left[\frac{\phi_{t1}(x_{t1}, y_{t1})}{\phi_{t0}(x_{t1}, y_{t1})}\frac{\phi_{t1}(x_0^t, y_0^t)}{\phi_{t0}(x_{t0}, y_{t0})}\right]^{\frac{1}{2}}}_{[B]} \text{ --- (3),}$$

where $\phi_{t\alpha}(x_{t\beta}, y_{t\beta})$ represents output-oriented efficiency scores produced by the benchmarking of a DMU in the year of β in comparison to the year of α.

Here, the part of 'A' in equation (3) represents change in technical efficiency (catch-up effect) between periods t0 and t1, while 'B' measures technological change (frontier shift effects) during the same periods. It has been argued that, in order to properly measure total factor productivity using this concept, constant returns to scale (CRS) distance functions are required. The reason is the following: A change in technical efficiency, representing the catch-up effect, consists of changes in scale efficiency and changes in non-scale technical efficiency, or 'pure' technical efficiency. As the DEA under VRS does not measure the impact of production scales on efficiency, the MPI with the VRS distance functions cannot measure change in scale efficiency (Fare et al. 1994). It thus leads to the misspecification of size of shift frontier effects.

By introducing some VRS DEA models, equation (2) or (3) can be turned into a more refined index in equation (4) (e.g. Fare et al. 1994; Zhu 2003; Cooper 2004) which has also been applied in some productivity studies recently (e.g. Estache 2004).

$$\frac{d_{t0}^{V}(x_{t0},y_{t0})}{d_{t1}^{V}(x_{t1},y_{t1})}\left[\frac{d_{t1}^{V}(x_{t1},y_{t1})}{d_{0}^{V}(x_{0},y_{0})}\frac{d_{t0}^{C}(x_{t0},y_{t0})}{d_{t1}^{C}(x_{t1},y_{t1})}\right]\left[\frac{d_{t1}^{C}(x_{t0},y_{t0})}{d_{t0}^{C}(x_{t0},y_{t0})}\frac{d_{t1}^{V}(x_{t1},y_{t1})}{d_{0}^{V}(x_{1},y_{1})}\right]^{\frac{1}{2}}$$

$$= \underbrace{\frac{\phi_{t0}^{V}(x_{t0},y_{t0})}{\phi_{t1}^{V}(x_{t1},y_{t1})}}_{A'}\underbrace{\left[\frac{\phi_{t1}^{V}(x_{t1},y_{t1})}{\phi_{0}^{V}(x_{0},y_{0})}\frac{\phi_{t0}^{C}(x_{t0},y_{t0})}{\phi_{t1}^{C}(x_{t1},y_{t1})}\right]}_{[\;A''\;]}\underbrace{\left[\frac{\phi_{t1}^{C}(x_{t0},y_{t0})}{\phi_{t0}^{C}(x_{t0},y_{t0})}\frac{\phi_{t1}^{V}(x_{t1},y_{t1})}{\phi_{0}^{V}(x_{1},y_{1})}\right]^{\frac{1}{2}}}_{[\;B\;]} \text{ --- (4)}$$

Where ϕ^{V} is output-oriented efficiency scores under VRS and ϕ^{C} is output-oriented efficiency scores under CRS.

In equation (4), the change in technical efficiency, A in equation (2), is separated into the change in ‘pure’ technical efficiency (A’) and the change in scale efficiency (A”). Therefore, the index can clearly decompose total factor productivity change into three different sources: ‘pure’ technical efficiency change (A’), scale efficiency change (A”), and technological progress (B). The product between ‘pure’ technical efficiency change (A’) and scale efficiency change (A”) is called total technical efficiency change (TTEC), representing the catch-up effect. This separation is interesting especially because changes in scale efficiency of ports are often determined by the changes in external demand driven by the economic sizes and strengths of port hinterlands. Port authorities and managers may not have strong control on these, while it is possible that port planning and strategic management still can do something about this in the long run. By separating the sources of inefficiency changes, it is possible to more closely examine the influence of different factors on port efficiency in the next chapters.

6.3 Efficiency Change of World Ports, 1991-2004

Appendix 6.1 presents the changes in total factor productivity for the major world ports from 1991 and 2004. Overall, during the last decade, the world major hub and national gateway ports improve their efficiency by more than 2.4 times (Average MPI = 2.418). The efficiency improvement in the port sector can be attributed to (1) 47% increase of 'pure' technical efficiency (TEC = 1.470), (2) 78.7% increase of scale efficiency (SEC = 1.787), and (3) 28.5% increase of efficiency due to technological progress (PFC = 1.285).

These statistics could be biased due to the three outlier ports, the port of Guangzhou (10.167), the port of Jawaharlal Nehru (12.754), and the port of Salalah (40.758), which show extremely high levels of efficiency changes compared to other ports during the period. Particularly, the port of Salalah achieved its improvement of total factor productivity mostly through changes in scale efficiency.

Therefore, the above stated statistics should be recalculated excluding the outliers, shown in Table 6.1.: the other 95 ports improved their efficiency by more than 82% (Average MPI = 1.823). Their sources of efficiency changes can be attributed to (1) 33.3% increase of 'pure' technical efficiency (TEC = 1.333), (2) 26% increase of scale efficiency (SEC = 1.262), and (3) 28.6% efficiency improvement due to technological progress (PFC = 1.286). Figure 6.1 and Table 6.2 illustrate clearly the relationships between MPI and other three sources of efficiency change of ports.

Table 6.1: Descriptive Statistics: Sources of Efficiency Change

	MPI	TEC	SEC	PFC
N	95	95	95	95
Mean	1.823	1.333	1.262	1.286
Median	1.626	1.017	1.114	1.238
Std. Deviation	1.006	1.119	.550	.217
Skewness	1.200	3.418	3.404	.401
Kurtosis	1.541	17.572	18.198	-.543
Minimum	.225	.13	.25	.919
Maximum	5.241	8.48	4.79	1.818
Sum	173.231	126.65	119.88	122.209

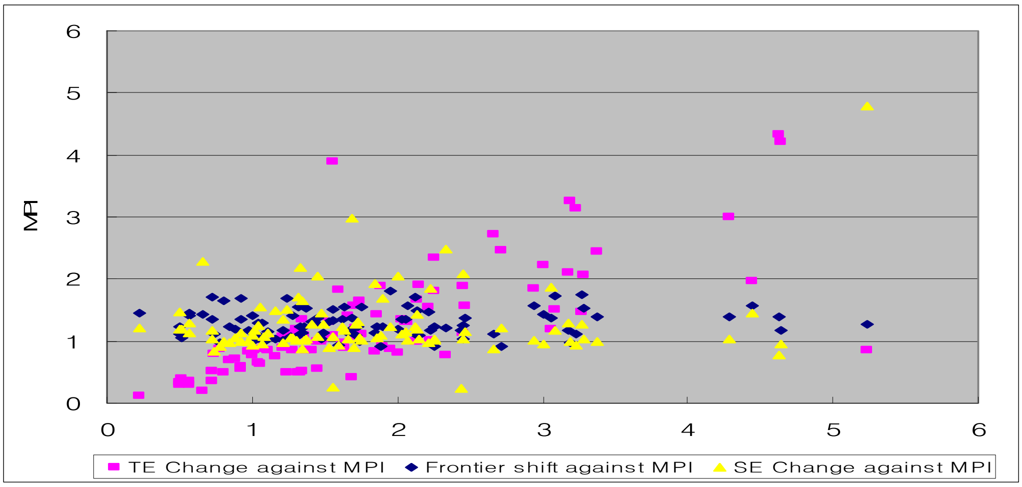
- *MPI: Malmquist Total Factor Productivity Index; TEC: 'Pure' Technical Efficiency Change; SEC: Scale Efficiency Change; PFC: Technological Change (Productivity Frontiers Shift)*

Table 6.2: Correlations of MPI and Sources of Efficiency Change

		MPI	TEC	SEC	PFC
MPI	Pearson Correlation	1	.588(*)	.193(*)	.090(*)
	t-statistics (2-tailed)		(4.928)	(5.216)	(5.184)
TEC	Pearson Correlation	.588(*)	1	-.388	-.145
	t-statistics (2-tailed)	(4.928)		(-.488)	(0.389)
SEC	Pearson Correlation	.193(*)	-.388	1	.005
	t-statistics (2-tailed)	(5.216)	(-.488)		(-.406)
PFC	Pearson Correlation	.090(*)	-.145	.005	1
	t-statistics (2-tailed)	(5.184)	(0.389)	(-.406)	

* *Correlation is significant at the 5% level (2-tailed).*

Figure 6.1: Correlations between MPI and Sources of Efficiency Change



Appendix 6.1 also shows that the majority of ports in the world improve their average total factor productivities (83 ports) from 1991 to 2004, while 15 ports have decreased their efficiency over the same period: Miami, Nagoya, Helsinki, Oakland, Keelung, Bangkok, Manila, Busan, Copenhagen, La Spezia, Fremantle, Houston, Lisbon, Piraeus, Kobe, Rijeka, and Buenos Aires. The problems of some ports above have been well known and reported. For example, it is known that the port of Busan has recently experienced severe congestion problems in their container terminals. The port now hopes to resolve this problem by opening newly developed privatized terminals, and restructuring of port governing structures in the country with a scheme of corporatization. The port of Bangkok's deterioration in efficiency could be caused by the port of Laem Chabang, located next to the port of Bangkok. As most volumes of container cargoes have been moving to the port of Laem Chabang, the old port, the port of Bangkok, is intended to focus more on general or bulk cargoes due to its traditional layouts of piers and berths. The port of Houston is the one of the largest oil ports in the world and its focus has been more and more oriented to handling liquid bulks, thereby it may reduce its efficiency in container handling. There are also some other Japanese, US, and Southern European ports which have experienced troubles in improving productivity. Finally, it seems that the port of Manila in the Philippines has not caught up to the higher levels of inter-port competition in the South Asian region.

In order to statistically examine the relative size of influence by the sources of efficiency on total factor productivity, an OLS regression is conducted with the three sources of efficiency changes as explanatory variables against MPI as a dependent variable. Again, three outliers in terms of MPI are excluded for the OLS regression. All variables are natural log-transformed to linearize the model MPI (MPI = TEC X SEC X PFC). The descriptive statistics for the transformed variables are presented in Table 6.3. Therefore, the result of OLS, Table 6.4, is an identity of equation (4), as it represents MPI through the linearized OLS.[1] According to the standardized coefficients of the OLS result, one unit change in the variance of pure technical efficiency have the strongest impact on the changes in total factor productivity.

Table 6.3: Descriptive Statistics of Transformed Variables

	LNMPI	LNTEC	LNSEC	LNPFC
Mean	.452	.050	.164	.238
Median	.486	.017	.108	.214
Std. Deviation	.568	.684	.371	.168
Skewness	-.419	-.026	-.423	.082
Kurtosis	.631	.958	7.012	-.709
Std. Error of Kurtosis	.490	.490	.490	.490
Minimum	-1.49	-2.06	-1.40	-.08
Maximum	1.66	2.14	1.57	.60

Table 6.4: Summary of OLS Results: Identity of Equation (4)

Independent Variables	Unstandardized Coefficients (B)	Standardized Coefficients (β)
Constant (t-statistics)	0.00002 (.139)	
LNTEC (t-statistics)	0.9998* (9422.1)	1.204
LNSEC (t-statistics)	0.9997* (5232.9)	0.653
LNPFC (t-statistics)	1.0000* (2698.2)	0.295

* *Significant at the 1% level*

[1] Table 6.2 and Table 6.4 show that the changes in total factor productivity (MPI) are explained in a statistically meaningful way by all three sources of efficiency changes decomposed by MPI. In table 6.4, since the result of OLS is the identity of equation (4), the *Adjusted R-Square* is 0.999.

Firstly, efficiency gains from non-scale technical efficiency have the stronger impacts on the improvement of overall productivity of ports (*Pearson's r* = 0.588, see Table 6.2; $\beta = 1.204$, see Table 6.4). In addition, the standardized coefficient (β), 1.204 shows that one-unit change in the variance of 'pure' technical efficiency can lead to 1.2-unit change in the variance of total factor productivity. The stronger impact of non-scale technical efficiency rather than scale efficiency or technological progress implies that over the last decade, the improvement of port efficiency has been achieved by focusing more on increasing "pure" technical efficiency. In other words, what this analysis implies is that hinterland conditions is neither the strongest nor the single source of change in port inefficiency.

Non-scale technical efficiency can increase mainly by the courses of actions that improve the ability and flexibility to rationalize factor inputs in order to maximize port outputs. These can often be driven by adoptions of port reform efforts and better managerial practices to catch up other best practices. This result is at odds with a preconception that port efficiency is most likely shaped by the external demand for port services from hinterlands and thereby there is not much role for port authorities to play in terms of port management. While port throughputs may possibly be strongly influenced by external demand, improvement of port efficiency certainly requires larger roles of port long-term planning, institutional reorganization, strategic management, and effective market regulation to create institutional structures and incentives to introduce better port efficiency.

Secondly, efficiency gains from the adjustment of port production scales also have substantial impacts on the improvement of overall productivity of ports, while the impacts are smaller than pure technical efficiency *(Pearson's r* = 0.193, see Table 6.2; $\beta = 0.653$, see Table 6.4). The scale of port production and scale efficiency are strongly influenced by exogenous factors such as demand from hinterlands (Estache et al. 2004). Since they meet the necessary preconditions by which ports can possibly increase their outputs vis-à-vis the given inputs, large and strong hinterland economies are certainly one of the advantages for a port in achieving increased efficiency over the last years. The ports located remotely from the global production networks and shipping routes thus have obviously strong disadvantages in increasing their port efficiency. However, as discussed previously, many larger scale ports operate at the size of decreasing returns to scale, which implies that the larger ports do not always reap the benefits of strong hinterland economies by properly sizing their production scales to improve their productivity levels.

Certainly here, the normative roles of ports need to be considered in the sense that ports in many parts of the world still aim to increase their total output levels rather than their efficiency. If they have been traditionally regarded as output maximizers as a way of sustaining regional trades rather than being efficiency maximizers, they have usually been allowed to enjoy the status of regional monopolists or national oligopolists. The business loss made by port authorities or the capital for long-term investment in port infrastructure has been compensated by tax revenues, since under this perspective, it is theoretically reasonable to use public resources based on the amount that a port generates economic externalities for the regions.

However, from a policy making point of view, it is not clear whether allowing the regional monopoly of a port is always an effective choice to achieve multiple but conflicting objectives: sustaining regional trade and effectively utilizing public resources. More often than not, the real issue is not a choice of what values policy makers select, but whether they can come up with appropriate amounts of the public resources to be spent to compensate and support the role of ports under regional monopoly. While their production costs may possibly be clearly estimated, the scopes of the benefits are much vaguer and geographically more disperse, and the social costs of allowing regional monopoly are clearly shown from their lack of interest in increasing productivity and changing the bureaucratic behaviors and organizational inertia.

In the past, the choice between the two conflicting values could be made by policy makers in the national or the upper-level governments that guide port authorities to follow the overall guidelines for managing and operating ports and terminals. However, given the increasingly fiercer competition in the contemporary global port sector, ports are asked to be equipped with the strong capacity to respond to the external demand as quickly and flexibly as possible in order not to lose their own competitive edge. Given the current market conditions, achieving the two conflicting objectives simultaneously becomes one of many necessary conditions for ports to sustain their competitive edge in many parts of the world. From the perspective of policy makers, as analyzed in Chapter 5, by bring in inter-port competition and separating a port operated under DRS into same total scales of multiple ports in a region operated under IRS or CRS may allow the region to achieve higher port efficiency at an aggregate level. From the perspective of a port manager, the strong abilities to analyze the medium-term market demand, monitor the current resources and assets, and match them to find the future gaps are certainly parts of the areas in strategic planning that port managers and authorities can work on in order to improve the medium-term scale efficiency.

Finally, with the strong influence of total technical efficiency (TEC plus SEC) on total factor productivity change (MPI), technological progress (PFC) also shows a statistically meaningful impact on changes in total factor productivity (MPI). Yet its size of impact on total factor productivity by changing one unit of variance in PFC amounts to approximately 45% of scale efficiency ($\beta = 0.295$, see Table 6.4). Over the last few decades, the global port sector has experienced an amazingly rapid development in their container handling, managerial, and security technologies. For example, the port of Rotterdam maintains (non-human) automated driving container cranes that pick up containers from the yards to distribute them directly to rail-cars or trucks. And the recently developed diverse container scanning and monitoring technologies are sometimes argued to be something that could allow ports to improve not only productive efficiency but also cost efficiency eventually in the future. Certainly, ports like Singapore and Hong Kong have been one of conspicuous examples that have made strategic and aggressive capital investment in the most cutting-edge technology.

And, more recently, the moves by the European ports such as the port of Rotterdam and the port of Antwerp have been impressive.

However, in terms of technology, many large-scale leading ports can speedily assimilate with each other by a relatively easier way of changing, or at least maintaining, the status quo, i.e. heavy capital investment in the new technology. The fact that the *frontier shift effects* among ports have a substantially smaller variance (see Figure 6.8 and Table 6.1) than other sources of efficiency change would certainly imply the limitation of the dependence on this strategy. Obviously, the change of technology through strong capital investment may be much easier than changes of behaviors, institutions, or hinterland market conditions. However, an easier way of making changes has inherently low entry barriers so that others can copy the strategies and set up the environments more easily. In this sense, making technical progress does not necessarily become a substantially effective strategy but a minimum necessity when ports attempt to achieve port efficiency, competing with others for advantages in the global market.

This analysis shows that, while it is still one of the important factors in shaping port efficiency, the external environment does not always either a determining or predominant source that causes port inefficiency. This holds especially true if geographical conditions are similar so that the ports share fairly similar sizes of hinterlands and strengths of economies. Ports that have innovative management with emerging technology obviously have stronger potential to operate more efficiently in the long term. If the level of inter-port competition is fierce enough among the ports that share same hinterlands (e.g. Northern Europe), it is more probable that efficient management and technical progress play substantially stronger roles in improving efficiency of ports. Thereby it gives the ports the higher competitive edge in the current global seaport sector.

The port of Dubai has been one of the examples of this for the last several years. As pointed out in the Chapter 3, Dubai has not only tried to formulate its strategy toward new port technologies, but also created new sections of markets by innovating their institutions and increasing the strategic capacity to prepare for and respond to the future demand. As it seems that its efforts for innovation have gone through its beginning stage there should much to be tested and researched in the future. Despite this uncertainty it may be still unfortunate for the US port sector that the government rejected the deal of purchasing the former P&O terminals by the port of Dubai. This is so because the decision is not driven by economic advantages or disadvantages but mostly by the political dimensions of the deal, which may eventually prevent some US ports from overcoming their inefficiency.

6.4. Types of Efficiency Change of World Ports

Let us turn to the discussion of what patterns of efficiency improvement have been realized during the temporal scope of this study and how ports are categorized into the typology.

The analysis is predicated firstly on a statistical classification technique of Hierarchical Cluster Analysis. The Squared Euclidean Distance Functions are used as an estimation method for intervals between data points: technical efficiency change, scale efficiency change, and technological progress of 95 ports. Based on the distributional structure of these data for each port, the technique suggests the similarities and the difference of ports, thereby suggesting ranges of classification alternatives.

In the next stage, more qualitative examinations are done though vector data mappings based on Geographic Information Systems (GIS) software, ArcView3.2, in order to more closely examine the similarities and differences of the ports in the clusters and to investigate the geographical distributions of efficiency improvement and the clusters.

These two stages of quantitative and qualitative examination allow us to evaluate the fitness of ports categorized into the clusters and to partly adjust the original clusters to identify the typology in Table 6.5.

Table 6.5: Patterns of Efficiency Change of World Ports

Type	Index	Average*	Membership
Type I N=3	MPI Pure TEC SEC TPC	3.63 1.85 1.34 1.49	Dubai, San Antonio, Port Sudan
Type II N=11	MPI Pure TEC SEC TPC	2.80 1.83 1.05 1.47	Port Kelang, Melbourne, Marsaxlokk, Khor Fakkan, Sydney, Montreal, Haifa, Damietta, Brisbane, Guayaquil, Mombassa
Type III N=13* N=15	MPI Pure TEC SEC TPC	2.43 2.17 1.03 1.11	Shanghai, Tianjin, Genoa, Osaka, Southampton, Savannah, Honolulu, Las Palmas de Gran Canaria, Dublin, Aqaba, Santo Tomas de Castilla, Shuaiba, Koper, (Jawaharlal Nehru, Guangzhou)
Type IV N=8	MPI TEC SEC TPC	2.51 1.06 1.99 1.23	Kaohsiung, Antwerp, Tacoma, Xiamen, Puerto Limon, Tauranga, Dar-es-Salaam, Belize City
Type V N=5	MPI Pure TEC SEC TPC	1.69 1.04 1.10 1.51	Hong Kong, Singapore, Tokyo, Algeciras, Auckland
Type VI N=18* N=19	MPI Pure TEC SEC TPC	1.44 0.71 1.72 1.24	Rotterdam, Los Angeles, Hamburg, Long Beach, New York/New Jersey, Bremen/Bremerhaven, Felixstowe, Yokohama, Le Havre, Seattle, Dalian, Taichung, Veracruz, Puerto Cortes, Montevideo, Djibouti, Pointe-a-Pitre, Constantza, (Port of Salalah)
Type VII N=7	MPI Pure TEC SEC TPC	2.12 3.25 0.70 1.24	Valencia, Durban, Vancouver, Zeebrugge, Casablanca, Bridgetown, Oranjestad
Type VIII N=4	MPI Pure TEC SEC TPC	1.74 1.73 1.07 0.95	Gothenburg, Gdynia, Mina Sulman, Aarhus
Type IX N=9	MPI Pure TEC SEC TPC	1.33 0.89 1.07 1.39	Tanjung Priok, Colombo, Charleston, Barcelona, Jeddah, Santos, Jacksonville, Izmir, St. Petersburg
Type X N=17	MPI Pure TEC SEC TPC	0.70 0.50 1.17 1.33	Busan, Kobe, Nagoya, Keelung, Oakland, Piraeus, Bangkok, Houston, La Spezia, Miami, Buenos Aires, Helsinki, Lisbon, Fremantle, Rijeka, Copenhagen, Manila
Total *N =95** *N= 98*	*MPI* *Pure TEC* *SEC* *TPC*	*1.82* *1.33* *1.26* *1.29*	

* The values are calculated excluding outliers.

Type I: Achieve Efficiency Improvement from All Three Sources

3 out of 98 ports in the sample are classified into this category. They show the patterns of productivity improvement from the all sources of efficiency decomposed by MPI. Their total factor productivity has increased by more than three times (average MPI =3.63) during the last decade, which is produced by interaction effects between technical efficiency, scale efficiency, and technological progress. Table 6.5 shows that Dubai, San Antonio and Port Sudan are included in this type.

Type II: Achieve Efficiency Improvement from both 'Pure' TE and EFC

This type includes 11 ports that improved their overall total productivity (average MPI=2.80) mainly from non-scale technical efficiency and technological progress. The change in scale efficiency is relatively minimal ranging from a 5% decrease to a 17% increase. The average of MPI in this type is secondly ranked among the groups. It is interesting to find three Australian ports here: Melbourne, Sydney, and Brisbane as it shows that the Australian ports seeking port reform policy have been able to increase their total factor productivity mainly from technical efficiency improvement and technological progress, while they do not have had much change in scale efficiency.

Given the limitation of size of hinterland economies it may be reasonable for them not to flexibly change their scale efficiency. As shown in the previous analysis, due to a similar reason, the Australian ports have not yet achieved the same levels of relative efficiency with the best practice in the world. Yet it is here shown that their institutional reform efforts may result in some level of improvement in technical efficiency and technological progress. Port Kelang in Malaysia also has reaped productivity benefits from these two sources. It is possibly so by the fact that they have sought substantial levels of port reform efforts over the past years, while the flexibility and improvement from scale efficiency could be limited given the severe competition with the port of Singapore and the highly competitive South Asian market.

Type III: Achieve Efficiency Improvement mainly from 'Pure' TEC

This type shows the patterns in which the major source of productivity improvement (average MPI = 2.52) should be attributed to changes in technical efficiency, while their scale efficiency changes and technological progress was relatively minimal, totaling from negative 10% to positive 20%, respectively. For example, some Chinese ports like Shanghai and Tianjin and the port of Genoa improved their non-scale technical efficiency by more than 2.5 times over the last decade. Other ports like Southampton also show the typical patterns of efficiency change in this group. Although the port of Honolulu shows patterns of efficiency change similar to ports in this group, the amount of change is substantially smaller than other ports in this group. The port of Jawaharlal Nehru and the port of Guangzhou, two of the outliers included in the analysis, achieve their improvement of efficiency from technical efficiency changes while other sources also show low rates of increase. They are thus classified in this group.

Type IV: Achieve Efficiency Improvement mainly from SEC

This class improves its total productivity (average MPI =2.51) by mainly increasing scale efficiency or a combination of scale efficiency and technological progress, while their ‘pure’ technical efficiency change only ranges from 0.9 to 1.2 approximately. The ports of Tacoma, Xiamen, Puerto Limon, and Belize City show the improvement of both scale efficiency and technological progress, while the ports of Antwerp and Tauranga show an emphasis on the improvement in scale efficiency. In increasing scale efficiency, ports that operated with increasing returns to scale (e.g. smaller ports) in 1991 may be successfully able to move from around point A to B in Figure 5.4 in Chapter 5 by increasing their production scale in 2004, given their small changes in input levels. In contrast, larger ports that operated with decreasing returns to scale in 1991 have been able to move from C to B in Figure 5.4.

Type V. Achieve Efficiency Improvement mainly from EFC

The ports in this group improve their total productivity (average MPI =1.69) mainly from technological progress, while other sources of efficiency do not change much. The ports of Hong Kong, Singapore, Tokyo, Algeciras, and Auckland are included in this category. The traditional large-scale leading ports like Hong Kong and Singapore are included in this category since their levels of efficiency have been continuously the highest in the world. While the port of Auckland may be included in this category since the flexibility to improve scale efficiency is limited due to its relatively small hinterland; and its port reforms were implemented in 1987, which was earlier than the scope of data point in this study (1991). The port of Tokyo may experience similar patterns of efficiency change. Their economic sanguinity in the hinterland has not grown impressively until recently, which leads to a lack of flexibility of changing scale efficiency and mostly makes the port depend on technological progress. The port of Algeciras in Spain also shows similar patterns to Tokyo while its overall MPI is higher.

<u>Type VI. Compensate Deterioration in 'Pure' TEC by SEC</u>

This category shows overall deterioration of non-scale efficiency while scale efficiency increased more than the rate of deterioration of non-scale efficiency. Relatively, this type includes many regional leading ports; 18 are included in this category such as the Ports of Rotterdam, Hamburg, Los Angeles, Long Beach, New York/New Jersey, Bremen/Bremerhaven, Felixstowe, Le Havre, Seattle, and Yokohama. In addition, while some ports simultaneously achieve some levels of technological progress ranging from 2% to 60%, the main feature of this category is the fact that they experienced deteriorations of their pure technical efficiency, TEC, ranging from 0.4 to 0.9. Thereby, the improvement of their scale efficiency (SEC: 1.2-2.5) is almost compensated, ending up with a generation of low medium levels of positive MPI, the improvement of total factor productivity, of less than 2. The exceptions to this are Hamburg and New York / New Jersey, which show higher levels of scale efficiency changes than others, thereby having a slightly higher MPI than 2. The port of Salalah, one of three outliers excluded in the analysis, is also categorized into this group. While it shows huge amounts of improvement in scale efficiency, its level of technical efficiency decreased overall. Therefore, even if its total MPI is ranked 1 among 98 ports, its efficiency gains mainly come from scale efficiency.

Type VII. Compensate Deterioration in SEC by 'Pure' TEC

This type has various levels of deterioration in scale efficiency while non-scale efficiency increased by more than the rates of deterioration in scale efficiency. As Table 6.5 presents, 7 ports are included in this category. While ports like Casablanca and Oranjestad also achieved some levels of technological progress ranging from 40 to 50%, this category is mostly characterized by the fact that they experienced deteriorations of their scale efficiency, which is mainly compensated by improvement in 'pure' technical efficiency. Thereby, the values of MPI end up ranging from 1.3 to 2.4. The only exception of this range of MPI is found from the port of Casablanca, showing MPI more than 4. Yet it has also experienced the deterioration of scale efficiency similarly to others in the group.

VIII. Compensate Deterioration of EFC by TEC/SEC

This group is characterized by the pattern that some levels of deterioration in technological progress are compensated by relatively smaller improvements of total technical efficiency, including both 'pure' technical efficiency and scale efficiency. This group includes 4 ports that have experienced small changes in the overall levels of all sources of efficiency. The 3 ports in Europe, Gothenburg, Gdynia, and Aarhus, show changes in total factor productivity of less than 1.9. The port of Mina Sulman in the Middle East only achieves an MPI higher than 2.0 due to relatively higher change in 'pure' technical efficiency (2.35) than other European ports in this group.

IX. Compensate Deterioration of TEC/SEC by EFC

The ports in this group mostly experienced low levels of deterioration in either technical efficiency or scale efficiency that are also compensated by relatively small improvements in total technological progress. So, the group consists of ports that have not experienced any severe changes in many ways: e.g. Charleston, Jacksonville, Tanjung Priok, Colombo, and Jeddah.

X. Not Able to Compensate Deterioration of TEC/SEC by EFC

The most conspicuous characteristic of the ports in this group is that they have had a large amount of deterioration of 'pure' technical efficiency, but have not compensated for the deterioration by technological progress. As briefly discussed previously, the port of Busan was one of the most efficient ports in 1991. Yet it was reported in the last few years as having severe congestion problems with their container berths. It now hopes to resolve this issue with newly opened privatized terminals and restructuring of ports with a new scheme of corporatization. The port of Bangkok's deterioration of efficiency can be attributed to the newly opened the port of Laem Chabang that is located right next to it. As the new port focuses more on containerized cargoes, the port of Bangkok works more on general or bulk cargoes with a traditional layout of piers and berths. Some other Japanese, US, and Southern European ports are also included in this group. Finally, the port of Manila shows deterioration in all of the three sources, not catching up the higher levels of inter-port competition in the South Asian market.

Finally, while the specific port by port characteristics are discussed above, the broader regional trends can be generalized to some degree. As is shown in Figure 6.2 and Table 6.6, the overall increase in total factor productivity is conspicuous in East Asia, the Middle East, Oceania, Central America, and some North African ports that are located closed to East Mediterranean and Red Sea. The major portions of ports in the Middle East and Central America show impressive improvement of 'pure' technical efficiency.

Table 6.6: Regional Patterns of Efficiency Change of World Ports

Region	N	MPI Mean (Stdev.)	TEC Mean (Stdev.)	SEC Mean (Stdev.)	EFC Mean (Stdev.)
Oceania	6	2.019 (0.812)	1.192 (0.560)	1.458 (0.569)	1.348 (0.174)
South Asia	6	1.312 (0.553)	0.924 (0.341)	1.011 (0.093)	1.407 (0.245)
East Asia	14	1.920 (1.474)	1.278 (1.094)	1.383 (1.000)	1.246 (0.209)
Middle East	7	2.630 (1.026)	1.985 (0.682)	1.108 (0.116)	1.206 (0.285)
Southern Europe	10	1.532 (0.910)	1.152 (0.785)	1.067 (0.146)	1.353 (0.215)
Northern Europe	13	1.621 (0.522)	1.080 (0.475)	1.356 (0.417)	1.198 (0.132)
East Europe	5	1.384 (0.586)	0.939 (0.623)	1.307 (0.275)	1.294 (0.373)
North America	14	1.467 (0.519)	0.982 (0.350)	1.270 (0.439)	1.233 (0.154)
Central America	8	2.000 (0.840)	2.460 (2.750)	1.140 (0.607)	1.354 (0.267)
South America	5	2.002 (1.702)	1.124 (0.924)	1.377 (0.486)	1.362 (0.172)
North Africa	4	3.240 (1.207)	2.162 (1.663)	1.504 (1.008)	1.475 (0.180)
South Africa	3	1.705 (0.282)	1.405 (0.402)	1.105 (0.165)	1.140 (0.207)
Total	95	1.823 (1.006)	1.333 (1.119)	1.262 (0.550)	1.286 (0.217)

In Asia, the change in scale efficiency plays little role in the Asian ports except the port of Xiamen. For technical efficiency change and technological progress show mixed impact on total factor productivity port by port, showing relatively large standard deviations. While ports in Malaysia, India, and China show relatively high rate of increase in technical efficiency, others do not follow the best practice in the region. It is also possible to observe that technological progress in South Asia is relatively stronger than other regions. It is mainly because ports in Singapore, Hong Kong, and Malaysia closely followed or led the practices in other continents through aggressive capital investment. In most South Asian countries, there has been little improvement in their regional economies, compared to those of North America or Europe. Even in the late 1990s some countries in the region experienced severe financial crises leading to the crumbling of the regional economies. Furthermore, they have a smaller size of regional economies compared to North America or Europe while the level of inter-port competition can be much higher due to the number of ports within the regions. In this context, it is therefore difficult for them to achieve an increase of total factor productivity by mainly depending on scale efficiency improvement. Given the context, the ports should compete with each other to increase technical efficiency to survive under the high levels of inter-port competition in the region.

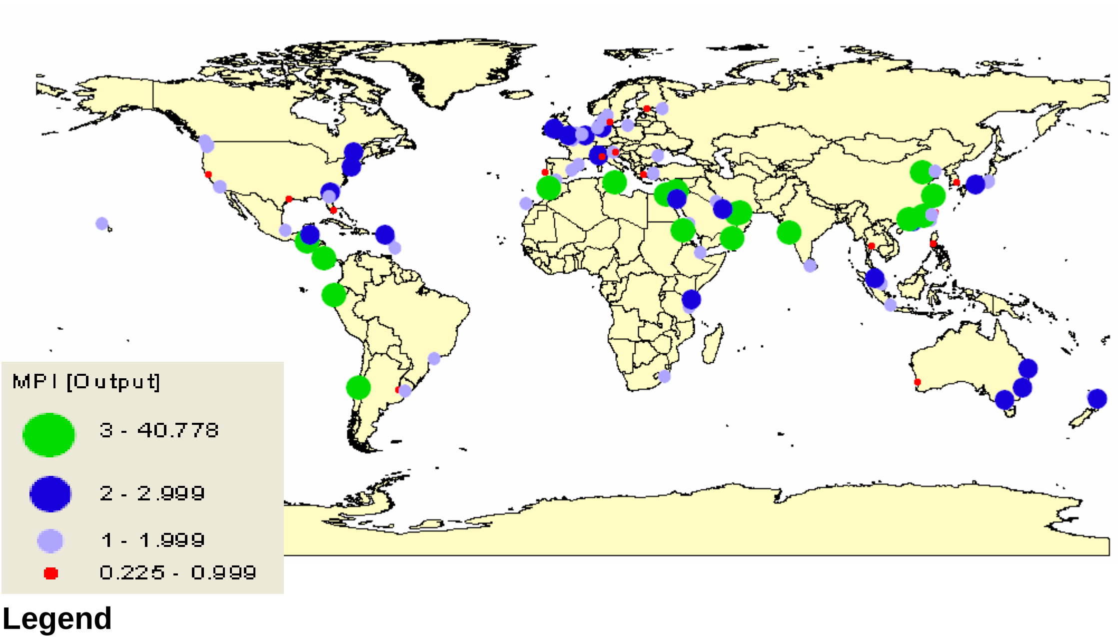
In Europe, a combination of technological progress and scale efficiency change has mainly generated total factor productivity although some ports in the UK and the Northern Europe have improved their ‘pure’ technical efficiency. The size and strength of the European economies are much larger and stronger than the South Asian region. It is still possible for the European ports to enjoy flexibility and room to choose their production scales over the long term. In the mean time, many North European ports face severe inter-port competition. Their efforts should also be directed to increasing technical efficiency and aggressive capital investment for technological progress, while the index shows mixed results of their policies.

In North America, non-scale technical efficiency change has a minimal role as a source of efficiency changes. While the efficient frontier shift effect also sustains the changes in efficiency in the region, the improvement in scale efficiency has the largest source of efficiency. Given the circumstance that the region's ports enjoy a larger size of hinterland areas and accessibility and stronger economies, it is reasonable that their efficiency improvement mostly depends on these two sources. Unlike the ports in North America, many ports in the Central America region enjoy the interacted effects among technical efficiency, technological progress, and scale efficiency by the order of influence on total factor productivity.

In Oceania and the Middle East, the total factor productivity changes are based on the improvement of 'pure' technical efficiency and technological progress. The statistics on Oceania in Table 6.6 are distorted due to the port of Fremantle in Australia that show significant decrease in technical efficiency which is partly compensated by scale efficiency change. Most of ports in the region depend mostly on the two sources. These regional characteristics of efficiency change, as previously discussed in detail, can be reflected by not only the economic limitations and geographical conditions but also the strategies and institutional reform efforts that ports adopted in their port policy and the ways of innovation in port technology and management.

Figure 6.2: Malmquist Productivity Index (1991-2004)

A. Total Factor Productivity Change 1991-2004



B. Non-scale Technical Efficiency Change 1991-2004

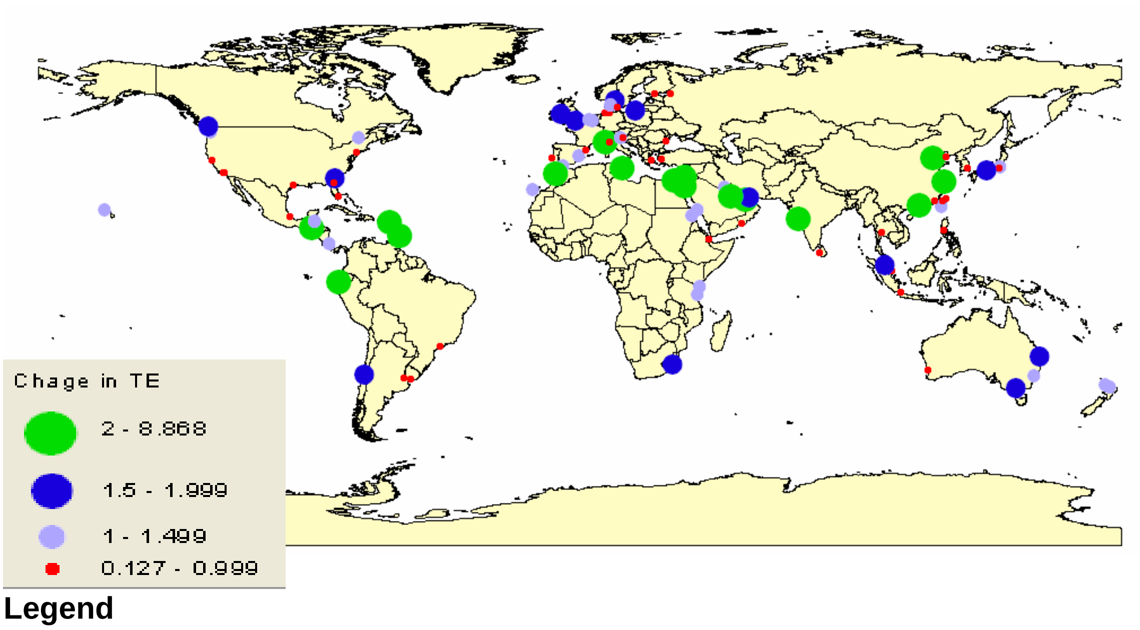
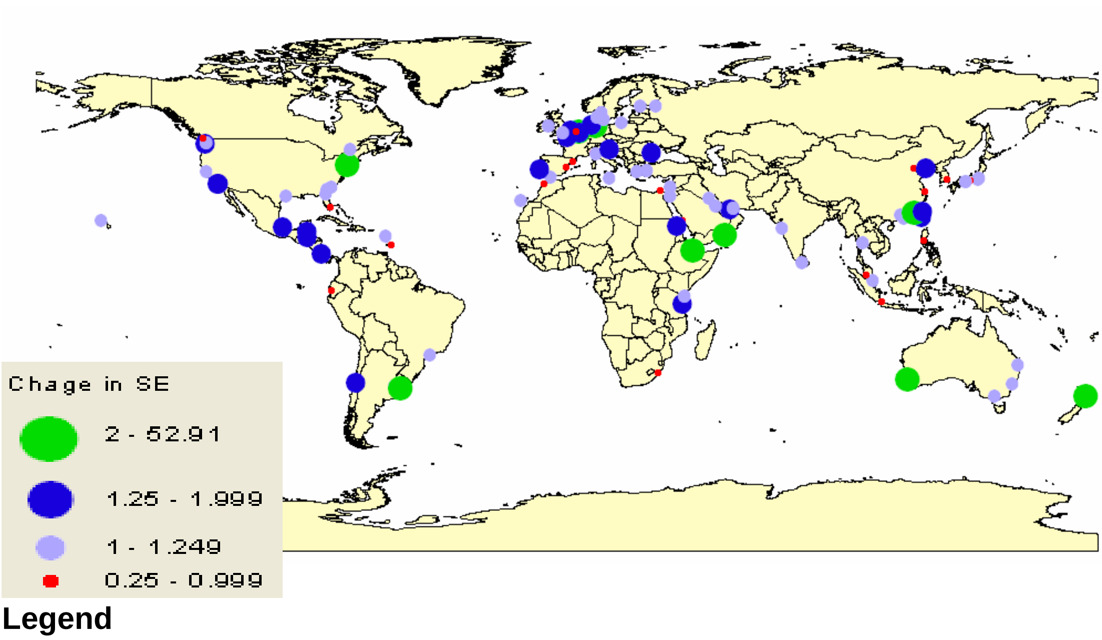
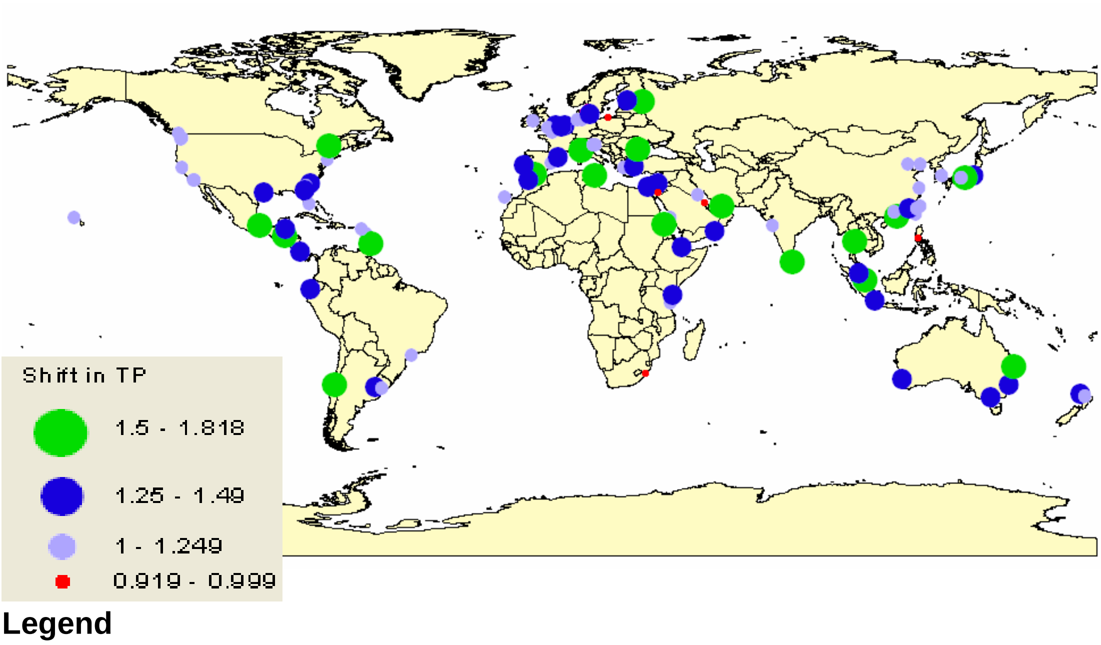


Figure 6.2. Malmquist Productivity Index (Continued)

C. Scale Efficiency Change 1991-2004



D. Efficient Frontier Shift: Technological Progress, 1991-2004



6.5 Findings and Conclusions

Chapter 5 and 6 conduct extensive analyses on productive efficiency of world ports and benchmarks them cross-sectionally, regionally, and temporally. In addition, these chapters also decomposes the sources of efficiency changes over the last decade to investigate whether port strategies and institutional reforms can be seen as potentials to increase port efficiency vis-à-vis the larger environments that ports cannot control easily. Finally, it has also observed how different patterns of efficiency changes can be typified and how these are influenced by not just regional hinterland conditions, but also policies and strategies that many ports have sought to sustain within the paradigm of contemporary global port industry and to capture the emerging shipping markets.

The diverse DEA models and MPI analysis allow us to systematically examine relative efficiency of ports and temporal changes of total factor productivity, rather than depending on a partial productivity indicator. The interesting points that these analyses demonstrate can be summarized by the following:

- Ports in the world have improved their efficiency over time due to technical progress, production scale adjustment, and improvement in management.
- In general, the larger scale ports are more efficient even without considering scale efficiency. They move more strategically to become efficient by driving and adopting technological development and better managerial practice. Even when considering scale efficiency, the general results are not totally reshaped.

- However, under the CRS model, many large ports are operated under DRS at each port level, thereby implying a potential for inter-port competition as a way to increase port productivity at an aggregated regional level.
- Some of the most efficiently managed ports in the world can be found in Asia (China, South Asia), Central America, and the Middle East, that recently have moved fast and been physically well-structured (e.g. Shanghai and Guangzhou) and some other Asian ports that have been traditionally managed quite efficiently (e.g. Hong Kong and Busan).
- The overall relative efficiency levels in the Asian ports have continuously maintained their dominance until 2004, while some North American and Japanese ports have shown their recent troubles in "improving" port efficiency.
- Since there have been substantial levels of reform efforts in Australia and New Zealand, there are promises of improvement in their efficiency over the last decade, although their level of relative efficiency has not yet outpaced ports in other regions.
- The MPI analysis decomposes the three sources of efficiency successfully. What it shows is that although scale efficiency mainly representing influences from external environments is still one of the important factors to shape port efficiency, it is neither determining nor predominant.
- The analyses suggest that, for ports of fairly similar sizes and strengths of hinterland economies where levels of inter-port competition are fierce, the roles of efficient management, strategic capital investment and institutional restructuring and reforms are not minimal but substantial for the operation of ports over the medium-long term. Given the current globalized shipping market and scopes of port activities, the

strategies to combine institutional restructuring and capital investment can suggest the potential to partly overcome the limitations of the external conditions, as can be found from such examples as the port of Dubai and the port of Singapore.

- Finally, technological changes have had strong factors to allow ports to become more productive in container handling over the last decade. However, the strategy focusing only on aggressive investment in technological progress has limitations in that it is relatively easier for other ports to replicate. Thereby it could lack the possibility to increase relative efficiency and competitiveness.
- The patterns of efficiency change of ports can be classified into 10 different types, based on how the different sources of efficiency can play a role in improving ports' overall total productivity and compensate for the deterioration of other sources of efficiency. The characteristics of efficiency changes are influenced not only by advantages of market and hinterland conditions but also from the strategic efforts to combat or to reap the benefits of these conditions. According to these characteristics and conditions, broader regional trends can be shaped and generalized to some degree, while the specific port by port characteristics still differ in many ways.
- These characteristics can be confirmed by the fact that many ports located in the regions having small hinterland accessibility and higher level of inter-port competition tried to capture the efficiency improvement by reforming their institutional and management practice rather than depending only on changing their scale of production.

CHAPTER 7

Roles of Port Institution on Port Efficiency and Output

7.1 Introduction

This chapter is devoted to revealing the relationship between the institutional features of seaports (i.e. competition, corporate structure, and ownership) and productive efficiency. I will examine how different macro-, meso-, and micro-levels of institutions around port organizations, and flexibility and vigilance on institutional changes interact together with other external hinterland conditions to shape port productive efficiency eventually. It builds on the work in Chapter 4 that analyzed world port institutions including ownership practice, corporate structure of port authorities, and temporal changes of port institutions, and Chapter 5 and Chapter 6 that reported my technical efficiency based Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI). This chapter uses DEA scores and MPI are indices for port productivity as main dependent variables.

This chapter first examines the bivariate relationship between: (1) port ownership and port efficiency, (2) port corporate structure and port efficiency, (3) institutional change and efficiency change, and (4) intensity of inter-port competition and port efficiency in order to preliminarily investigate the hypothesis raised in this dissertation. This analysis is essential to clearly understanding how changing port institutions and increasing private sector participation in the port sector have influenced port efficiency over the last decade. From the analyses, this chapter tries to come up with meaningful implications on whether and by what mechanism port efficiency can be influenced by private sector participation and intra-port competition at terminal levels, corporatization at port levels, and inter-port competition at hinterland levels in the port sector.

The second part of the chapter develops multivariate models for examining the determinants of port outputs and efficiency, presented based on structural equation models, focusing on a case of recursive path between port efficiency and production scales. The multivariate models not only systematically appraise the impact of port institutions on port efficiency and competitiveness, but they also identify other exogenous and endogenous factors influencing port productive efficiency.

The models of port infrastructure productivity and port output aim to examine whether port institutions are important factors in creating port efficiency when other non-institutional and exogenous factors are appropriately controlled on the basis of theoretical conceptions. This analysis especially focuses on productivity at a port level as a unit of analysis rather than a container terminal level. It is so because this study's objective is to identify what institutional aspects of ports and port managers can influence relative efficiency based on a perspective of policy making, rather than a perspective of cargo handling businesses. This approach attempts to resolve the complex endogenous and exogenous relationships among port efficiency, port institutions, port outputs, and other exogenous environmental and geographical factors.

It is, however, less interested in looking into the role on terminal productivity of micro-level physical structure and the engineering aspects of container terminals.

7.2 Bivariate Analysis: Roles of Meso- and Micro-Institutions on Port Efficiency

7.2.1 Data and variables

The data used for the analysis in this section come from the two previous chapters. The specific methods for data collection were detailed in Chapters 4, 5, and 6. For the bivariate preliminary analysis, data on port efficiency come from DEA scores based on inter-temporal and contemporaneous analysis for 1991 and 2004. It is produced from output-oriented models under variable returns to scale assumption.

Port institution data consists of different institutional and organizational aspects faced by global seaports, hypothesized in Chapter 3: a. port ownership (micro-level port institutional practice and independence), b. corporate structure of port authorities/managers (meso-level port institutional structure), and c. intensity of port competition (macro-level port institutional environment). In order to capture the levels of inter-port competition facing each port, an index of spatial competition, discussed in the section 7.3., was designed based on theories of port economics and spatial competition.

7.2.2 Port ownership and port efficiency

Port ownership, as noted in Chapter 4, is complied based on four different categories: (1) Public Operating Port, (2) Mixed Ownership Port, (3) Public Landlord Port, and (4)

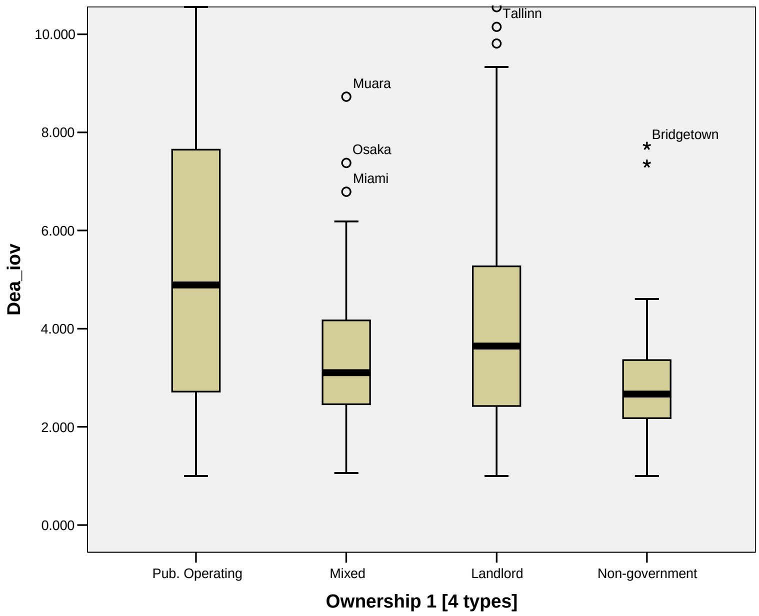
Non-Governmental Port. Both Table 7.1 and the box plot in Figure 7.1 show average efficiency levels for each category of port ownership. The most distinctive feature is that the mean (Table 7.1) and the median (Figure 7.1) of intertemporal DEA scores of public operating ports are in general higher than those of the three other types of ports. The confidence interval of DEA scores for public operating ports at the 95 percent level is higher and does not overlap with those of other ports. Welch's statistics (7.5, p=0.000) and Brown & Forsythe's F test (10.5, p=0.000) for equality of means are rejected.[1] The post hoc tests for multiple group comparisons of mean difference show that the mean inefficiency level (DEA scores) of public operating ports is higher than that of the three other types of port.[2] It notes that ports that are purely public operating are less efficient than ports with private sector participation in terminal operation and port infrastructure investment.

Table 7.1 Intertemporal DEA Scores for Port Ownership

DEA_IOV	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower	Upper		
Pub. Operating	102	6.020	4.540	.452	5.163	6.956	1.000	26.679
Mixed	36	3.626	1.700	.283	3.051	4.201	1.057	8.727
Landlord	85	4.357	2.812	.305	3.750	4.963	1.000	16.649
Non-government	13	3.319	2.098	.582	2.051	4.587	1.000	7.722
Total	236	4.919	3.658	.239	4.449	5.389	1.000	26.679

[1] Welch's test of equality of means is more robust than ANOVA when group variances and sizes are unequal. Brown & Forsythe's F-test of equality of means is more robust than ANOVA when groups are unequal in size and deviations from the group means are highly skewed.
[2] All four tests under the non-equal variance assumption (Tamhane, Dunnett T3, Games-Howell, and Dunnett C) show the mean difference between public operating port and three other types of port.

Figure 7.1: Box Plot: Port Efficiency for Port Ownership



In Table 7.1, port efficiency is shown to be higher as the levels of private sector participation become larger. The DEA scores for both Mixed Ownership and Landlord Ports are smaller than that of Public Operating Ports, while they are a bit higher than Non-Governmental Ports. While it may be relatively insufficient to conclude that port efficiency in Non-governmental ports is statistically and substantially higher than efficiency of the two mixed ownership ports, this analysis can show the following: Private sector participation and the separation of the government from day-to-day operations at a container terminal level can encourage more efficient container production at a port level. The complex relationship between port efficiency, production scales, and other exogenous variables will be discussed in the sections 7.4 and 7.5.

Table 7.2 is a cross-tab analysis between port efficiency quartiles categorized in Chapter 5 and typologies of port ownership. This analysis also confirms the similar results shown in Table 7.1 and Figure 7.1, demonstrating that public operating ports are less likely categorized in efficient quartiles such as “DEA efficiency & Quartile 1” and “Quartile 2.” It is a probability that the results of the analyses are confused if intertemporal DEA scores are used, since the analysis may not sort out the impact of time on port efficiency. Nonetheless, as shown at the bottom part of Table 7.2, the analysis with port efficiency quartiles based on contemporaneous DEA scores for each year (1991, 2004) shows similar results to those of the intertemporal DEA scores.

Table 7.2: Expected and Observed Counts of Ports by Ownership and Efficiency

Ownership \ Intertemporal Efficiency	Observed Counts					Expected Counts**	Total
	Excellent		Good	Fair	Poor		
	DEA Efficient	Quartile 1	Quartile 2	Quartile 3	Quartile 4		
Public Operating	5	18	16	22	**41**	25.5	102
Mixed	0	9	**16**	8	**3**	9	36
Landlord	5	17	22	**27**	14	21	85
Non-Government	1	4	5	1	2	3	13
Total	11	48	59	58	60		236
Ownership \ Contemporaneous Efficiency	DEA Efficient	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Expected Counts	Total
Public Operating	7	13	**15**	19	**28**	20.5	82
Mixed	1	8	**12**	**4**	6	8	31
Landlord	6	8	17	**24**	16	18	71
Non-government	2	3	4	1	0	3	10
Total	16	32	48	48	50		194

**Port quartiles are classified by standard deviation of DEA scores, as noted in Chapter 4.*
DEA Efficient & Quartile 1: Excellent efficiency, Quartile 2: Good, Quartile 3: Fair, Quartile 4: Poor
***Expected Counts: Total number of ports in each ownership divided by four (number of efficiency groups: DEA Efficient & Quartile 1, Quartile 2, Quartile 3, and Quartile 4)*

7.2.3 Management corporate structure and port efficiency

The management and corporate structure was originally compiled with six different types represented: (1) National government (or National port authority), (2) State or provincial government (or State port authority), (3) Local government department, (4) Statutory authority or corporation, (5) Government Owned Corporation operated under corporate law, (6) Private Enterprise operated under corporate law.

Table 7.3: Intertemporal DEA Scores for Port Corporate Structure[3]

DEA_IOV	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower	Upper		
National	63	5.180	4.217	.531	4.118	6.242	1.000	23.648
State	16	4.743	2.300	.575	3.518	5.969	1.880	9.284
Local	69	4.574	3.785	.456	3.665	5.484	1.000	26.679
Statutory Corporate	50	4.984	3.382	.478	4.022	5.945	1.000	18.576
GOC u/ Corp. law[4]	22	5.175	3.638	.776	3.562	6.788	1.109	16.649
Private Enterprise	8	3.843	2.396	.847	1.840	5.846	1.000	7.722
Total	228	4.876	3.671	.243	4.397	5.355	1.000	26.679

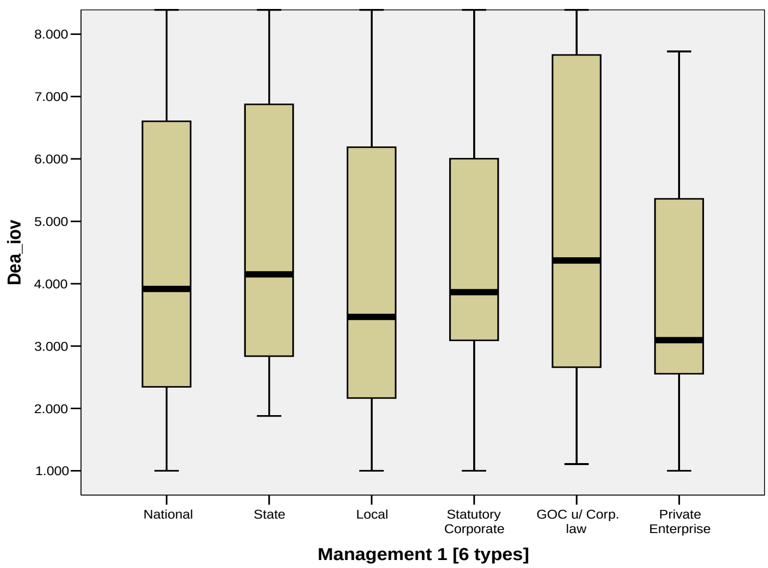
Again, Table 7.3 presents the mean of DEA scores for each category and their confidence interval, and Figure 7.2 shows the median value of DEA scores for each category. The average levels of port efficiency for each category of management

[3] In the database, there are ten cases that this research cannot identify port corporate structure out of 238 ports that we estimated intertemporal DEA scores: Port of Santos in Brazil (1991), Port of La Spezia in Italy (1991), Port of Damietta in Egypt (1991), Port of Helsinki in Finland (1991), Port of Gdynia in Poland (1991), Port of Constantza in Romania (1991), Port of Bridgetown in Barbados (1991), Port of Belize City in Belize (1991), Port of Santos in Brazil (2004), and Port of Havana in Cuba (2004). These missing data were carefully reviewed to see whether they can influence the result analysis. The average efficiency of the missing data (5.179) is very similar to other types of corporate structure and their range is quite widely distributed from 1.953 to 10.299. Therefore, the list-wise deletion was adopted to treat the missing cases.

[4] Among the small number of GOC ports (total 22), one port (Port of Constantza) is extreme outlier in efficiency (DEA =16.7), the mean excluding the port is 4.629.

structure are not substantially and statistically different from each other. However, a total of eight ports[5] managed by private enterprise show signs of being relatively more efficient than other publicly managed ports. The small number of observations in the category leads to a statistical inference that the efficiency levels of ports managed by private enterprises are not significantly different from other types of ports. Conversely, this analysis can also reject the idea that "private ports are inherently less effective in port management and operation than public ports because of difficulties of large-scale resource mobilization and long-term investment." Even if there are disadvantages existing against private ports, they are compensated by the benefits created by private sector participation at the port management level.

Figure 7.2: Box Plot: Port Efficiency for Port Corporate Structure



[5] These ports are proprietary or the minor shares (less than 50%) are owned by government agencies: Felixstowe in UK (1991, 2004), Puerto Manzanillo in Panama (2004), Saigon Newport in Vietnam (Cat Lai & Tan Cang Terminal) (2004), Tauranga in New Zealand (2004), Bridgetown in Barbados (2004), Jurong (2004) in Singapore, and Belize City in Belize (2004).

It is also interesting to note that neither Statutory Corporate Authority nor Government-Owner Corporation (GOC) are necessarily any more efficient than other port types, while private enterprise ports has some weak signs of better efficiency. As Everette (2005) argues, even more important may be how substantive organizational changes can be secured through legal frameworks of corporatization rather than nominally becoming a “corporate port” which can be even defined differently as shown in the review in Chapter 2. Another possibility can be the following: Corporatization is a mechanism that depends on “relational contracts” on the basis of statute (statutory port corporation) or share controlling (government-owned port corporation) rather than “classical” or “neoclassical contracts” including concession contracts. Since relational contracts are originally loosely defined between governments and port enterprises, they inherently have more variance in terms of mechanisms of implementation and actual practice. It may be therefore possible for port enterprises to be still captured by special interests and exercise port managers’ discretion in ways that do not encourage port efficiency in the long term. Unless they are specifically secured through additional legal or institutional mechanisms, the performance benefits may not be as high as those of concession contacts that include detail statements regarding efficiency or performance targets.

Overall, from the results of the analysis between port efficiency and the two institutional characteristics, it is preliminarily possible to reject the second hypothesis, “The more decentralized corporate structure at a port authority and management level does lead to statistically proven higher productivity of ports.” Alternatively, as shown in the analysis between port efficiency and ownership; container port productivity largely comes from the actual institutional practices of ports – (a) the levels of intra-port competition based on "vertical unbundling," (b) the allocation of terminal assets to attract private sector investment, which has lead to an upgraded port and terminal infra- and superstructure, and (c) the degree of separation of day-to-day container terminal operation and production from the government's hand.

This analysis suggests that the direct business side of port operation and management such as container handling and production, terminal operation, and investment in terminal assets can be more effectively pursued through private sector participation such as leaseholds and concessions of terminals and assets. The government sector should focus more on policy making on environmental, safety, and customs regulations, long-term planning and finance for port and nautical infrastructure, and creating a market structure to reduce regional and national monopolistic characters and induce inter-port competition by 'leveling a fair ground for competition,' which is discussed in the next sections.

7.2.4 Temporal change of port institution and MPI (Sources of Efficiency)

Table 7.4 compares the changes in port efficiency (MPI) between ports that have experienced private sector participation in port ownership (Group 2) and those that have not (Group 1).[6] From 1991 to 2004, in general, the ports in Group 2 have a higher MPI than Group 1. The group means are statistically different at the 10 percent level based on ANOVA (F=3.364, *p*=0.070), while it is not rejected that their means are statistically different based on either Welch's test or the Brown-Forsythe test (2.591, *p*=0.114).

Table 7.4 Port Ownership Change and MPI, TEC, SEC, and PFC

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
MPI	No OWN Change	55	1.79	.90	.12	1.55	2.04	.50	4.63
	OWN Change	39	2.45	2.41	.39	1.66	3.23	.51	12.75
	Total	94	2.06	1.72	.18	1.71	2.42	.50	12.75
TEC	No OWN Change	55	1.41	1.24	.17	1.08	1.74	.31	8.48
	OWN Change	39	1.65	1.85	.30	1.05	2.25	.20	8.87
	Total	94	1.51	1.52	.16	1.20	1.82	.20	8.87
SEC	No OWN Change	55	1.19	.42	.06	1.08	1.30	.25	2.98
	OWN Change	39	1.37	.69	.11	1.15	1.59	.26	4.79
	Total	94	1.26	.55	.06	1.15	1.38	.25	4.79
PFC	No OWN Change	55	1.26	.23	.03	1.20	1.32	.92	1.74
	OWN Change	39	1.31	.20	.03	1.24	1.38	1.00	1.82
	Total	94	1.28	.22	.02	1.24	1.33	.92	1.82

- *TEC: technical efficiency change, SEC: scale efficiency change, PFC: technology progress*

In terms of the source of efficiency changes, scale efficiency change (SEC: F=2.427, *p*=0.123) shows a larger and statistically more meaningful, though not significant, difference between Group 1 and Group 2 than technical efficiency change (TEC: F=0.587, *p*=0.446) and technology change effect (PFC: F=1.058, *p*=0.306). It implies that the impact made by the separation of terminal operation function from government hands can be directed more to scale efficiency change, which will be reconfirmed from

[6] Among 98 ports that have data for MPI, ports with maximum MPI values (Salalah) and minimum values (Buenos Aires) are excluded for this analysis due to the fact they are extreme outliers. In addition, the analysis excludes two Taiwanese ports that recentralize their terminal operation function for the reform purpose in transition.

the multivariate models of port efficiency and throughput based on cross-sectional data in the section 7.4. Though not presented here, the median values of each index between the two groups show similar results.

When only 63 ports in the dataset ranked within the Top 100 are considered[7], the whole picture is depicted a bit differently in Table 7.5. The gap between the two groups in the MPI is more strongly confirmed at the five per cent level from ANOVA (F =5.184, p=0.026) and the 10 per cent level from the Welch and the Brown-Forsythe (3.611, p=0.068) tests.

Table 7.5: Port Ownership Change and MPI of Ports Ranked within 100

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
MPI	No OWN Change	38	1.66	.82	.13	1.39	1.93	.51	4.29
	OWN Change	25	2.79	2.88	.58	1.60	3.97	.51	12.75
	Total	63	2.11	1.98	.25	1.61	2.61	.51	12.75
TEC	No OWN Change	38	1.13	.55	.09	.95	1.32	.34	3.00
	OWN Change	25	1.91	2.17	.43	1.01	2.80	.40	8.87
	Total	63	1.44	1.47	.18	1.07	1.81	.34	8.87
SEC	No OWN Change	38	1.19	.37	.06	1.07	1.31	.83	2.49
	OWN Change	25	1.36	.77	.15	1.04	1.68	.88	4.79
	Total	63	1.26	.56	.07	1.12	1.40	.83	4.79
PFC	No OWN Change	38	1.29	.21	.03	1.22	1.36	.93	1.74
	OWN Change	25	1.26	.19	.04	1.18	1.33	1.00	1.60
	Total	63	1.27	.20	.03	1.22	1.32	.93	1.74

- *TEC: technical efficiency change, SEC: scale efficiency change, PFC: technology progress*

In terms of sources of efficiency, the largest gap can be found in TEC. According to ANONVA, Welch, and Brown-Forsythe, their means are statistically different at the 10 percent level, while their median values do not show large gaps from each other. This is

[7] In terms of production scales in 2001

possibly because, for larger ports, their efficiency improvement is much easier to be realized from a technical efficiency change than increasing scale efficiency, given that their production scales were already large enough and sometimes even exceeded optimum production scales. The difference between mean and median values also suggests that significant efficiency achievement may be realized unevenly from some selected ports that have been efficiently managed over the last decade (e.g. a few Chinese ports and Jawaharlal Nehru).

More facts can be clearly observed when 14 ports that experienced leasehold and concession in their terminals but resided outside of the Top 100 in 2001 are examined. For the 14 ports in Group 2, all show improvement in SEC (except Bridgetown) and significant improvement in PFC. Especially, their improvement in PFC is significantly higher and statistically different at the five percent level than the 17 ports in Group 1. Six out of 14 ports in Group 1 show negative improvement in TEC (Constantza in Romania, Fremantle in Australia, Helsinki in Finland, Lisbon in Portugal, Montevideo in Uruguay, and St. Petersburg in Russia), thereby leading three ports to end up having negative total factor productivity improvement despite their institutional transformation efforts (Fremantle, Lisbon, and Helsinki).

Table 7.6 presents the difference in efficiency change between ports; which, in the last decade, have implemented decentralization in corporate and management structure (Group B) and those that have not (Group A). In general, the ports in Group A have a larger MPI than Group B. However, there is no statistically meaningful difference in all categories of efficiency sources. The ports in Group B have even a lower mean TEC than ports in Group A, while the reverse is the case for the two other sources of efficiency. Overall, due to the lack of statistical significancy, it is difficult to conclude that changes in corporate structure has either promoted or discouraged the changes in port efficiency.

Table 7.6: Port Corporate Structure Change and MPI

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
MPI	No MGT Change	70	2.13	1.91	.23	1.67	2.58	.50	12.75
	MGT Change	17	1.96	1.02	.25	1.43	2.48	.51	4.45
	Total	87	2.10	1.77	.19	1.72	2.47	.50	12.75
TEC	No MGT Change	70	1.59	1.67	.20	1.19	1.99	.20	8.87
	MGT Change	17	1.16	.75	.18	.78	1.54	.40	3.14
	Total	87	1.50	1.54	.17	1.17	1.83	.20	8.87
SEC	No MGT Change	70	1.25	.59	.07	1.11	1.39	.25	4.79
	MGT Change	17	1.40	.45	.11	1.17	1.63	.83	2.49
	Total	87	1.28	.56	.06	1.16	1.40	.25	4.79
PFC	No MGT Change	70	1.27	.22	.03	1.22	1.32	.92	1.82
	MGT Change	17	1.31	.17	.04	1.23	1.40	1.06	1.60
	Total	87	1.28	.21	.02	1.23	1.32	.92	1.82

In line with the analysis of DEA scores by institutional characteristics, it is again possible to claim that improvement in container port productivity is mainly generated from the actual institutional practice of ports through concessioning and leasing port assets, rather than decentralization and corporatization at port authority levels. It has promoted intra-port competition and contributed to attracting new investment for upgrading terminals from global terminal operators, shippers, and other private cargo handlers.

From another angle, this result also reflects that, over the last decade, the roles and powers of terminal operators and cargo handlers have become much stronger in the port industry. For many parts of the world, global operators and cargo handlers have tried to capture new sections of the market where economic opportunities have not yet been taken. It has therefore allowed some selected ports that had higher, but not yet realized, potential to harvest larger scale efficiency and economies of scale and, at the same time, to separate terminal operation from direct duties under the governments' wing. The trend of transformation can also be supported by increasing inter-port competition and their roles on port efficiency analyzed in the sections 7.3 and 7.4.

7.3 Bivariate Analysis: Roles of Inter-port Competition on Port Efficiency

7.3.1 Defining and measuring inter-port competition

Despite the theoretical importance of the topic and the debates, prior studies in port economics and management have not systematically and empirically examined the impact of inter-port competition on efficiency. It is partially because of the lack of agreement on the definition of inter-port competition and the lack of attempts for measuring it. A definition on inter-port competition should be first clarified to bring the concept of inter-port competition into the port management and evaluate the impact on port efficiency.

This chapter develops the initial intuition suggested by Cullinane et al. (2005) to design the inter-port competition index: "[I]nter-port competition can be simply understood as the competition among (or between) different ports. The most important criterion for judging whether container ports are competing with each other is to examine whether they serve the same, or an overlapping, hinterland."

In order to specify the concept of inter-port competition, the concept of spatial competition in geography can be adopted. An application of geographical concept is particularly reasonable since the mobility of ports is lacked more so than firms in other industries. If ports, as firms, are truly mobile, the density of ports and the condition of port hinterland may not be important factors in shaping the intensity of inter-port competition. However, this is not the case for most ports due to their huge sunken cost and economic attachment to the hinterland and surrounding regions. The classic theories of spatial competition (e.g. Lösch; Hotelling) imply that the distance (as impedance) between firms (or density) is negatively related to the intensity of competition faced by firms in a region. Moreover, the difference of the size between firms can also influence the competitive intensity, although the evidence on the effects of firm size on competition intensity has not yet been clearly proved in recent studies of industrial ecology (Carroll & Hannan 2000).

As previously noted, it is reasonable to view the fact that they compete with each other if ports share the overlapping hinterlands. Moreover, since the ports selected for this study are either global hub ports or national and regional gateway ports, it can be regarded that they are not supplementary based on the relationship between hubs and feeders. However, often in transport geography, the concept of hinterlands is vague at best. Fageda (2005) argues that it is the area where a port has a monopolistic position. Others see it as "land space over which a port sells its services and interacts with its clients." More concepts are available: e.g. (a) "origin and destination area of port," i.e. "the inner region provided by a port," (b) "the market area served by a port and from where a port draws its cargo," and (c) "the market reach of the port, that is, the areas from which cargo originates, as well as the areas where cargo moving through the port is destined. Some ports will have hinterlands that extend across many states, while other ports will have smaller hinterlands," (UN ESCAP 2005, 14).

The concept in this chapter is that the impact of ports on hinterlands does not discretely disappear at some point of the surrounding region but is continuously dispersed, weakened, or strengthened, as a few of the conditions facing ports change over the span of the areas impacted. Consequently, the index presented below attempts to capture the areas where the impact of each port reaches. Another line of reasoning implied in the concept of index is that there is relatively more intense inter-port competition between firms within a similar hierarchy of ports.

An index for inter-port competition is designed to measure the Hinterland Accessibility (HA) faced by each port in the following:[8, 9]

$$\underset{i\neq k}{HA_i} = \sum_J \frac{\frac{GDP_J}{D_{i,J}^2}}{\sum_{k=1}^{m} \frac{Q_k}{D_{k,J}^2}} = \frac{\sum_J \frac{GDP_J}{D_{i1,J}^2}}{\sum_J \sum_{k=1}^{m} \frac{Q_k}{D_{kJ}^2}} \text{ -------------- } Eq.(1)$$ [10]

Where GDP_J = Gross Domestic Products[11] of Country J (J=1,2,…,N)

$D_{i,J}$ = Distance[12] between port i (i=1,2,…,m) and country J

Q_k = Total capacity of port k (k ≠ i)

D_{kJ} = Distance between port k and country J

---

[8] Programming codes are created with Matlab 6.5 to calculate the index for the years of 1991 and 2004. An example of code is presented in Appendix 7.1.

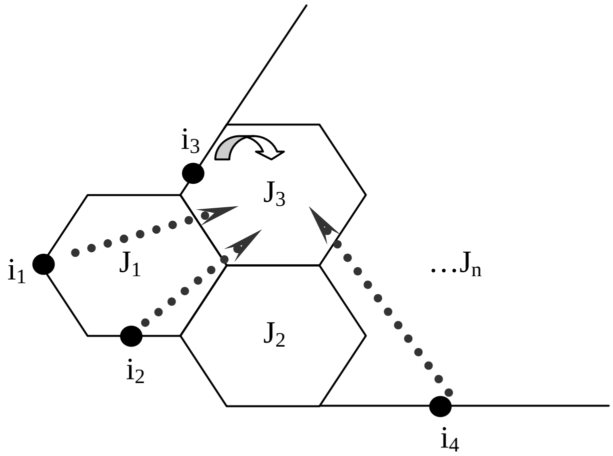
[9] In order to calculate the index for the years of 1991 and 2004 respectively, selected are the 257 ports, which produced more than 90 percent of total TEU handled in the world in 2001. The total number of countries considered to calculate this index is 186, which include almost all countries in the world except several small island countries that do not have large ports.

[10] After calculating HA_i, the natural log was taken to make equation (1) as an index.

[11] For the 1991 and 2004 GDP data, World Bank's World Development Indicators (WDI) is used (2000 Real dollars). When the WDI data are missing for 12 countries, the data for these countries are supplemented from the CIA's World Fact Books. If the measurement method is not the same between the two sources, data are reasonably handled.

[12] For the distance calculation, I created point themes for countries and ports based on latitude and longitude from ArcView3.2 and used an Avenue-programmed extension, Distance and Azimuth Matrix v.2 Extension for ArcView 3.2 with a geodesic curve option, which is developed by Jenness (2005).

Figure 7.3: Concept of Inter-port Competition (Hinterland Accessibility) Index



Firstly, shown in the numerator of equation (1) and Figure 7.3, the hinterland SIZE of port i_1 can be estimated with an interval measure by a simple gravity model based on GDP of country J_1, J_2, J_3,…J_N and the distance between port i_1 and the countries: $HS_{i1} = \sum_J \frac{GDP_J}{D_{i1,J}^2}$. In other words, the hinterland size of port i_n discounts aggregated opportunities of hinterlands (GDPs of countries) by distance as impedance. Yet, this hinterland size does not consider competition for opportunities from other neighboring ports. For example, country J_3 can be served not just by port i_3 but also port i_1, i_2, i_4,…,i_m. With the same logic, port i_3 is competing with other ports to serve country J_3. This logic can be applied for all other countries and ports.

Therefore, the hinterland size (i.e. the numerator of equation (1)) should be discounted by the degree of threats from competing neighboring ports, or the chances for neighboring ports to serve the overlapping hinterlands. The intensity of threats can be captured by the denominator of equation (1), which is the capacity of container handling of port k discounted by the distance between port k and country J.[13, 14] Since this is a way to discount hinterland size by external threats, it is named as the degree of hinterland ACCESSIBILITY of port i.

The hinterland accessibility for a port can be an inverse function of the intensity of inter-port competition faced by the respective port. Therefore, the larger the hinterland accessibility indexes, the smaller the degree of inter-port competition. In contrast, if the hinterland accessibility for a port is smaller: in general, the inter-port competition is larger. In the analysis of the relationship between inter-port competition and port efficiency, the hypothesis is that the smaller the hinterland accessibility index (i.e. the larger the intensity of spatial competition), the higher the port efficiency, as proposed in Chapter 3.

Figure 7.4-A shows the hinterland sizes based only on aggregated GDP discounted by the distance between ports and countries. In general, many European ports have large hinterlands because many high-income countries with high volumes of trade are gathered around the regions. South and East Asian ports also have large hinterlands due partly to the emerging Chinese and Indian economies. North and Central American ports have relatively large or medium hinterland sizes due mainly to such large

[13] In estimating the index, one assumption is that the economic activities of country J are universally distributed throughout the countries. This allows us to measure the distance between a port and a country based on the central point of a country. Yet, this may be a source of error especially for large countries like Russia, India, US, Mexico, and Brazil if their economic activities are unequally distributed by being concentrated in one or several regions asymmetrically. One possible approach to correct this source of error is to divide the world (or these countries) into smaller zones with the economic activity data for each zone and then calculate the index. However, the data for the ideal calculation are certainly difficult to acquire for all world countries at this point.

[14] For the capacity of port, the scale of container production is used as proxy data due to the lack of data availability.

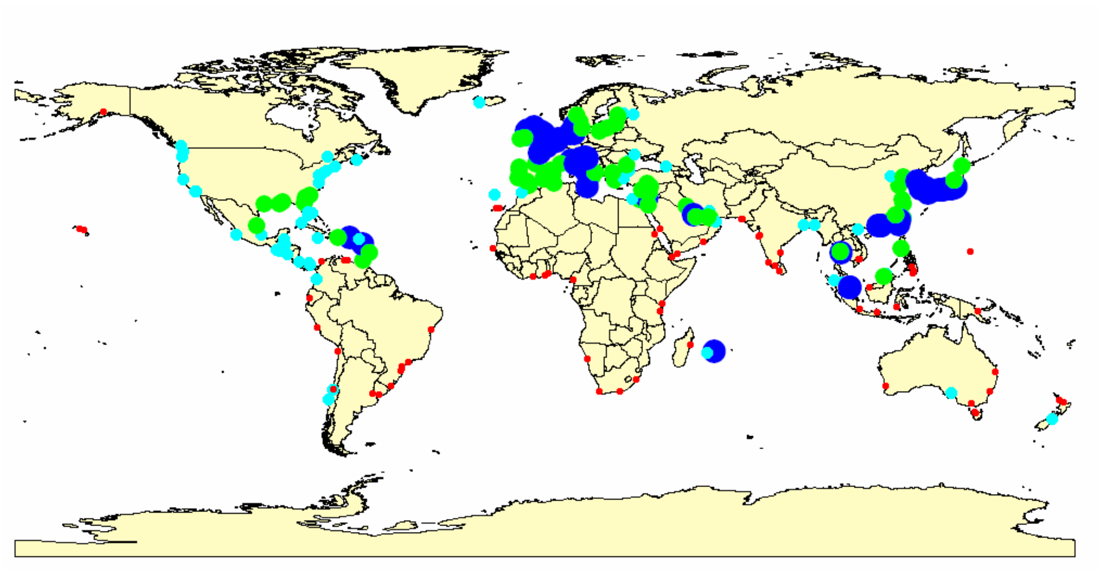
economies, the US, Canada and Mexico. In contrast, ports in Oceania, Africa, and South America can only secure smaller sizes of hinterland.

Figure 7.4-B presents the Hinterland Accessibility Index (HAI) considering opportunities discounted by threats from other ports. In contrast to the case of hinterland size, ports in North America show the highest levels of hinterland accessibility mainly because of the lack of threats from neighboring ports. This analysis suggests that the North American ports enjoy a regionally oligopolistic nature of market, compared to European and Asian ports. The European and Asian ports' hinterland accessibility are relatively smaller than for those in North America, demonstrating their higher levels of spatial inter-port competition.

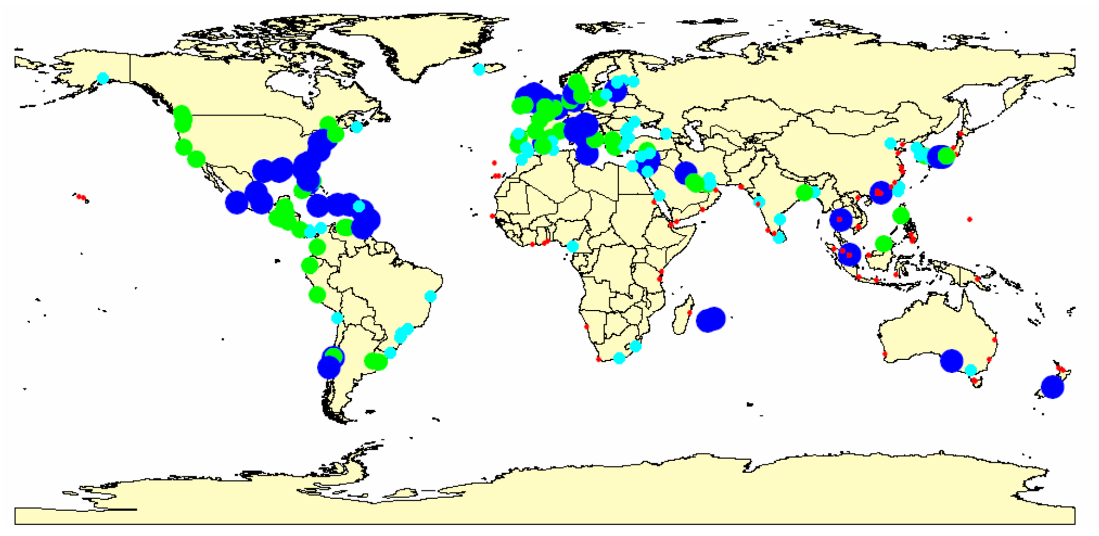
The analysis of index is in line with the observations proposed in the last decade that more intense levels of competition among ports and terminal operators have existed particularly in Northern Europe, East Asia, and South Asia. Finally, ports in other continents still show a smaller hinterland accessibility index, or higher inter-port competition, than North America and Europe. The main reasons are their smaller hinterland sizes (aggregated GDP) that are mostly caused by scales of economic activities and the large distance from major shipping routes in the North.

Figure 7.4: Hinterland Size and Accessibility in 2004

A. Hinterland Size ($HS_i = \sum_J \frac{GDP_J}{D_{i,J}^2}$)



B. Hinterland Accessibility Index ($HA_i = \sum_J \frac{\frac{GDP_J}{D_{i,J}^2}}{\sum_{k=1}^{m} \frac{Q_k}{D_{k,J}^2}}$)



Legend of Hinterland Size and Hinterland Accessibility

Blue ⬤: Very High *Green ⬤: High* *Light Blue ⬤: Medium* *Red •: Low*

7.3.2 Relationship between port efficiency and competition

Regarding the relationships between inter-port competition and port efficiency, it is most interesting to observe the change of the relationship from 1991 to 2004. Table 7.7 and Figure 7.5 present *Pearson's r* correlation and the non-parametric correlation (*Spearman's rho*) based on the rank of data between the two variables.

Table 7.7: Correlation between Port Efficiency and Inter-port Competition

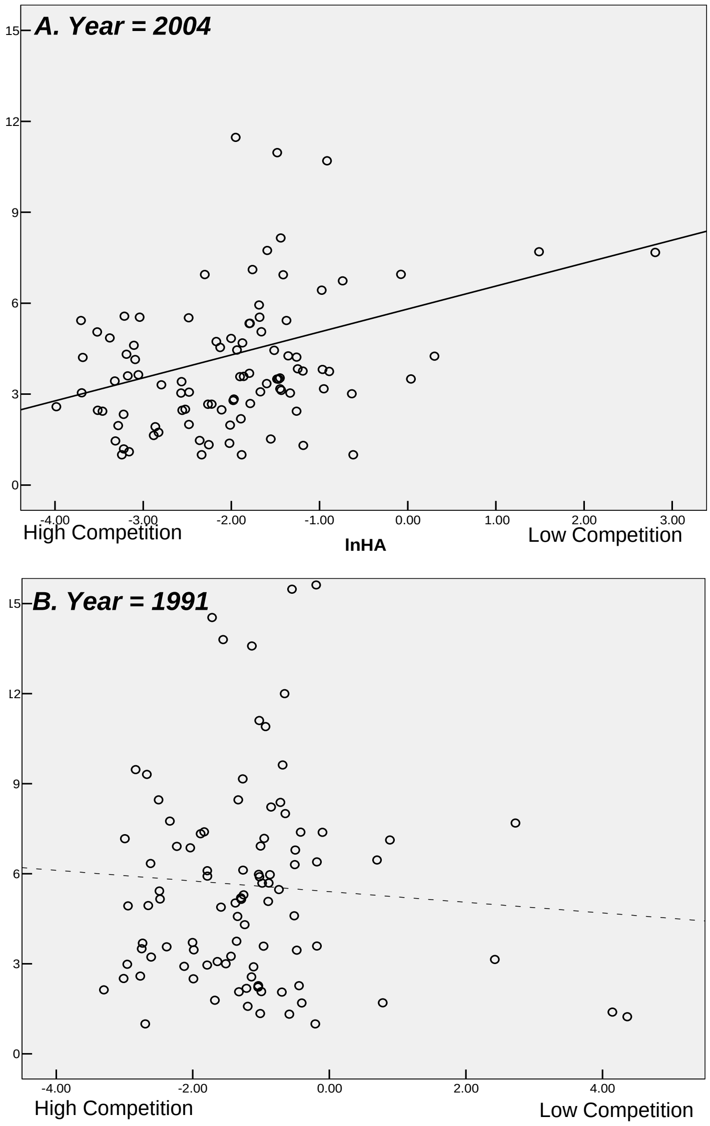
Year = 2004 N = 98[15]	HA Index	DEACOV	DEACOC	Note
HA Index	1.000	*0.206 (p=0.043)*	**0.282 (p=0.005)**	*Pearson's r*
	1.000	*0.219 (0.030)*	**0.306 (0.002)**	*Spearman's rho*
DEACOV	*0.206 (0.043)*	1.000	**0.901 (0.000)**	*Pearson's r*
	0.219 (0.030)	1.000	**0.845 (0.000)**	*Spearman's rho*
DEACOC	**0.282 (0.005)**	**0.901 (0.000)**	1.000	*Pearson's r*
	0.306 (0.002)	**0.845 (0.000)**	1.000	*Spearman's rho*
Year = 1991 N = 98[16]	HA Index	DEA_COV	DEACOC	*Note*
HA Index	1.000	-0.059 (0.561)	-0.064 (0.533)	*Pearson's r*
	1.000	-0.001 (0.990)	-0.001 (0.992)	*Spearman's rho*
DEACOV	-0.059 (0.561)	1.000	**0.419 (0.000)**	*Pearson's r*
	-0.001 (0.990)	1.000	**0.785 (0.000)**	*Spearman's rho*
DEACOC	-0.064 (0.533)	**0.419 (0.000)**	1.000	*Pearson's r*
	-0.001 (0.992)	**0.785 (0.000)**	1.000	*Spearman's rho*

HA Index: Hinterland Accessibility Index (Inverse function with intensity of inter-port competition)
DEACOV: DEA scores from Contemporaneous analysis under VRS, DEACOC: DEA scores under CRS
Italic: Correlation is significant at the 5 % level; **Bold***: significant at the 1 % level (2-tailed)*

[15] For Pearson's r between HA Index and DEACOV and between HA Index and DEACOC in 2004, N=97 (exclude an outlier, port of port of Rijeka (e.g. DEACOV = 26.685, DEACOC = 26.857)
[16] For Pearson's r between HA Index and DEACOC in 1991, N=97 (exclude an extreme outlier, port of Salalah (e.g. DEACOC = 56.318)

Figure 7.5: Inter-port Compeititon and Port Efficiency

x-axis: Hinterland Accessibility Index, y-axis: DEA scores

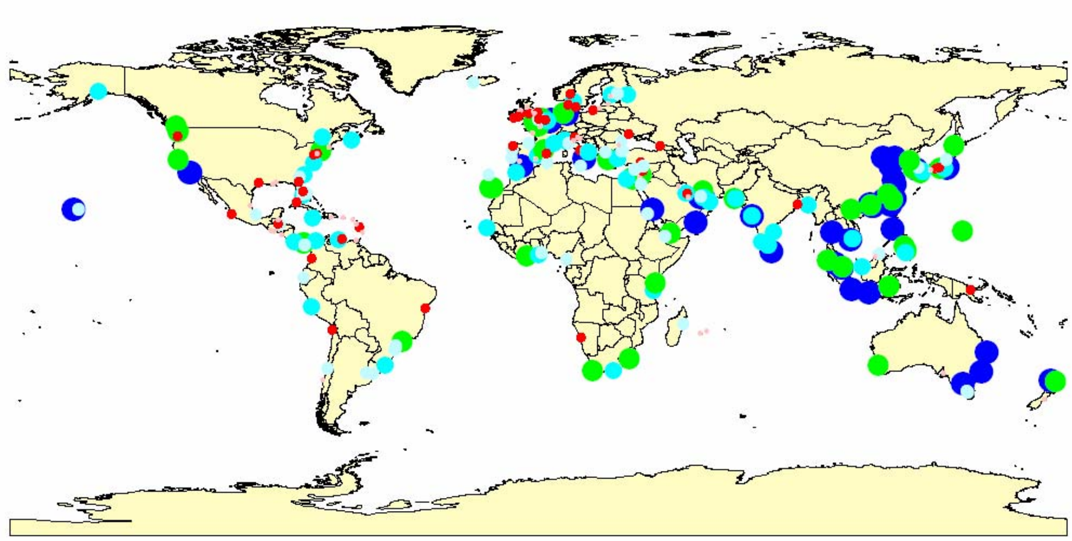


In 2004, there is a statistically significant and quite strong relationship between inter-port competition (HA Index) and port efficiency (DEA scores). In general, as the intensity of inter-port competition faced by a port is stronger (low HAI), ports become more efficient (small DEA scores) in 2004. In 1991, however, there was no statistically significant relationship between HAI and DEA scores. The strength of the relationship was very weak.

This analysis demonstrates the evidence that inter-port competition has become considerable in influencing overall port efficiency especially since the 1990s. Since the 1990s, one has observed the new ages of strong rivalry and contests between ports or among global terminal operators and carriers. The strong inter-port competition in the last decade has created institutional conditions and external incentives under which many ports act more proactively and strategically so that they achieve higher port efficiency.

Figure 7.6: Port Performance Index in 2004

Normalized Hinterland Accessibility (HA_i / Q_i)



Legend of Port Performance

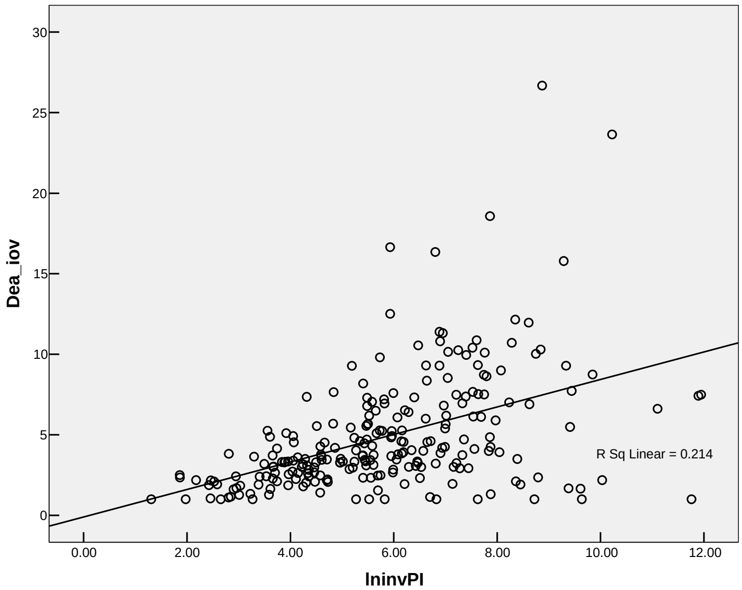
Blue ● *: Very High* *Green* ● *: High* *Light Blue* ● *: Medium* *Red* ● *: Low*

As shown in Figure 7.6 and Appendix 7.2, the Hinterland Accessibility Index (HA_i) for each port is normalized by dividing the index by total container throughputs of the respective ports (Q_i) in order to capture the performance of each port (HA_i / Q_i). It notes how large hinterland accessibility is required to produce a unit of container throughputs. Inversely, it can be interpreted as how many throughputs are produced for each unit of hinterland accessibility. Therefore, as the normalized hinterland accessibility (HA_i / Q_i) is larger, the performance of ports is smaller overall. The concept of performance in this index is based on the scale of port outputs when considering the advantages and disadvantages of hinterland sizes and the threats created by inter-port competition.

Figure 7.6 illustrates that many East and South Asian ports still have a very high performance index when the hinterland conditions are taken into account. In line with the diverse analyses in the previous chapters, in Europe, Antwerp, Rotterdam, Hamburg, Gioia Tauro, and Algeciras: performance indexes are ranked approximately with 40 out of 139 ports in 2004, showing a relatively high performance level. In North America, both Los Angeles and Long Beach show similar levels of performance with the above mentioned European ports, while other ports in the region have medium and low performance index levels. The most interesting part of the results is that many ports in Oceania have a very high performance index. That is to say, ports in New Zealand and Australia are performing very well, especially when the disadvantages from the relatively small hinterland conditions are taken into account.

Finally, port performance is closely related to relative port efficiency as presented in Figure 7.7. The index therefore confirms that ports that have made continuous efforts to improve productivity by reforming their policies and adopting innovative management over the last decade can be ranked high in terms of port performance index discounting hinterland conditions. This result implies that, if the external conditions of a region are not as good as those in other regions, the strategic efforts and management by port authorities to improve port efficiency are crucial elements in allowing the room for overcoming the various limitations.

Figure 7.7: Relationship between Port Performance and Efficiency



7.4 Multivariate Models for Port Efficiency and Throughput: Recursive Paths

7.4.1 Conceptualized theoretical model and estimation methods

I proposed the conceptual models in equations (2) and (3) in order to investigate the determinants of productive port efficiency for container ports:

EFF = f (TEU x COM x MGT x OWN x e1) ….. Eq. (2)

Where EFF = Port efficiency
TEU = Port throughput (economies of scale)
COM = Inter-port competition (Macro-level institutional environment)
MGT = Port's management structure (Meso-level institutional structure)
OWN = Port ownership (Micro-level institutional practice)
e1 = error term

In equation (2), it should be considered that port throughput can be determined by such factors in the following:

TEU = g (EFF_{t-1} x CON x DEP x WHR x GLB x PUB x FTZ x CTYP x INF x REG x e2)

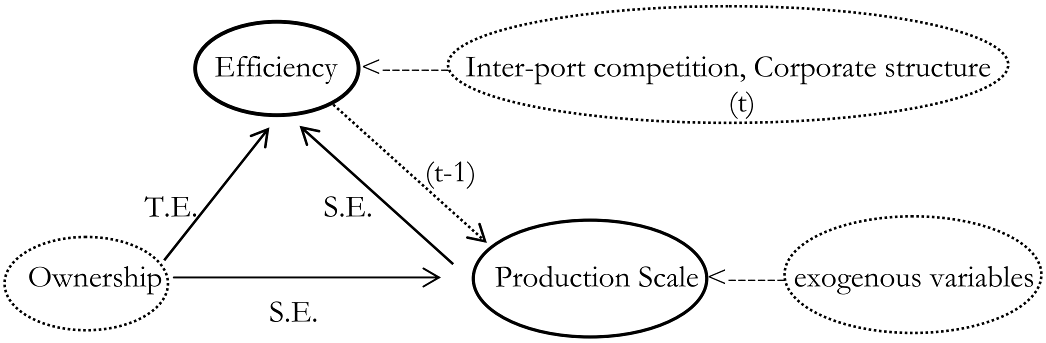
………………………………… Eq. (3)

Where

Port-level condition and strategy:
EFF_{t-1} = Port efficiency at a previous period
CON = Port connectivity
DEP = Terminal depth
WHR = Port service flexibility (24 hour 7 day service)
GLB = Terminal operation aspect
PUB = Dummy for Purely Public Operating Port
Surrounding area condition and strategy:
FTZ = Regional development strategy
CTYP = Direct hinterland condition
INF = Surface infrastructure condition
Regional-level Condition:
REG = Dummy for regions far from major shipping routes
e2 = error term

From the structural models of equations (2) and (3), an econometric issue can be noted. It is imperative to consider the aspect that port output can be endogenous in the relationship among the variables. The relationship between port production scales, port efficiency, port institutions, and other exogenous variables should be theoretically resolved.

Figure 7.8: Causal Path Diagram: Recursive Model



Let us consider the path diagram conceptualized in Figure 7.8. Initially, port efficiency at a previous period can be a factor to increase port output at time t by attracting more cargos, since shippers choose ports having higher efficiency levels, better service, and lower port charges than competitors, based on their previous knowledge and experience. In the next stage, large scales of port output at time t, by itself, can create higher efficiency at that moment, based on economies of scale, as discussed in DEA analysis in Chapter 5. While there is a loop between port efficiency and port throughput in Figure 7.8, they theoretically occur in different time periods.[17] The structural equations for the factors of port efficiency and throughput are therefore subject to a case of recursive path

[17] It can be theoretically conceptualized that the impact of port efficiency on port output is made in one period earlier than the impact of port output on port efficiency is generated.

models in which the errors from different equations are independent. Additionally, port output is endogenous in this relationship.[18] Moreover, most of the geographical and environmental exogenous variables (e.g. port conditions and strategies, local and surrounding area conditions and strategies, and regional conditions) influence port productivity by changing the conditions and mechanisms in which ports produce their outputs in the first stage. Thus, the variables cannot be integrated into the port efficiency model in the second stage, together with port output, as determinant variables.[19] It is therefore not only econometrically but also theoretically more reasonable and appropriate to use two-stage least squares regression.[20]

In order to estimate the final model for the determinants of port productive efficiency that interests this chapter most, the models adopt the structural forms in the following:

1st stage:

$$\widehat{TEU} = C \cdot EFF_{t-1}^{\gamma_1} \cdot CON^{\gamma_2} \cdot DEP^{\gamma_3} \cdot WHR^{\gamma_4} \cdot GLB^{\gamma_5} \cdot PUB^{\gamma_6} \cdot FTZ^{\gamma_7} \cdot CTYP^{\gamma_8} \cdot INF^{\gamma_9} \cdot REG^{\gamma_{10}} \quad \ldots\ldots \text{Eq. (4)}$$

2nd stage:

$$\widehat{EFF} = C \cdot \widehat{TEU}^{\beta_1} \cdot COM^{\beta_2} \cdot MGT^{\beta_3} \cdot PUB^{\beta_4} \cdot MIX^{\beta_5} \cdot LORD^{\beta_6} \cdot CHN^{\beta_7} \quad \ldots\ldots \text{Eq. (5)}$$

Where $\widehat{TEU}$ refers to projected value of TEU from the first stage, C refers to the constant terms, and the error terms are assumed to be normally distributed with constant

---

[18] Under the recursive path case, OLS estimations yield consistent estimates (Pindyck and Rubinfeld 1991).

[19] It violates an econometric assumption of "independence among explanatory variables."

[20] Firstly, regress port throughput on other theorized predictor variables, i.e. TEU = a + b_i*Eff_{t-1} + b_2OWN + b_nX_n (X_n=Other exogenous and control variables). Secondly, regress port efficiency (DEA scores) with the prediction values of port throughput and other determinants of port efficiency.

variances. Nonlinear relationships are estimated for both equations.[21] The equations are linearized for parameter estimation by taking respective natural logs. The models conceptualize that port efficiency is determined by scales of container production and different levels of spatial and institutional factors, as will be detailed.

7.4.2. Port institution and port efficiency

Port ownership

In terms of port institutions, port ownership as micro-level institutional practice can influence port efficiency. In this model, it is hypothesized that the mechanisms with which port ownership influence port efficiency can be bi-directional:

Firstly, port ownership, noting the degree of intra-port competition and separation of the public sector from direct terminal operation and container production, can impact port efficiency directly through a behavioral change in terminal operation and management. It is closed to a mechanism that such private sector participation as leaseholds and concessions can directly increase the pure technical efficiency captured in DEA and MPI in the last chapters.

Secondly, port ownership can also influence port efficiency through the process of increasing production scales, or scale efficiency. When ports are purely publicly operated, they exclude opportunities to invite global operators or other terminal

[21] Out of many possible mathematical forms, this functional form is most appropriate based on economic and statistical criteria.

operators that have achieved substantial expansion of cargo handling mainly by mobilizing investment in new construction and expansion of container terminals. In other words, by leasing and concessioning terminals and assets to finance investment in newly constructed and expanded terminals, ports are able to handle more outputs that eventually create economies of scale. Therefore, theoretically, the mechanisms that port ownership influence port efficiency can be conceptualized in Figure 7.8. as one of the dependent variables for both models of port efficiency and port throughputs.

Three dummy variables capture port ownership (Public Operating, Mixed, and Landlord) in the port efficiency model. They are compared with port efficiency of "Non-government Operating Port." It is expected based on the bivariate analysis that container port productivity comes from actual institutional practice of ports. The sources of port efficiency can be (1) intra-port competition, (2) allocation of terminal assets to attract private sector investment which leads to upgraded port and terminal infra- and superstructure, and (3) the separation of day-to-day container production terminal operation and production from the government's hand.

Corporate structure

This is the meso-level institutional framework discussed in the Chapters 2, 3, and 4. The corporate and management structure may directly influence port efficiency based on the autonomy and decentralization acquired at a port authority level. It may create behavioral changes and efficient utilization of resources in ports. It is thus modeled as one of the exogenous variables that directly influence port efficiency. The variable is designed to be a dummy for either a corporate port (Government Owned Corporation or Private port) or a non-corporate port (National, State, Local, Statutory Authority).

Inter-port competition

This involves a macro-level institutional environment. The intensity of Hinterland Accessibility Index (HAI) generally attempts to capture spatial (locational) and economic opportunities of hinterland discounted by threats from competing ports. Higher inter-port competition induces ports to act more proactively and strategically. Therefore, when ports face higher intensity of inter-port competition (the lower HA index), port efficiency becomes higher (smaller DEA scores).

China factor (CHN): control and confirmatory variable

One dummy variable is included in the port efficiency model in order to capture the difference in terms of port efficiency between Chinese ports and ports in other countries. Chinese ports have been regarded as an unusual case in their expansion and productivity improvement in the last several years. Their successes are attributed to many factors.[22] The dummy variable is designed to capture, firstly, whether there is any difference in port efficiency and, secondly, confirm whether there are other reasons that cannot be explained by the factors suggested in the models. It thus allows us to confirm whether the models can explain globally consistent phenomena and determinants of port efficiency.

[22] The reasons of their successes include rapidly emerging hinterland economies, locational factor in relation to global shipping routes and systems, newly constructed and physically well-organized terminal structure, institutionally joint-venture cooperation linking governments and global port operators. Most of which are considered by the models in this chapter.

7.4.3. Determinants of port throughput

Along with institutional factors discussed in the section 7.4.2., another factor to consider, as suggested in Chapters 5 and 6 is that ports become more efficient when they have larger production scales and can reap the benefits of economies of scale. The scales of container port throughput are, on the one hand, a determinant of port efficiency and, on the other hand, modeled at the first stage based on factors classified by three different levels of conditions and strategies facing ports: port and terminal level, local and surrounding area level, and continental and regional level. These conditions and strategies tend to influence port efficiency through allowing ports to have larger outputs rather than direct behavioral changes in port management and terminal operation.

7.4.3.1 Port and terminal-level condition and strategy

Port efficiency at a previous period (EFF_{t-1})

Port efficiency can be one of the most important variables in generating large port outputs. Most shippers choose ports based on reputation on service efficiency, which consists of such factors as delays, reliability, and urgency, documentation and tracing capabilities (Tongzon 1995). Moreover, port efficiency represents levels of port charge since it should be highly correlated with levels of port charges (Clark et al. 2002; Tonzon 1995; Tongzon et al. 2005). In general, the more efficient the port, the lower the port charges.

Port connectivity and economies of network (CON)

The most important key players in the operation of logistics services are ports and the shipping lines connecting them. The port should be connected since the "connectedness" influences the container volumes that are moved through each port. In many studies of port choice models, the frequency of shipping services and directness and flexibility of routes is one of the crucial determinants of port choice (Slack 1985; Bird and Bland 1988). Moreover, it is also argued that ports face the constant risk since the, "port client has rearranged its service networks or has engaged in new partnerships with other carriers" (Notteboom and Winkelmans 2001; Tongzon 2005). Yet, it seems that, from the perspective of ports and shippers, port connectedness is also related to economies of network.[23] Shipping networks can be more valuable to shipping lines and clients when there is more connectedness with direct liner services and port partners. Large networks with more players and connectedness will have better opportunities to attract more shipping lines and cargoes than smaller networks. As a result, ports with larger networks would have a greater potential to grow faster. In short, the more players in a network of ports and shippers, the higher the value of network due to the advantages (e.g. flexibility) produced by the connectedness. The connectivity enjoyed by a port is proxied by the number of direct liner service in a port.

[23] If economies of network exist [regionally], a universal interconnected network in the region is likely to emerge because of the advantages it offers subscribers, but it does not mean that the network inevitably will be operated by a single firm. That occurs only if there are economies of scale in the supply of networks such that it is cheaper for one firm to provide a universal network than for several independent or interconnected firms to do so (Gomez-Ibanez 2005: 9).

Container terminal depth (DEP)

The depth of container terminals is an essential element in attracting super mega ships such as Super Post-Panamax that allow ports to enjoy economies of scale. Consequently, in order to increase scales of total throughput, dredging has thus been one of the most important components for port infrastructure investment. The average meter of container terminals is thus included to capture these aspects.

24 hour handling service (WHR)

The "24-hour 7-day" cargo handling service has been increasingly adopted by ports. Basically, it is a strategy to increase the flexibility of cargo handling that provides shipping lines and carriers with the benefits of promptness in transit time and convenience in cargo service.[24] In order to capture the effects of this service, ports are classified as three different types based on the scope and practice of the service implemented in the terminals. Ordinal values are assigned if 1 = the service is adopted at entire terminal levels in a port, 0.5 = the service is adopted in parts of container terminals, and 0 = the service is not adopted at a port.

Global terminal operator (GLOP): Terminal-level "Coopetition"

In the last decade, a total of 25 companies have emerged as global terminal operators which have significantly transformed the structure of the global seaport sector (DSC, 2004). They are either private or state-owned companies that operate container

[24] The importance of this issue was discussed and developed based on comments from Professor Elizabeth Deakin in Fall 2005.

terminals in more than one geographic region. They are classified as global stevedores, global carriers, and global hybrids.[25]

Their involvement in terminal operation means that container terminals are operated by specialized entities for cargo handling and operating terminals with better investment programs for port infrastructure and superstructure. They are often under the force of "coopetition," both competing and cooperating with each other within a port (Song 2006). Therefore, ports working with global operators are expected to become more efficient in general. The shares of TEU handled by global operators in a port's container production are used as a variable.

7.4.3.2 Local and surrounding area condition and strategy

Regional development strategy (FTZ)

A Foreign/Free Trade Zone (FTZ) is adopted in many countries as a strategy to promote regional development. While the mechanisms that FTZ uses to attempt to create regional advantages are varied, they promote "freer trade" within certain areas by adopting diverse frameworks of incentive (e.g. tax free) (UN ESCAP 2005). The designation of FTZ around a port may encourage manufacturers to move into the zone, which in turn attracts more container cargoes to the respective ports.

[25] Global Operators include eleven global stevedores (HPH, PSA, P&O, Eurogate, DPA, SSA Marine, HHLA, CSX World, Dragados, Group TCP, ICTSI), ten global carriers (CMA CGM, Evergreen, Hanjin, American President Line (APL), K Line, Mediterranean Shipping Company, Mitui OSK Line, P&O Nedlloyd, Yangming Line, Hyndai merchant line), and four global hybrids (APM, Cosco Pacific, NYK Line, OOCL).

Port-city as direct influence (CTYP)

The city-port relationship and integration is often considered as a crucial element in explaining prospering and declining ports. Cities are the most direct and closest economic hinterland and port efficiency is accompanied by economic performance of port cities.[26] The additional social and environmental issues surrounding port cities are also urgent matters that influence port efficiency. Sustainable and harmonious cohabitation between city and port should be ensured if ports intend to achieve a higher level of performance. Moreover, port-cities are a potential source to acquire abundant labor and other resources for port competitiveness. Along those lines, in order for ports to have larger outputs, port cities should prosper in economic and demographic terms. It is thus projected that larger populations of port cities attract more cargoes in their respective ports.

Surface infrastructure condition of surrounding regions (INF)

The condition of the surface infrastructure including such things as roads, rails, and telecommunications is one of the strongest elements to influence port production activities (Clark 2001; Turner et al. 2004). If the condition of the infrastructure in the surrounding regions is not favorable for the shipping of cargoes, shippers can choose other ports and this is mainly due to the lack of reliability of the shipping service, thereby deviating cargoes to other areas. The surface infrastructure index is created in order to capture infrastructure conditions, as shown in Appendix 7.3.[27]

[26] For detail discussions, see http://www.aivp.org

[27] Ideally, infrastructure index should be created at local levels around which each port resides, but the data is not available at the local levels for the ports. This study uses the country level index to proxy the infrastructure condition faced by ports.

7.4.3.3 Regional-level condition

Regional dummy (REG)

In a large geographical picture, such regions located far from the major economic areas and shipping routes in the North have inherent disadvantages against generating demands for cargo handling and opportunities for becoming hub ports. The regional dummy captures the locational disadvantage at continental and regional levels in order to generate cargo traffic. The regional dummy noted as "Far Region" includes ports located in Australasia, Southern Africa, West Africa, North Africa, East Africa, and Scandinavia/Baltic.[28]

7.4.4. Data and sources

The cross-sectional data used for the models are in line with the data used for Chapters 4 and 5 as well as the previous sections in Chapter 7. The port efficiency data are generated by contemporaneous DEA analysis for the years 2003 and 2004 with 139 ports. It is produced from output-oriented models under the constant returns to scale assumption. Other data sources and descriptive statistics are detailed in Appendix 7.3.

[28]The regions are defined in CIY (2005).

7.4.5. Results of estimation

The OLS results for equations (4) and (5) are presented in the columns (a) and (c) in Table 7.8. Column (d) shows the result of the Tobit regression estimation for equation (5). Since the DEA scores do not have negative values and several zero values noting the most efficient ports, the distribution of the dependent variables are not truly normal. For the truncated normal distribution of dependent variable, a Tobit procedure produces better estimation results (Tobin 1958, Maddala 1983; Windle and Dresner 1995).

The Jarque-Bera test points to the normal distribution of residuals for the specified models. The Breusch-Pagan test shows that no hetereoskedasticity at the five percent significance level.

7.4.5.1 First Stage: Port output model

Most of the parameters in the port output model (Table 7.8) are statistically significant as portrayed previously. Port efficiency at the previous period is one of the most crucial variables in explaining the port output level. Port connectivity, terminal depth, and the percent of TEU handled by global operators are also important and statistically significant.

Purely public operating ports are significantly smaller than other types of port ownership, thereby preventing ports from bringing in the benefits from economies of scale. Other hinterland economic and geographical factors such as city population and regional dummy can also capture the effect on scales of port production in a statistically meaningful way. In addition, the surface infrastructure conditions at a country level is weakly meaningful on the borderline at the 10 percent level.

Table 7.8: Results of OLS and Tobit Estimation[29]

Dependent / Explanatory	lnTEU (Port Throughput)		lnDEA (Port Efficiency)		
	Coefficients (a)	Coefficients (b)	Variables	Coefficients (c)	Tobit Coeff. (d)
Constant	9.04	8.99	Constant	7.49	7.57
	(8.08)***	(8.19)***		(15.99)***	(21.76)***
$lnDEA_{t-1}$ (-)	-1.03	-1.03	lnTEU_P (-)	-0.45	-0.46
	(-11.64)***	(-12.00)***		(-14.39)***	(-19.58)***
lnCON (+)	0.39	0.39	lnCOM (+)	0.08	0.08
	(5.90)***	(5.99)***		(2.66)***	(2.73)***
lnDEP (+)	1.48	1.49	CORP (-)	-0.05	-0.04
	(4.27)***	(4.34)***		(-0.40)	(-0.40)
lnWHR (+)	-0.05		OWN		
	(-0.35)		PUB (+)	-0.12	-0.13
PUB (-)	-0.38	-0.36		(-0.74)	(-0.96)
	(-2.92)***	(-2.92)***	MIX (+)	0.34	0.35
FTZ (+)	0.03			(2.00)**	(2.38)**
	(0.26)		LORD(+)	0.30	0.30
lnCTYP (+)	0.09	0.09		(1.98)**	(2.41)**
	(2.37)**	(2.38)***	CHN (-)	-0.14	-0.18
lnINF (+)	0.03	0.03		(-0.97)	(-1.28)
	(1.57)	(1.66)*			
lnGLB (+)	0.12	0.11			
	(3.82)***	(-3.83)***			
REG (-)	-0.24	-0.25			
	(-1.76)*	(-1.76)*			
Adjusted R^2	0.818	0.821		0.664	Pseudo R^2 = 0.680
F-test	62.138	78.754		39.076	
Jarque-Bera	2.343	2.124		5.277	
Breusch-Pagan	15.473	8.286		13.558	

*** statistically significant at the 1 % level, ** significant at the 5 % level, * significant at the 10 % level

[29] Jarque-Bera test is used for the normality of residuals. Breusch-Pagan test is to check an absence of heteroskedasticity. Jarque-Bera: critical value 4.61 (10%), 5.99 (5%). Breuschi-Pagan: critical value 15.99 (10%) 18.31 (5%) for (1).

Two variables, WHR and FTZ, do not show their statistical significance and less explanatory power for container production scales. However, the variable of WHR (service flexibility) is partly reflected by the variables of PUBLIC and DEA (port efficiency) according to some levels of correlations between the variables. Many ports which do not provide "24 hour, 7 day service" are purely publicly operating ports and less efficient in terms of port and terminal service. Therefore, the parameters should be carefully interpreted by comprehending that it may still be possible for the service flexibility to influence port outputs through this mechanism.

Finally, FTZ does not show both strong explanatory power and statistical significance. It is mainly due to the fact that, in recent years, a large portion of the world governments attempted to designate a FTZ around their ports and airports in the recent years, and therefore, it is relatively difficult to make a distinction as to port efficiency, by only adopting FTZs as regional development policies. It implies that, at the current stage of FTZ development, the discussion should be directed more importantly to what types of FTZ should be developed in order to attract foreign firms and cargoes and how effective incentives and strategies can be implemented to yield better outcomes among various mechanisms of FTZ that have been emerging. Column (b) in Table 7.8 presents the results of equation (4) without including FTZ and WHR to reduce multi-collinearity. The results in column (b) show no difference from those in column (a).

7.4.5.2 Second stage: Port efficiency model

The parameters in the port efficiency model demonstrate the importance of economies of scale as the source of port efficiency. At the same time, the model also emphasizes the role of port institution:

Firstly, the intensity of spatial inter-port competition is an important source to induce ports to become more efficient. As hinterland accessibility becomes larger (or less inter-port competition), DEA scores get higher (less port efficiency). Therefore, a macro-level institutional environment is critical in shaping ports to act more strategically and proactively.

Secondly, regarding port ownership, as is shown in the previous bivariate analysis, the model suggests that both Mixed and Landlord ports are usually less efficient than Non-government Operating ports at the five percent level. Yet, public operating ports do not show any statistically meaningful difference from Non-government Operating ports. The results of the two models imply that less efficiency in public operating ports comes mostly from their inability to generate economies of scales since they handle significantly fewer outputs than other types of port. It is reasonable in the sense that they do not use the mechanisms of lease and concession, which has been popular in the last decade, to construct container terminals with newly induced investment.

Consistent with the bivariate analysis, the corporate and management structure of port authorities do not necessarily determine port efficiency. Finally, the dummy variable for

Chinese ports (CHN) does not have statistically significant parameters, noting that the growth and efficiency of Chinese ports in the current period can be adequately explained by factors suggested in the models.

In general, regarding the role of institution on port infrastructure productivity, from the results of the analyses, it is possible to identify the importance of inter-port competition and ownership and asset management practice of ports. The specific findings and policy implications are discussed in Chapter 8.

CHAPTER 8

Conclusions and Policy Implications

8.1 The Role of Inter-port Competition

From the results of previous analyses from Chapter 4, 5, and 6 and the models presented in Chapter 7, I identify and emphasize the role of port competition policy and vertical unbundling of separation between port regulatory function and container terminal operation function.

Those who have anti-inter-port competition perspectives argue that inter-port competition may cause ports to bear higher risks during the process of maintaining their competitiveness. Container ports under a competitive market may have to overly invest in sophisticated equipment or in dredging channels to accommodate recently popular super-mega ships. In contrast, since container-shipping lines have multiple choices among ports to handle their cargoes, the ports therefore face the risk of losing their customers to competitors. As a result, it may lead to the lack of productivity.

However, as shown in the models in Chapter 7, it is doubted that the nature of inter-port competition always creates disadvantages against ports from the policy making perspective. The higher risks faced by a firm in a competitive market are not a unique phenomena in the port sector and are not always disadvantageous against ports. In many other industries, risks for bankruptcy by losing from competition are usually an inherent incentive for firms to adopt innovative and strategic behaviors.

In the past, the major reasons why the oligopolistic market could be justified in the port sector were that port infrastructure may be subject to natural monopoly that (1) requires durable and immobile investments and (2) can possibly acquire increasing returns to scale at a firm level: However, firstly, it seems that the problem of durable and immobile investments can be, at least, partly resolved through concession contracts or long-term leases, as suggested in the models. Moreover, even if the port industry is characterized by lumpiness of investment, it is questionable that the characteristics can be a more substantial reason to rationalize mistakes from forecasting errors than other industries. As observed from large investments by most of successful manufacturing firm, in technology and R& D, the port sector is not the only one that is subject to lumpy investment. Secondly, as shown in Chapter 5, while many large scale ports are efficient than smaller ports, they are operating under decreasing returns to scale at each firm level. In this sense, it can be possible to increase port productive efficiency in a region by introducing inter-port competition that may theoretically replace one large port operating under DRS with two ports operating IRS.

From a societal perspective, the status of ‘hyper-competition’ may exist at a certain point under which social costs and disadvantages from the status exceed the benefits produced by competition at societal levels. However, many problems of low productivity in the port sector and its impact on economy and society were not mainly caused in the past by 'hyper-competition' but by a lack of competition. This is particularly so in the current period since no sign of non-linearity is observed in Figure 7.5.A in Chapter 7. Given the oligopolistic nature of port sectors in the past, creating certain levels of inter-port competition is essential in inducing innovative behaviors and better services to the current status of port production. Consequently, policies sustaining inter-port competition provide a potential to shape better productivity as macro-level institutional environments.

Under this circumstance, it is reasonable for port authorities and managers to consider the increasing capacity of strategic capital management and long-term capital programming rather than blaming the competitive market structure. Ports are responsible for projecting future demand as correctly as possible, closely monitoring their assets, assessing their strengths and weakness under market conditions, developing scenarios and creating new sections of markets, and upgrading facilities and technology through diverse and innovative financing mechanisms. Especially when it is considered that many ports are publicly managed and operated with public resources, the capability of strategic management by port authorities is much more crucial in order not to waste the resources. Only when ports can effectively and strategically respond to the newly created environments in the contemporary era, can ports survive and flourish in the existing nodes and networks.

Especially in the regions that currently enjoy both small numbers of competitors and large hinterland sizes based on rapidly developing economies and trades, ports will face much larger demands, which may be qualitatively different amounts from those experienced in the past. Furthermore, even though some nuances of protectionism may still exist within those arrangements, increasing numbers of regional trading arrangements (RTA), as well as bilateral and multilateral free trade agreements (FTA), may also have the potential to create new waves of international trade.

However, the qualitatively enlarged demands allow entry barriers to be lowered by reducing the risks caused by the initial sunken costs and lumpy investment in the previous system of nodes and networks. It will be relatively easier in the future in that this environment will create the conditions in which some incumbent ports face serious challenges to realign the previous nodes and the networks. Parts of this scenario are already being realized in East Asia, South Asia, as well as Northern and Southern Europe, as observed in the battles among transnational terminal operators in many ports. For example, some expect that, in the future, the hierarchies of Busan and Hong Kong will not as high as the level in the current system (Loo and Hook 2002).

In terms of policy making perspective, as argued here, creating appropriate levels of inter-port competition is a meaningful tool for inducing better port productivity and addressing organizational inertia. However, despite the meaningful theoretical findings on the roles of inter-port competition on port efficiency, two interconnected policy making issues are still not totally resolved and will require further attention in the future:

Firstly, it is still essential to contemplate how much policy making vis-à-vis inherent geographical conditions can either promote or discourage the intensity of inter-port competition among ports. Sometimes, it cannot be fully refutable that inter-port competition is something that can be achievable only when certain geographical features are conditioned. For example, the reasons why ports in Europe and South Asia have a higher intensity of competition than those in the US can be the proximity among many different countries within the relatively small regions, and therefore ports should inherently compete with each other under the global system. However, in general, the US lacks the possibility to bring in this sort of "natural spatial competition." Under this circumstance, it is still essential to look further into whether, how much, and what efforts should be devoted to create conditions that allow those ports to face some levels of pressure that makes the European and South Asian ports more productive.

One clue is that, as argued in Chapter 2, in the port sector, it is not inherently always clear where the boundaries between institutions and geographical forces. In other words, the concept of inter-port competition includes not only characteristics of locational advantages but also country or regional level institutional mechanisms and policies making market structure more competitive. The role of governments should be involved in creating and shaping the market structure that become a fair ground for competition through diverse policies, regulations, and customs procedures.

Furthermore, in many cases, inter-port competition has been more severe over the last decade, not because ports have wanted to create or face it, but partly because terminal operators and other cargo handlers in the global system have tried to compete to attract more shippers and cargoes. It has been also enlarged as the power of shippers (clients) has more strengthened than the market power exercised by ports. If different global terminal operators can be invited in ports around the same region, it may be a signal to intensify inter-port competition and private sector participation in port investment and operation. In other words, while they are not an exactly the same concept with different names (such as head and tail of a coin), the inter-port competition that emerged in the last decade certainly had an overlapped interface with "intra-port competition" or "private sector participation" through leaseholds and concessions at container port and terminal levels.

Secondly, the first issue is naturally related to the policy question, "What are the geographical boundaries or scopes within which inter-port competition optimally work?" Of course, the scopes certainly vary, and this based on many different economic and social conditions and how society values economic and social costs differently. For example: Whether or not a country, like Korea, where the total size is smaller than California must require freer inter-port competition between ports even within a country? It may be a daunting question for policy makers to find answers despite a general finding in this chapter inclining toward encouraging inter-port competition. Economic simulation studies may be helpful at a country or a state level to resolve this enigma. Or, it is also meaningful to develop a comparative organizational case study to see how different levels of pressure from inter-port competition can change and impact inner organizational behaviors differently.

8.2 The Role of Corporate Structure and Asset Ownership Practice

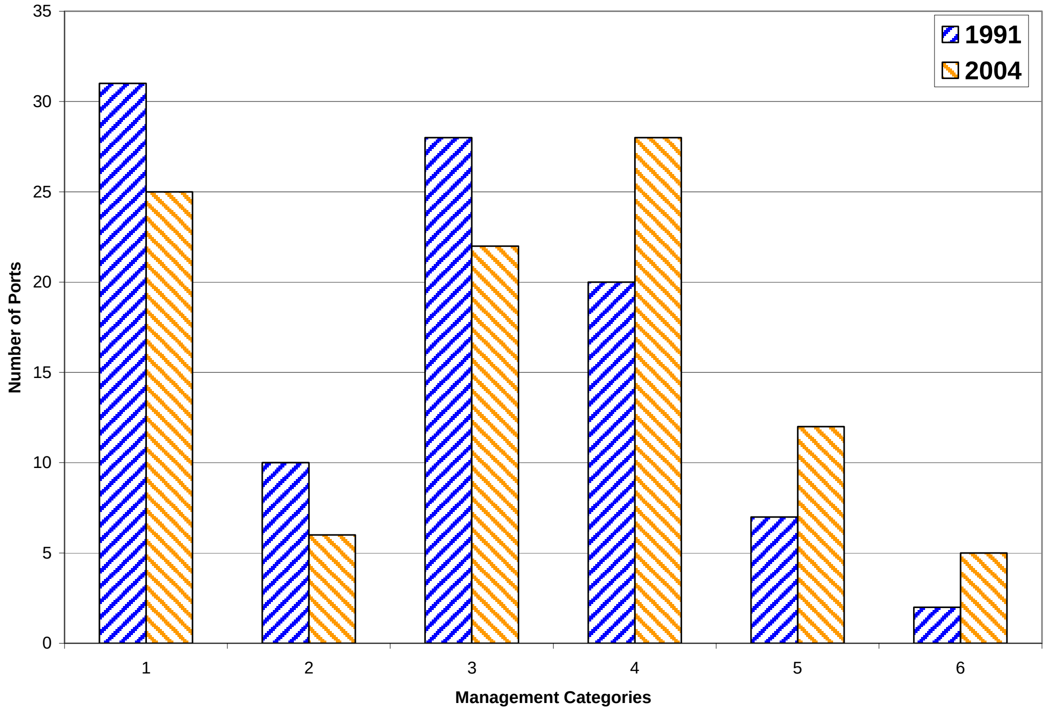
Regarding the relationship between port efficiency and meso- and micro-institutional characteristics, on the one hand, it is not possible to accept the hypothesis, "The more decentralized corporate structure of port authorities does always lead to proven higher productivity of ports, based on growing autonomy in management of port authorities." It seems that, unlike concession contracts, port corporatization is predicated on relational contracts on the basis of statute. Since the corporatization scheme can be originally loosely defined and produce various mechanism of implementation. Unless they are specifically secured through additional legal or institutional mechanisms, the performance benefits may not be as high as those of concession contacts that include detail statements regarding efficiency or performance targets. Therefore, too much attention paid to *formal* institutional structure at a port level may not seriously improve port productivity and competitiveness. The more important focus should be directed to: "how strategic behavior and management of a port can be assured through the corporatization frameworks as contracts between port enterprises and governments?"

On the other hand, it is my view that container port productivity largely comes from the actual ownership practice and asset management of ports. The mechanisms that have improved port infrastructure productivity are mainly based on ports' efforts to seek *strategic flexibility with institutional bindings*, which can be "vertical unbundling" through concessions and leases. If container production and terminal operation functions are maintained internally, port authorities or governments have to develop an effective internal monitoring and management system to sustain the performance of employees handling containers by motivating them to work it efficiently. In the past, when both container production and regulation are practiced by the same government entities, it does not sufficiently generate the momentum for ports act more productively. By adopting long-term lease and concession contracts, ports induce intra-port, or sometimes even inter-port, competition that can partly provide incentives for operators to keep their efficiency high and new investment in upgrading of infra- and super-structure.

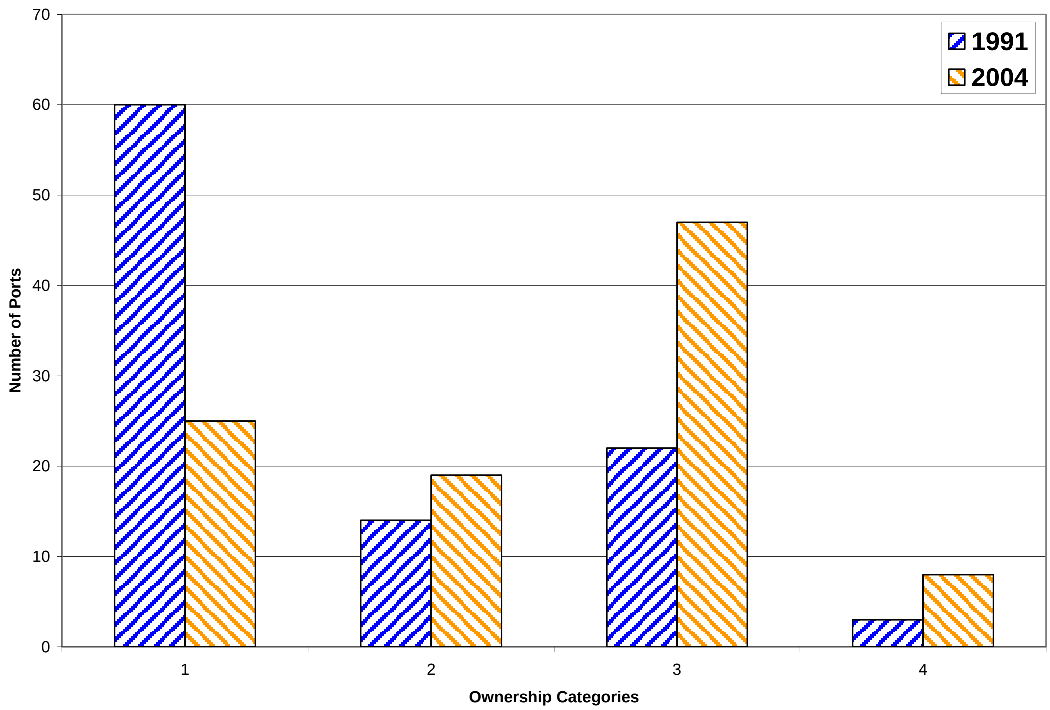
The lesson is that, therefore, the direct business side of terminal operation and management can be pursued through private sector participation. The government sector should focus more on policy making on environmental, safety, and customs regulations. They also collaborate with other partners on long-term planning and finance for port and nautical infrastructure, and creating a market structure to reduce regional and national monopolistic characters.

Appendix 4.1 Ownership and Management Transformation of Top 100 Ports

***Management**: (1) national government; (2) state or provincial government; (3) local government; (4) statutory authority or corporation; (5) government owned corporation; (6) private enterprise*



***Ownership**: (1) public operating Port; (2) mixed ownership Port; (3) public landlord port; (4) Non-Government port*



Appendix 5.1 DEA Scores from Intertemporal Analysis

DEA (IOV): DEA Score acquired from the Intertemporal, Output-oriented, Variable Returns-to-Scale DEA Model
DEA (IOC): DEA Score acquired from the Intertemporal, Output-oriented, Constant Returns-to-Scale DEA Model

Year	Port Name	DEA (IOV)	Rank (IOV)	DEA (IOC)	Rank (IOC)	Σλ	RTS
2004	Hong Kong	1.000	1	1.000	1	1.00	Constant
2004	Singapore	1.109	14	1.309	9	11.62	Decreasing
2004	Busan	1.271	17	1.519	15	10.05	Decreasing
2004	Kaohsiung	1.057	13	1.378	11	8.19	Decreasing
2004	Shanghai	1.000	1	1.102	7	1.82	Decreasing
2004	Rotterdam	2.550	63	3.178	69	8.55	Decreasing
2004	Los Angeles	2.425	58	3.180	70	5.83	Decreasing
2004	Hamburg	3.323	97	3.767	103	2.79	Decreasing
2004	Long Beach	3.309	96	3.497	84	1.65	Decreasing
2004	Antwerp	3.345	100	4.220	116	8.92	Decreasing
2004	Port Klang	2.351	53	2.436	40	5.44	Decreasing
2004	Dubai	1.341	20	1.381	12	0.35	Increasing
2004	New York/New Jersey	3.598	112	4.270	119	2.87	Decreasing
2004	Bremen/Bremerhaven	3.502	110	3.533	86	0.56	Increasing
2004	Felixstowe	2.633	65	2.690	54	0.35	Increasing
2004	Yantian	1.000	1	1.000	1	1.00	Constant
2004	Qingdao	2.168	43	2.278	34	12.08	Decreasing
2004	Tokyo	2.100	40	2.381	38	7.35	Decreasing
2004	Gioia Tauro	2.287	49	2.310	35	1.74	Decreasing
2004	Laem Chabang	2.227	47	2.558	48	12.32	Decreasing
2004	Yokohama	3.820	123	4.314	121	9.50	Decreasing
2004	Manila	1.865	30	2.069	29	3.16	Decreasing
2004	Tanjung Priok	2.504	62	2.590	50	1.17	Decreasing
2004	Algeciras	2.647	66	2.668	52	1.59	Decreasing
2004	Tanjung Pelepas	2.188	45	2.189	31	0.74	Increasing
2004	Kobe	6.116	175	7.852	186	15.57	Decreasing
2004	Tianjin	1.689	27	1.739	19	2.64	Decreasing
2004	Nagoya	4.536	142	4.547	123	0.93	Increasing
2004	Keelung	1.616	23	1.775	20	5.61	Decreasing
2004	Guangzhou	1.000	1	1.000	1	1.00	Constant
2004	Colombo	2.113	41	2.227	33	7.00	Decreasing
2004	Oakland	5.547	166	7.224	174	7.24	Decreasing
2004	Charleston	3.724	118	3.814	104	0.32	Increasing
2004	Genoa	3.266	92	3.673	97	2.31	Decreasing
2004	Le Havre	4.279	138	5.167	142	9.26	Decreasing
2004	Osaka	3.266	91	3.558	88	6.17	Decreasing
2004	Valencia	3.512	111	3.833	105	5.28	Decreasing
2004	Barcelona	3.293	95	3.626	93	7.03	Decreasing
2004	Tacoma	3.659	114	3.694	98	1.04	Decreasing
2004	Seattle	4.518	141	5.376	146	3.29	Decreasing
2004	Virginia	2.960	75	3.012	62	1.29	Decreasing
2004	Xiamen	1.159	16	1.197	8	0.33	Increasing
2004	Tanjung Perak	1.880	31	1.880	23	0.97	Increasing

2004	Melbourne	3.292	94	3.410	79	3.02	Decreasing
2004	Ningbo	1.926	34	1.931	25	1.13	Decreasing
2004	Dalian	3.645	113	3.645	94	0.94	Increasing
2004	Durban	2.620	64	2.869	58	1.85	Decreasing
2004	Jawaharlal Nehru	1.908	32	1.926	24	0.78	Increasing
2004	Salalah	1.844	29	1.963	27	0.17	Increasing
2004	Jeddah	3.197	88	3.308	74	0.32	Increasing
2004	Piraeus	2.668	68	2.850	57	4.09	Decreasing
2004	Marsaxlokk	2.662	67	3.013	63	6.06	Decreasing
2004	Southampton	2.178	44	2.191	32	0.63	Increasing
2004	Vancouver BC	3.444	106	3.583	91	2.35	Decreasing
2004	Khor Fakkan	1.639	24	1.648	17	1.38	Decreasing
2004	Savannah	3.750	120	3.753	102	0.76	Increasing
2004	Taichung	3.009	79	3.078	66	1.39	Decreasing
2004	Bangkok	4.879	153	5.024	139	1.86	Decreasing
2004	Houston	4.253	137	4.258	118	0.72	Increasing
2004	Santos	2.420	56	2.546	47	3.16	Decreasing
2004	Sydney	5.257	160	5.570	151	4.88	Decreasing
2004	Montreal	4.037	130	4.489	122	6.54	Decreasing
2004	Kingston	5.553	167	5.611	152	0.47	Increasing
2004	La Spezia	3.101	85	3.130	68	1.44	Decreasing
2004	Puerto Manzanillo	2.479	60	2.605	51	2.54	Decreasing
2004	Miami	6.791	183	6.939	172	0.34	Increasing
2004	Honolulu	2.404	55	2.471	44	0.40	Increasing
2004	Chiwan	2.424	57	2.446	42	2.06	Decreasing
2004	Gwangyang	3.774	121	4.292	120	2.44	Decreasing
2004	Zeebrugge	5.450	164	6.018	161	7.52	Decreasing
2004	Haifa	1.408	21	1.684	18	2.64	Decreasing
2004	Jacksonville	6.412	179	6.437	166	0.62	Increasing
2004	Gothenburg	4.813	150	5.052	140	2.18	Decreasing
2004	Karachi	1.796	28	1.858	22	2.22	Decreasing
2004	Buenos Aires	9.811	216	11.056	217	10.94	Decreasing
2004	Damietta	2.821	70	3.037	64	0.14	Increasing
2004	Puerto Cabello	3.133	86	4.761	133	3.83	Decreasing
2004	Shahid Rajaee	2.259	48	2.351	36	1.97	Decreasing
2004	Las Palmas de Gran Canaria	3.400	103	3.655	95	3.02	Decreasing
2004	Puerto Limon	1.000	1	1.000	1	1.00	Constant
2004	Abidjan	2.089	39	2.099	30	0.96	Increasing
2004	Veracruz	1.943	35	2.441	41	0.09	Increasing
2004	Cartagena	3.331	98	3.474	81	1.98	Decreasing
2004	Izmir	2.073	38	2.467	43	0.08	Increasing
2004	Rio Haina	2.928	74	2.986	61	0.85	Increasing
2004	Chittagong	1.000	1	1.000	1	1.00	Constant
2004	St Petersburg	5.692	171	5.839	158	0.62	Increasing
2004	Brisbane	5.106	157	5.300	145	4.02	Decreasing
2004	Auckland	4.151	133	4.210	115	0.78	Increasing
2004	Helsinki	4.707	148	4.737	131	1.15	Decreasing
2004	Lisbon	5.241	159	5.498	149	4.53	Decreasing
2004	Dublin	3.012	80	3.098	67	1.47	Decreasing

2004	Guayaquil	2.470	59	2.839	56	0.19	Increasing
2004	Aarhus	6.817	184	6.868	169	1.16	Decreasing
2004	Saigon Newport (Cat Lai & Tan Cang)	3.012	81	3.234	71	0.14	Increasing
2004	Aden	7.649	201	8.609	195	0.12	Increasing
2004	San Antonio	5.274	162	5.432	148	0.47	Increasing
2004	Fremantle	4.924	154	5.429	147	3.33	Decreasing
2004	Casablanca	2.333	52	2.377	37	1.46	Decreasing
2004	Puerto Cortes	3.916	126	4.024	108	0.84	Increasing
2004	Montevideo	3.787	122	4.691	130	0.08	Increasing
2004	Tauranga	3.176	87	3.313	75	0.49	Increasing
2004	Port of Spain	5.897	172	5.923	160	0.97	Increasing
2004	Havana	4.192	135	4.842	134	0.37	Increasing
2004	Aqaba	2.332	51	2.723	55	0.35	Increasing
2004	Limassol	3.841	124	4.047	109	1.68	Decreasing
2004	Gdynia	4.598	145	4.851	135	0.62	Increasing
2004	Santo Tomas de Castilla	3.350	101	3.550	87	0.61	Increasing
2004	Shuaiba	10.408	223	10.769	213	1.61	Decreasing
2004	Port Louis	5.489	165	5.798	156	2.13	Decreasing
2004	Oslo	11.315	228	11.875	222	0.30	Increasing
2004	Djibouti	4.314	139	5.544	150	0.12	Increasing
2004	Mina Sulman	5.392	163	6.027	162	0.43	Increasing
2004	Douala	3.468	107	4.067	110	0.26	Increasing
2004	Dakar	7.303	191	7.524	180	1.96	Decreasing
2004	Dar-es-Salaam	4.610	147	4.982	137	0.63	Increasing
2004	Port Sudan	5.102	156	5.880	159	0.56	Increasing
2004	Pointe-a-Pitre	7.422	195	8.353	192	0.39	Increasing
2004	Constantza	16.649	235	16.829	231	2.16	Decreasing
2004	Riga	4.246	136	5.221	143	0.30	Increasing
2004	Koper	7.666	202	8.401	193	0.42	Increasing
2004	Toamasina	7.595	200	9.492	203	0.53	Increasing
2004	Tallinn	10.150	220	10.387	211	1.63	Decreasing
2004	Bridgetown	7.722	203	7.975	189	0.93	Increasing
2004	Muara	8.727	208	8.838	198	1.10	Decreasing
2004	Oranjestad	4.119	132	7.559	181	0.16	Increasing
2004	Jurong	7.359	193	7.395	178	1.39	Decreasing
2004	Klaipeda	11.393	229	11.862	221	0.71	Increasing
2004	Varna	10.256	221	11.691	220	0.47	Increasing
2004	Belize City	1.000	1	7.742	185	0.01	Increasing
2004	Walvis Bay	16.353	234	16.465	230	1.13	Decreasing
2004	Rijeka	26.679	238	27.138	237	1.18	Decreasing
2004	Copenhagen	10.808	226	11.570	219	2.19	Decreasing
2004	Inchon	3.091	84	3.322	76	3.12	Decreasing
2004	Mombasa	3.469	108	3.476	82	1.02	Decreasing
2004	Corinto	1.000	1	21.570	234	0.30	Increasing
2004	Doha	3.243	90	3.477	83	0.86	Increasing
2004	Lome	5.236	158	5.268	144	1.04	Decreasing
1991	Hong Kong	1.656	25	1.810	21	7.97	Decreasing
1991	Singapore	1.676	26	1.939	26	12.69	Decreasing

1991	Busan	1.000	1	1.000	1	1.00	Constant
1991	Kaohsiung	2.028	37	2.390	39	4.86	Decreasing
1991	Shanghai	3.285	93	3.324	77	0.88	Increasing
1991	Rotterdam	3.691	116	4.657	129	19.89	Decreasing
1991	Los Angeles	2.873	72	3.590	92	3.33	Decreasing
1991	Hamburg	5.270	161	6.918	170	9.43	Decreasing
1991	Long Beach	4.474	140	5.752	155	4.26	Decreasing
1991	Antwerp	6.945	186	9.059	200	10.77	Decreasing
1991	Port Klang	4.192	134	4.245	117	1.30	Decreasing
1991	Dubai	3.432	104	3.750	101	1.56	Decreasing
1991	New York/New Jersey	8.184	204	9.924	207	3.24	Decreasing
1991	Bremen/Bremerhaven	4.929	155	5.818	157	4.30	Decreasing
1991	Felixstowe	3.361	102	3.364	78	1.03	Decreasing
1991	Tokyo	3.029	82	3.297	73	5.65	Decreasing
1991	Yokohama	3.718	117	4.155	112	6.23	Decreasing
1991	Manila	1.553	22	1.584	16	0.67	Increasing
1991	Tanjung Priok	2.719	69	2.903	59	2.30	Decreasing
1991	Algeciras	3.679	115	3.890	106	2.32	Decreasing
1991	Kobe	3.498	109	4.110	111	12.12	Decreasing
1991	Tianjin	7.202	190	7.301	175	1.36	Decreasing
1991	Nagoya	3.344	99	3.570	90	3.22	Decreasing
1991	Keelung	1.278	18	1.338	10	3.97	Decreasing
1991	Guangzhou	9.308	214	10.191	209	0.46	Increasing
1991	Colombo	2.488	61	2.686	53	2.29	Decreasing
1991	Oakland	6.187	177	6.925	171	7.42	Decreasing
1991	Charleston	4.551	143	4.646	128	0.39	Increasing
1991	Genoa	9.957	217	10.597	212	3.09	Decreasing
1991	Le Havre	6.079	174	7.179	173	2.66	Decreasing
1991	Osaka	7.378	194	7.944	188	4.18	Decreasing
1991	Valencia	4.712	149	4.745	132	0.92	Increasing
1991	Barcelona	4.003	129	4.169	113	2.96	Decreasing
1991	Tacoma	6.493	180	6.495	167	0.93	Increasing
1991	Seattle	5.679	170	6.280	164	4.61	Decreasing
1991	Xiamen	1.000	1	6.164	163	0.22	Increasing
1991	Melbourne	7.048	189	7.633	183	5.02	Decreasing
1991	Cristobal	4.857	152	4.857	136	1.00	Constant
1991	Dalian	2.998	77	3.569	89	0.20	Increasing
1991	Durban	4.559	144	4.579	124	1.02	Decreasing
1991	Jawaharlal Nehru	18.576	236	20.570	233	0.35	Increasing
1991	Salalah	1.000	1	316.458	238	0.30	Increasing
1991	Jeddah	3.442	105	3.464	80	0.86	Increasing
1991	Piraeus	1.135	15	1.385	13	0.31	Increasing
1991	Marsaxlokk	8.746	209	8.931	199	1.22	Decreasing
1991	Southampton	4.607	146	4.610	127	1.01	Decreasing
1991	Vancouver BC	6.003	173	6.350	165	2.28	Decreasing
1991	Khor Fakkan	4.046	131	4.601	125	0.53	Increasing
1991	Savannah	6.957	187	7.386	177	1.33	Decreasing
1991	Taichung	3.214	89	3.712	99	0.23	Increasing
1991	Bangkok	3.071	83	3.236	72	0.24	Increasing

1991	Houston	2.113	42	2.529	46	0.06	Increasing
1991	Santos	2.316	50	2.562	49	0.22	Increasing
1991	Sydney	9.284	211	9.860	206	3.88	Decreasing
1991	Montreal	10.552	224	10.985	215	7.36	Decreasing
1991	La Spezia	1.953	36	1.996	28	1.21	Decreasing
1991	Miami	5.663	169	5.693	154	0.89	Increasing
1991	Honolulu	2.976	76	3.041	65	0.74	Increasing
1991	Zeebrugge	8.530	206	9.269	202	3.57	Decreasing
1991	Haifa	4.835	151	5.005	138	1.93	Decreasing
1991	Jacksonville	8.999	210	10.086	208	0.09	Increasing
1991	Gothenburg	8.363	205	8.654	197	1.32	Decreasing
1991	Buenos Aires	3.920	127	3.926	107	1.03	Decreasing
1991	Damietta	9.294	213	9.774	205	1.82	Decreasing
1991	Las Palmas de Gran Canaria	6.529	181	6.547	168	1.03	Decreasing
1991	Puerto Limon	1.313	19	2.476	45	0.24	Increasing
1991	Veracruz	1.916	33	3.666	96	0.53	Increasing
1991	Izmir	3.009	78	3.725	100	0.51	Increasing
1991	St Petersburg	10.873	227	11.035	216	1.36	Decreasing
1991	Brisbane	12.509	232	13.241	224	2.24	Decreasing
1991	Auckland	5.644	168	5.649	153	0.99	Increasing
1991	Helsinki	3.866	125	4.604	126	0.22	Increasing
1991	Lisbon	2.924	73	2.953	60	1.20	Decreasing
1991	Dublin	7.529	199	7.902	187	1.83	Decreasing
1991	Guayaquil	7.505	198	7.986	190	0.55	Increasing
1991	Aarhus	6.900	185	7.379	176	0.50	Increasing
1991	San Antonio	23.648	237	25.508	236	0.85	Increasing
1991	Fremantle	2.843	71	3.512	85	0.69	Increasing
1991	Casablanca	7.486	196	8.069	191	0.62	Increasing
1991	Puerto Cortes	3.996	128	4.169	114	0.92	Increasing
1991	Montevideo	2.359	54	5.078	141	0.13	Increasing
1991	Tauranga	3.745	119	8.604	194	0.27	Increasing
1991	Aqaba	6.135	176	7.398	179	0.26	Increasing
1991	Gdynia	8.636	207	9.159	201	0.44	Increasing
1991	Santo Tomas de Castilla	10.713	225	11.352	218	0.61	Increasing
1991	Shuaiba	15.786	233	16.407	228	0.71	Increasing
1991	Reykjavik	1.000	1	1.518	14	0.10	Increasing
1991	Djibouti	7.016	188	10.287	210	0.57	Increasing
1991	Mina Sulman	12.153	231	13.586	225	0.43	Increasing
1991	Dar-es-Salaam	6.191	178	7.653	184	0.48	Increasing
1991	Port Sudan	10.103	219	16.425	229	0.20	Increasing
1991	Pointe-a-Pitre	7.492	197	8.641	196	0.28	Increasing
1991	Constantza	10.299	222	17.358	232	0.20	Increasing
1991	Koper	10.025	218	10.920	214	0.54	Increasing
1991	Bridgetown	6.619	182	14.868	226	0.12	Increasing
1991	Oranjestad	11.964	230	21.591	235	0.03	Increasing
1991	Belize City	2.189	46	16.400	227	0.01	Increasing
1991	Rijeka	9.293	212	11.997	223	0.23	Increasing
1991	Copenhagen	9.329	215	9.630	204	2.10	Decreasing
1991	Mombasa	7.325	192	7.574	182	1.38	Decreasing

Appendix 5.2. DEA Scores from Contemporaneous Analysis

DEA (COV): DEA Score from the Contemporaneous, Output-oriented, Variable Returns-to-Scale DEA Model
DEA (COC): DEA Score from the Contemporaneous, Output-oriented, Constant Returns-to-Scale DEA Model

Reference Observations Set: t (year) = 2004

Port Name	DEACOV04	Rank (COV)	DEACOC04	Rank (COC)	Σλ	RTS
Hong Kong	1.000	1	1.000	1	1.00	Constant
Singapore	1.109	11	1.309	7	11.61	Decreasing
Busan	1.262	13	1.520	12	10.05	Decreasing
Kaohsiung	1.039	10	1.333	8	4.37	Decreasing
Shanghai	1.000	1	1.100	5	2.77	Decreasing
Rotterdam	2.550	34	3.179	41	8.54	Decreasing
Los Angeles	2.425	31	3.177	40	7.20	Decreasing
Hamburg	3.323	54	3.763	56	4.10	Decreasing
Long Beach	3.308	52	3.495	46	2.27	Decreasing
Antwerp	3.344	55	4.221	61	8.92	Decreasing
Port Klang	2.352	28	2.436	21	5.43	Decreasing
Dubai	1.341	14	1.381	9	0.35	Increasing
New York/New Jersey	3.597	62	4.264	63	4.46	Decreasing
Bremen/Bremerhaven	3.502	60	3.533	49	0.56	Increasing
Felixstowe	2.633	36	2.690	30	0.35	Increasing
Tokyo	1.975	23	2.335	20	5.63	Decreasing
Yokohama	3.697	64	4.315	64	9.49	Decreasing
Manila	1.724	18	1.977	17	1.83	Decreasing
Tanjung Priok	2.375	29	2.586	27	1.81	Decreasing
Algeciras	2.646	37	2.668	28	1.59	Decreasing
Kobe	6.077	88	7.697	91	11.90	Decreasing
Tianjin	1.637	17	1.739	14	2.63	Decreasing
Nagoya	4.536	75	4.542	67	0.97	Increasing
Keelung	1.430	15	1.457	10	4.08	Decreasing
Guangzhou	1.000	1	1.000	1	1.00	Constant
Colombo	1.957	22	2.000	18	5.92	Decreasing
Oakland	5.487	86	7.109	89	4.89	Decreasing
Charleston	3.725	65	3.815	57	0.32	Increasing
Genoa	3.001	42	3.499	47	2.02	Decreasing
Le Havre	4.124	68	5.058	74	6.80	Decreasing
Osaka	3.107	47	3.500	48	5.07	Decreasing
Valencia	3.313	53	3.835	58	5.28	Decreasing
Barcelona	3.186	49	3.577	50	6.09	Decreasing
Tacoma	3.442	58	3.688	54	1.63	Decreasing
Seattle	4.309	72	5.334	75	3.04	Decreasing

Xiamen	1.159	12	1.195	6	0.48	Increasing
Melbourne	3.294	51	3.412	44	3.02	Decreasing
Dalian	3.472	59	3.640	53	1.43	Decreasing
Durban	2.467	32	2.671	29	1.37	Decreasing
Jawaharlal Nehru	1.908	20	1.926	15	0.78	Increasing
Salalah	1.844	19	1.963	16	0.17	Increasing
Jeddah	3.197	50	3.308	42	0.34	Increasing
Piraeus	2.560	35	2.790	31	3.01	Decreasing
Marsaxlokk	2.662	38	3.013	33	6.06	Decreasing
Southampton	2.178	25	2.187	19	0.93	Increasing
Vancouver BC	3.150	48	3.585	51	2.34	Decreasing
Khor Fakkan	1.635	16	1.639	13	1.43	Decreasing
Savannah	3.686	63	3.748	55	1.14	Decreasing
Taichung	2.831	41	3.064	37	1.37	Decreasing
Bangkok	4.606	77	4.611	68	3.79	Decreasing
Houston	4.211	70	4.253	62	1.08	Decreasing
Santos	2.304	27	2.482	25	2.02	Decreasing
Sydney	5.260	83	5.572	82	4.87	Decreasing
Montreal	4.038	67	4.446	65	5.99	Decreasing
La Spezia	3.101	45	3.126	39	1.46	Decreasing
Miami	6.791	91	6.939	86	0.34	Increasing
Honolulu	2.404	30	2.467	24	0.62	Increasing
Zeebrugge	5.262	84	5.941	83	6.57	Decreasing
Haifa	1.000	1	1.000	1	1.00	Constant
Jacksonville	6.414	89	6.429	84	0.93	Increasing
Gothenburg	4.555	76	4.840	71	1.26	Decreasing
Buenos Aires	9.566	94	10.969	95	10.20	Decreasing
Damietta	2.821	39	3.037	34	0.14	Increasing
Las Palmas de Gran Canaria	3.401	57	3.604	52	2.58	Decreasing
Puerto Limon	1.000	1	1.000	1	1.00	Constant
Veracruz	1.943	21	2.439	22	0.11	Increasing
Izmir	2.072	24	2.467	23	0.08	Increasing
St Petersburg	5.519	87	5.520	79	1.44	Decreasing
Brisbane	4.979	80	5.053	73	4.58	Decreasing
Auckland	4.152	69	4.211	60	0.78	Increasing
Helsinki	4.706	78	4.735	70	1.15	Decreasing
Lisbon	5.225	82	5.336	76	4.33	Decreasing
Dublin	3.013	43	3.038	35	1.13	Decreasing
Guayaquil	2.470	33	2.837	32	0.23	Increasing
Aarhus	6.562	90	6.738	85	1.10	Decreasing
San Antonio	5.274	85	5.432	78	0.48	Increasing
Fremantle	4.924	79	5.429	77	3.33	Decreasing
Casablanca	1.000	1	1.473	11	0.61	Increasing

Puerto Cortes	3.072	44	3.077	38	1.90	Decreasing
Montevideo	3.787	66	4.691	69	0.08	Increasing
Tauranga	2.826	40	3.044	36	0.39	Increasing
Aqaba	2.203	26	2.502	26	0.28	Increasing
Gdynia	4.249	71	4.458	66	0.50	Increasing
Santo Tomas de Castilla	3.101	46	3.349	43	0.39	Increasing
Shuaiba	10.411	95	10.697	94	1.48	Decreasing
Djibouti	4.314	73	5.538	80	0.17	Increasing
Mina Sulman	5.046	81	5.539	81	0.34	Increasing
Dar-es-Salaam	4.370	74	4.854	72	0.39	Increasing
Port Sudan	3.512	61	4.142	59	0.91	Increasing
Pointe-a-Pitre	6.896	92	7.675	90	0.32	Increasing
Constantza	16.138	97	16.181	97	2.76	Decreasing
Koper	7.459	93	8.152	93	0.36	Increasing
Bridgetown	1.000	1	6.952	88	0.75	Increasing
Oranjestad	1.000	1	6.946	87	0.13	Increasing
Belize City	1.000	1	7.742	92	0.01	Increasing
Rijeka	26.685	98	26.857	98	1.06	Decreasing
Copenhagen	10.810	96	11.471	96	2.03	Decreasing
Mombasa	3.372	56	3.431	45	0.85	Increasing

Reference Observations Set: t (year) = 1991

PORTNAME	DEACOV91	RANK (COV)	DEACOC91	RANK (COC)	Σλ	RTS
Hong Kong	1.000	1	1.238	3	2.84	Decreasing
Singapore	1.000	1	1.392	6	3.32	Decreasing
Busan	1.000	1	1.000	1	1.00	Constant
Kaohsiung	1.264	14	2.069	12	3.14	Decreasing
Shanghai	3.138	45	3.224	30	0.70	Increasing
Rotterdam	1.407	15	3.592	37	6.09	Decreasing
Los Angeles	1.842	22	3.590	36	3.33	Decreasing
Hamburg	2.709	37	6.303	63	5.28	Decreasing
Long Beach	2.784	38	5.686	55	3.89	Decreasing
Antwerp	3.417	50	8.003	80	5.34	Decreasing
Port Klang	3.635	51	3.689	38	0.78	Increasing
Dubai	2.811	40	3.750	40	1.56	Decreasing
New York/New Jersey	2.784	39	8.224	81	6.54	Decreasing
Bremen/Bremerhaven	3.202	48	5.473	54	2.84	Decreasing
Felixstowe	2.226	30	2.897	23	1.70	Decreasing
Tokyo	2.149	28	2.589	22	1.83	Decreasing
Yokohama	2.407	32	3.502	34	2.53	Decreasing
Manila	1.510	18	1.584	7	0.67	Increasing

Tanjung Priok	2.058	26	2.131	14	0.62	Increasing
Algeciras	2.950	43	3.004	27	0.75	Increasing
Kobe	2.073	27	3.144	29	3.63	Decreasing
Tianjin	6.885	82	6.914	69	0.94	Increasing
Nagoya	2.501	35	2.502	19	0.99	Increasing
Keelung	1.000	1	1.000	1	1.00	Constant
Guangzhou	7.983	86	9.308	86	0.36	Increasing
Colombo	1.684	20	1.788	10	0.50	Increasing
Oakland	3.890	55	5.296	52	2.61	Decreasing
Charleston	3.190	47	3.452	32	1.16	Decreasing
Genoa	8.190	90	8.375	82	1.08	Decreasing
Le Havre	4.064	56	7.179	73	2.66	Decreasing
Osaka	5.642	75	6.393	65	1.45	Decreasing
Valencia	4.499	59	4.601	43	0.74	Increasing
Barcelona	2.444	33	2.565	21	0.57	Increasing
Tacoma	3.677	53	5.195	51	2.08	Decreasing
Seattle	3.646	52	5.148	49	2.45	Decreasing
Xiamen	1.000	1	4.940	46	0.08	Increasing
Melbourne	5.145	67	6.103	61	1.71	Decreasing
Dalian	2.210	29	3.569	35	0.20	Increasing
Durban	4.521	61	4.579	42	1.02	Decreasing
Jawaharlal Nehru	16.921	98	20.571	97	0.35	Increasing
Salalah	1.000	1	56.318	98	0.02	Increasing
Jeddah	3.412	49	3.464	33	0.86	Increasing
Piraeus	1.035	10	1.344	5	0.25	Increasing
Marsaxlokk	5.512	72	6.457	66	0.31	Increasing
Southampton	4.155	57	4.304	41	0.64	Increasing
Vancouver BC	4.922	66	5.028	47	0.76	Increasing
Khor Fakkan	2.479	34	2.917	24	0.27	Increasing
Savannah	6.116	78	7.384	76	1.33	Decreasing
Taichung	2.526	36	3.712	39	0.23	Increasing
Bangkok	2.270	31	2.273	18	0.98	Increasing
Houston	1.489	16	1.704	9	0.36	Increasing
Santos	1.849	23	2.184	15	0.40	Increasing
Sydney	6.939	84	8.459	83	1.68	Decreasing
Montreal	5.264	69	5.900	57	1.52	Decreasing
La Spezia	1.113	11	1.321	4	0.27	Increasing
Miami	5.623	74	5.693	56	0.89	Increasing
Honolulu	2.875	42	2.985	26	0.74	Increasing
Zeebrugge	6.920	83	6.923	70	1.00	Decreasing
Haifa	2.997	44	3.074	28	0.69	Increasing
Jacksonville	6.368	79	6.791	67	0.53	Increasing
Gothenburg	7.521	85	8.462	84	1.22	Decreasing
Buenos Aires	1.220	13	1.695	8	0.18	Increasing

Damietta	6.876	81	7.333	74	0.52	Increasing
Las Palmas de Gran Canaria	4.894	65	5.427	53	0.40	Increasing
Puerto Limon	1.191	12	2.221	16	0.13	Increasing
Veracruz	1.000	1	2.057	11	0.10	Increasing
Izmir	2.024	25	2.958	25	0.17	Increasing
St Petersburg	4.774	64	5.919	58	0.23	Increasing
Brisbane	9.186	93	9.468	87	0.65	Increasing
Auckland	4.562	63	4.929	45	0.46	Increasing
Helsinki	2.845	41	3.251	31	0.33	Increasing
Lisbon	1.583	19	2.076	13	0.27	Increasing
Dublin	5.686	76	5.971	59	0.54	Increasing
Guayaquil	5.479	71	5.980	60	0.39	Increasing
Aarhus	6.672	80	7.379	75	0.50	Increasing
San Antonio	10.426	95	15.479	95	0.16	Increasing
Fremantle	1.000	1	2.510	20	0.16	Increasing
Casablanca	4.328	58	4.888	44	0.32	Increasing
Puerto Cortes	1.510	17	2.272	17	0.15	Increasing
Montevideo	1.875	24	5.078	48	0.13	Increasing
Tauranga	3.180	46	7.169	72	0.10	Increasing
Aqaba	5.417	70	7.398	77	0.26	Increasing
Gdynia	8.061	87	9.159	85	0.44	Increasing
Santo Tomas de Castilla	10.097	94	10.900	89	0.46	Increasing
Shuaiba	14.663	97	15.619	96	0.50	Increasing
Djibouti	1.793	21	6.864	68	0.12	Increasing
Mina Sulman	11.868	96	13.586	92	0.43	Increasing
Dar-es-Salaam	4.514	60	6.342	64	0.18	Increasing
Port Sudan	5.157	68	7.752	79	0.14	Increasing
Pointe-a-Pitre	5.905	77	7.687	78	0.32	Increasing
Constantza	8.073	88	13.799	93	0.18	Increasing
Koper	8.404	91	9.623	88	0.33	Increasing
Bridgetown	3.889	54	7.123	71	0.12	Increasing
Oranjestad	8.483	92	14.536	94	0.20	Increasing
Belize City	1.000	1	11.102	90	0.07	Increasing
Rijeka	8.163	89	11.997	91	0.23	Increasing
Copenhagen	5.607	73	6.121	62	0.43	Increasing
Mombasa	4.549	62	5.156	50	0.32	Increasing

Appendix 5.3 Movement of Quartile for Port Efficiency by Country

Legend of Quartile Movement:

- Increase of Relative Efficiency Groups from 1991 to 2004: 4,3,2, and 1
- No Change in Relative Efficiency Groups from 1991 to 2004: 0
- Decrease of Relative Efficiency Groups from 1991 to 2004: -1, -2, -3, and -4

4: [4th quartile (the most inefficient group) to DEA Efficiency]
3: [4th to 1st]; [3rd to Efficiency]
2: [4th to 2nd]; [3rd to 1st]; [2nd to Efficiency]
1: [4th to 3rd]; [3rd to 2nd]; [2nd to 1st] [1st to Efficiency]
0: [4th to 4th]; [3rd to 3rd] [2nd to 2nd] to [1st to1st]
-1: [Efficiency to 1st]; [1st to 2nd]; [2nd to 3rd]; [3rd to 4th]
-2: [Efficiency to 2nd]; [1st to 3rd]; [2nd to 4th];
-3: [Efficiency to 3rd]; [1st to 4th]
-4: [Efficiency to 4th]

Quartile Movement & COUNTRY	Number of Ports in Quartile Movement									Total number of ports	Average quartile movement
	-4	-3	-2	-1	0	1	2	3	4		
Argentina		1								1	-3.0
Aruba									1	1	4.0
Australia	1				3					4	-1.0
Barbados								1		1	3.0
Belgium					2					2	0.0
Belize					1					1	0.0
Bharain					1					1	0.0
Brazil				1						1	-1.0
Canada					1	1				2	0.5
Canary Islands					1					1	0.0
Chile					1					1	0.0
China				2	1		1	1	1	6	1.2
Costa Rica						1				1	1.0
Croatia					1					1	0.0
Denmark				1	1					2	-0.5
Djibouti			1							1	-2.0
Ecuador						1				1	1.0
Egypt							1			1	2.0
Finland			1							1	-2.0
France					1					1	0.0
Germany				2						2	-1.0
Greece				1						1	-1.0
Guadeloupe					1					1	0.0

Guatemala							1			1	2.0
Honduras				1						1	-1.0
India								1		1	3.0
Indonesia					1					1	0.0
Ireland							1			1	2.0
Israel							1			1	2.0
Italy				1			1			2	0.5
Japan			2	1		1	1			5	-0.4
Jordan						1				1	1.0
Kenya					1					1	0.0
Kuwait					1					1	0.0
Malaysia						1				1	1.0
Malta						1				1	1.0
Mexico				1						1	-1.0
Morocco								1		1	3.0
Netherlands				1						1	-1.0
New Zealand					2					2	0.0
Oman				1						1	-1.0
Philippines					1					1	0.0
Poland						1				1	1.0
Portugal		1								1	-3.0
Romania					1					1	0.0
Russia				1						1	-1.0
Saudi Arabia				1						1	-1.0
Singapore				1						1	-1.0
Slovenia					1					1	0.0
South Africa						1				1	1.0
South Korea				1						1	-1.0
Spain					3					3	0.0
Sri Lanka					1					1	0.0
Sudan					1					1	0.0
Sweden					1					1	0.0
Taiwan				1	2					3	-0.3
Tanzania				1						1	-1.0
Thailand			1							1	-2.0
Turkey					1					1	0.0
UAE						2				2	1.0
UK					1		1			2	1.0
Uruguay			1							1	-2.0
US			1	5	5	1				12	-0.5
Grand Total	**1**	**2**	**7**	**24**	**38**	**12**	**8**	**4**	**2**	**98**	**0.0**

Appendix 6.1 Malmquist Productivity Index: TFP Change, 1991-2004

PORTNAME	MPI	rank	Change in Technical Efficiency	rank	Change in Scale Efficiency	rank	Change in Technical progress	rank
Hong Kong	2.119	33	1.000	51	1.238	33	1.711	4
Singapore	1.638	50	0.902	57	1.179	41	1.541	15
Busan	0.734	89	0.792	72	0.831	95	1.116	74
Kaohsiung	1.712	46	1.217	38	1.276	27	1.103	77
Shanghai	3.231	12	3.138	8	0.934	89	1.103	76
Rotterdam	1.447	59	0.552	81	2.048	9	1.281	46
Los Angeles	1.158	73	0.760	75	1.488	18	1.025	87
Hamburg	2.009	37	0.815	70	2.055	8	1.200	59
Long Beach	1.841	42	0.841	68	1.934	10	1.132	71
Antwerp	2.234	28	1.022	49	1.855	12	1.179	63
Port Klang	2.213	29	1.545	28	0.980	83	1.462	20
Dubai	3.173	14	2.096	15	1.295	25	1.168	65
New York/New Jersey	2.337	25	0.774	73	2.492	4	1.211	57
Bremen/Bremerhaven	1.903	39	0.914	56	1.694	14	1.228	54
Felixstowe	1.413	60	0.846	67	1.273	29	1.312	43
Tokyo	1.361	62	1.088	45	1.019	70	1.228	55
Yokohama	1.047	78	0.651	78	1.246	31	1.290	45
Manila	0.774	88	0.876	59	0.914	90	0.966	93
Tanjung Priok	1.065	76	0.867	60	0.951	84	1.293	44
Algeciras	1.755	43	1.115	43	1.010	74	1.558	13
Kobe	0.506	96	0.341	94	1.198	38	1.238	49
Tianjin	4.647	5	4.207	5	0.945	86	1.169	64
Nagoya	0.929	83	0.551	82	0.999	78	1.686	6
Keelung	0.839	86	0.699	77	0.982	81	1.222	56
Guangzhou	10.167	3	7.983	3	1.166	45	1.092	79
Colombo	1.375	61	0.860	63	1.040	64	1.537	16
Oakland	0.886	85	0.709	76	1.051	59	1.190	61
Charleston	1.279	68	0.856	64	1.057	58	1.413	27
Genoa	2.660	20	2.729	10	0.877	94	1.111	75
Le Havre	1.471	57	0.985	54	1.441	21	1.036	86
Osaka	2.249	27	1.816	23	1.006	75	1.231	51
Valencia	1.347	64	1.358	33	0.884	93	1.123	72
Barcelona	1.005	80	0.767	74	0.935	88	1.402	28
Tacoma	1.730	45	1.068	46	1.319	24	1.228	53
Seattle	1.114	74	0.846	66	1.141	48	1.154	67
Xiamen	5.241	4	0.863	62	4.789	2	1.268	47
Melbourne	2.464	21	1.562	27	1.145	47	1.378	33
Dalian	1.051	77	0.637	79	1.540	16	1.072	83
Durban	1.601	52	1.832	22	0.936	87	0.934	94
Jawaharlal Nehru	12.754	2	8.868	1	1.204	36	1.194	60
Salalah	40.778	1	0.542	83	52.907	1	1.421	25
Jeddah	1.219	71	1.067	47	0.981	82	1.164	66
Piraeus	0.512	95	0.404	91	1.192	39	1.062	84
Marsaxlokk	3.281	10	2.070	16	1.035	66	1.531	17
Southampton	2.151	30	1.907	18	1.032	67	1.093	78
Vancouver BC	1.697	47	1.563	26	0.898	91	1.210	58
Khor Fakkan	3.090	15	1.516	29	1.174	43	1.736	3
Savannah	2.134	31	1.659	24	1.187	40	1.083	80
Taichung	1.218	72	0.892	58	1.358	23	1.005	89

Bangkok	0.809	87	0.493	88	1.000	76	1.642	8
Houston	0.568	93	0.354	93	1.133	50	1.418	26
Santos	1.003	81	0.803	71	1.097	52	1.140	70
Sydney	2.054	35	1.319	35	1.151	46	1.353	38
Montreal	2.073	34	1.304	37	1.018	71	1.562	11
La Spezia	0.719	91	0.359	92	1.177	42	1.702	5
Miami	0.970	82	0.828	69	0.991	79	1.182	62
Honolulu	1.301	67	1.196	39	1.012	73	1.075	82
Zeebrugge	1.533	55	1.315	36	0.886	92	1.315	42
Haifa	4.287	8	2.997	9	1.026	69	1.395	31
Jacksonville	1.452	58	0.993	53	1.064	56	1.374	34
Gothenburg	1.735	44	1.651	25	1.059	57	0.992	90
Buenos Aires	0.225	98	0.127	98	1.212	35	1.455	21
Damietta	3.376	9	2.437	12	0.991	80	1.398	29
Las Palmas de Gran Canari	1.855	41	1.439	31	1.046	61	1.232	50
Puerto Limon	3.065	16	1.191	40	1.865	11	1.380	32
Veracruz	1.349	63	0.515	85	1.639	15	1.599	9
Izmir	1.626	51	0.976	55	1.228	34	1.356	37
St Petersburg	1.949	38	0.865	61	1.240	32	1.818	1
Brisbane	2.937	18	1.845	21	1.016	72	1.568	10
Auckland	1.552	53	1.099	44	1.065	55	1.326	41
Helsinki	0.924	84	0.605	80	1.135	49	1.346	40
Lisbon	0.564	94	0.303	96	1.284	26	1.449	22
Dublin	2.452	22	1.887	20	1.042	63	1.247	48
Guayaquil	3.006	17	2.218	14	0.950	85	1.426	23
Aarhus	1.082	75	1.017	50	1.077	54	0.988	91
San Antonio	4.445	7	1.977	17	1.442	20	1.560	12
Fremantle	0.659	92	0.203	97	2.277	5	1.425	24
Casablanca	4.633	6	4.328	4	0.767	96	1.396	30
Puerto Cortes	1.245	70	0.491	89	1.503	17	1.686	7
Montevideo	1.330	65	0.495	87	2.186	6	1.229	52
Tauranga	2.448	23	1.125	42	2.093	7	1.039	85
Aqaba	2.717	19	2.459	11	1.202	37	0.919	95
Gdynia	1.888	40	1.897	19	1.083	53	0.919	95
Santo Tomas de Castilla	3.198	13	3.256	7	0.999	77	0.983	92
Shuaiba	1.668	49	1.408	32	1.037	65	1.142	68
Djibouti	1.688	48	0.416	90	2.983	3	1.362	35
Mina Sulman	2.254	26	2.352	13	1.043	62	0.919	95
Dar-es-Salaam	1.490	56	1.033	48	1.265	30	1.141	69
Port Sudan	3.265	11	1.468	30	1.275	28	1.745	2
Pointe-a-Pitre	1.018	79	0.856	65	1.170	44	1.016	88
Constantza	1.315	66	0.500	86	1.705	13	1.542	14
Koper	1.271	69	1.127	41	1.048	60	1.077	81
Bridgetown	1.550	54	3.889	6	0.263	97	1.513	18
Oranjestad	2.445	24	8.483	2	0.247	98	1.168	65
Belize City	2.130	32	1.000	51	1.434	22	1.485	19
Rijeka	0.499	97	0.306	95	1.460	19	1.116	73
Copenhagen	0.724	90	0.519	84	1.029	68	1.357	36
Mombasa	2.024	36	1.349	34	1.114	51	1.347	39
Average	***2.418***		***1.470***		***1.787***		***1.285***	

Appendix 7.1 MATLAB code to Calculate Hinterland Accessibility Index

From equation (1), $\underset{i\neq k}{HA_i} = \sum_J \frac{\frac{GDP_J}{D_{i1,J}^2}}{\sum_{k=1}^{m} \frac{Q_k}{D_{kJ}^2}} = \frac{\sum_J \frac{GDP_J}{D_{i1,J}^2}}{\sum_J \sum_{k=1}^{m} \frac{Q_k}{D_{kJ}^2}}$, Hinterland Accessibility of port 1

(HA_1) can be written as the following:

$$\begin{aligned}\underset{i\neq k}{HA_1} = &\ \frac{GDP_1}{D_{1,1}^2} \Big/ \left(\frac{Q_2}{D_{2,1}^2} + \frac{Q_3}{D_{3,1}^2} + \frac{Q_4}{D_{4,1}^2} + \ldots + \frac{Q_m}{D_{m,1}^2}\right) \\ &+ \frac{GDP_2}{D_{1,2}^2} \Big/ \left(\frac{Q_2}{D_{2,2}^2} + \frac{Q_3}{D_{3,2}^2} + \frac{Q_4}{D_{4,2}^2} + \ldots + \frac{Q_m}{D_{m,2}^2}\right) \\ &+ \frac{GDP_3}{D_{1,3}^2} \Big/ \left(\frac{Q_2}{D_{2,3}^2} + \frac{Q_3}{D_{3,3}^2} + \frac{Q_4}{D_{4,3}^2} + \ldots + \frac{Q_m}{D_{m,3}^2}\right) \\ &+ \ldots\ldots. \\ &\quad\vdots \\ &+ \frac{GDP_n}{D_{1,n}^2} \Big/ \left(\frac{Q_2}{D_{2,n}^2} + \frac{Q_3}{D_{3,n}^2} + \frac{Q_4}{D_{4,n}^2} + \ldots + \frac{Q_m}{D_{m,n}^2}\right)\end{aligned}$$

In order to come up with HA for all other ports, this process should be repetitively applied for all ports. This can be done by running the MATLAB code in the following:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%       Matlab 6.5. Code                                                    %%
%       To calculate Hinterland Accessibility Index for ports in 2004       %%
%       Programmed by Sanghyun Cheon for Chapter 7 of his Ph.D. Dissertation  %%
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all

% set the common parameters
beta = 2.0;

% set the program parameters
Nctry = 186; % Number of country
Nport = 257; % Number of port

% call data files
load Q2004.txt          % 257 ports, portID, TEU
load distmatrix.txt     % 257 x 186 array, km
load gdp04.txt          % 186 countries GDP data, billion dollar

% read GDP
for i1 = 1 : Nctry
   gdp(i1) = gdp04(i1,2);

end

% read port output
for j1 = 1: Nport
   Q(j1) = Q2004(j1,2);

end

% read distance between port and country
for k1 = 1 : Nport
   for m1 = 1: Nctry
      dist(k1, m1) = distmatrix(k1, m1+1);
   end
end

% calculate Hinterland Accessibility
for i = 1 : Nport
   ha_star = 0;
   hs_star = 0;

   for j = 1 : Nctry
      q_star = 0;
```

```
        for k = 1: Nport
            q_star = q_star + Q(k)/power(dist(k,j),beta);

            if k == i
                q_star = q_star - Q(k)/power(dist(k,j),beta);
            end
        end
        ha_star = ha_star + gdp(j)/power(dist(i,j),beta)/q_star;
        hs_star = hs_star + gdp(j)/power(dist(i,j),beta);

    end

    % calculate Hinterland Accessibility with million dollar GDP
    HA(i,1) = ha_star*1e+3;

    % calculate normalized HA, or Performance Index with unit of billion_gdp
    PI(i,1) = Q(i)/HA(i,1)*1e-3;;

    % calculate Hinterland Size
    HS(i,1) = hs_star*1e+3;

HA
PI
HS

end

save HA04.out HA -ascii
save PI04.out PI -ascii
save HS04.out HS -ascii
```

Appendix 7.2 Ranking of Port Performance Index

(Normalized Hinterland Accessibility[1] $= \frac{HA_i}{Q_i}$)

Ranking	Portid	Port name	Country Code	Port Performance Index
1	5	Shanghai	CH	1.310
2	12	Port Klang	MY	1.860
2	24	Tanjung Priok	ID	1.860
4	17	Yantian	CH	1.980
5	26	Tanjung Pelepas	MY	2.180
6	45	Tanjung Perak	ID	2.420
7	4	Kaohsiung	TW	2.450
8	18	Qingdao	CH	2.460
9	19	Tokyo	JA	2.520
10	48	Ningbo	CH	2.580
11	32	Guangzhou	CH	2.650
12	2	Singapore	SN	2.810
12	22	Yokohama	JA	2.810
14	44	Xiamen	CH	2.850
15	31	Keelung	TW	2.900
16	71	Chiwan	CH	2.950
17	28	Tianjin	CH	2.960
18	3	Busan	KS	3.010
19	52	Salalah	MU	3.030
20	13	Dubai	TC	3.230
21	1	Hong Kong	HK	3.270
22	49	Dalian	CH	3.300
23	51	Jawaharlal Nehru	IN	3.380
24	70	Honolulu	US	3.410
25	53	Jeddah	SA	3.490
26	7	Los Angeles	US	3.530
27	64	Sydney	AS	3.560
28	58	Khor Fakkan	TC	3.610
28	61	Bangkok	TH	3.610
30	20	Gioia Tauro	IT	3.660
31	121	Saigon Newport (Cat Lai & Tan Cang)	VM	3.660
32	25	Algeciras	SP	3.700
33	33	Colombo	CE	3.740
33	112	Auckland	NZ	3.740
35	10	Long Beach	US	3.840
36	46	Melbourne	AS	3.880
37	9	Hamburg	GM	3.900
38	109	Brisbane	AS	3.920
39	11	Antwerp	BE	3.960
39	23	Manila	RP	3.960

[1] The natural logs are taken to make an index.

41	6	Rotterdam	NL	3.970
42	130	Fremantle	AS	4.050
43	86	Las Palmas de Gran Canaria		4.060
44	29	Nagoya	JA	4.070
45	85	Shahid Rajaee	IR	4.110
46	14	New York/New Jersey	US	4.140
47	16	Felixstowe	UK	4.150
48	60	Taichung	TW	4.220
49	146	Tauranga	NZ	4.240
50	80	Karachi	PK	4.250
51	15	Bremen/Bremerhaven	GM	4.290
52	300	Jurong	SN	4.320
52	566	Inchon	KS	4.320
54	50	Durban	SF	4.340
55	63	Santos	BR	4.350
56	82	Damietta	EG	4.360
57	54	Piraeus	GR	4.460
58	91	Abidjan	IV	4.480
59	40	Barcelona	SP	4.500
60	34	Oakland	US	4.510
61	37	Le Havre	FR	4.580
61	68	Puerto Manzanillo	PM	4.580
61	74	Haifa	IS	4.580
64	72	Gwangyang	KS	4.590
65	41	Tacoma	US	4.600
66	57	Vancouver BC	CA	4.610
67	42	Seattle	US	4.660
68	56	Southampton	UK	4.700
69	582	Mombasa	KE	4.710
70	21	Laem Chabang	TH	4.720
71	103	Izmir	TU	4.730
72	107	St Petersburg	RS	4.830
73	124	Aden	YM	4.840
74	36	Genoa	IT	4.960
75	39	Valencia	SP	4.970
76	73	Zeebrugge	BE	5.170
77	43	Virginia	US	5.210
78	79	Gothenburg	SW	5.240
78	95	Cartagena	CO	5.240
80	65	Montreal	CA	5.270
81	106	Chittagong	BG	5.270
82	214	Dar-es-Salaam	TZ	5.340
83	35	Charleston	US	5.400
84	132	Casablanca	MO	5.410
85	66	Kingston	JM	5.470
85	67	La Spezia	IT	5.470
87	114	Helsinki	FI	5.480
87	213	Dakar	SG	5.480
89	69	Miami	US	5.490
90	89	Puerto Limon	CS	5.520
91	159	Aqaba	JO	5.560
92	200	Djibouti	DJ	5.580

93	59	Savannah	US	5.610
93	84	Puerto Cabello	VE	5.610
95	225	Port Sudan	SU	5.670
96	119	Guayaquil	EC	5.690
97	81	Buenos Aires	AR	5.730
98	115	Lisbon	PO	5.780
99	228	Constantza	RO	5.930
100	632	Lome	TO	5.960
101	55	Marsaxlokk	MT	5.980
102	264	Toamasina	MA	5.990
103	210	Douala	CM	6.050
104	139	Montevideo	UY	6.080
105	168	Gdynia	PL	6.150
106	125	San Antonio	CI	6.160
106	161	Limassol	CY	6.160
108	135	Puerto Cortes	HO	6.190
109	92	Veracruz	MX	6.210
110	78	Jacksonville	US	6.290
110	116	Dublin	EI	6.290
112	171	Santo Tomas de Castilla	GT	6.460
113	38	Osaka	JA	6.470
114	361	Walvis Bay	WA	6.800
115	302	Klaipeda	LH	6.880
116	542	Copenhagen	DA	6.900
117	152	Havana	CU	6.940
118	198	Oslo	NO	6.950
119	120	Aarhus	DA	6.970
120	62	Houston	US	6.990
120	207	Mina Sulman	BA	6.990
122	266	Tallinn	EN	7.050
123	622	Doha	QA	7.210
124	317	Varna	BU	7.250
125	105	Rio Haina	DR	7.450
126	177	Shuaiba	KU	7.520
127	253	Koper	SI	7.530
128	295	Oranjestad	AA	7.560
129	27	Kobe	JA	7.690
130	290	Muara	BX	7.740
131	245	Riga	LG	7.870
132	150	Port of Spain	TO	7.970
133	359	Belize City	BH	8.720
134	433	Rijeka	HR	8.870
135	189	Port Louis	MP	9.410
136	279	Bridgetown	BB	9.440
137	602	Corinto	NU	9.640
138	226	Pointe-a-Pitre	GP	11.890

Appendix 7.3 Variables and Data Descriptions for Multivariate Models

TEU: Total port throughput for years 2004. S*ource: CIY 2005.*

TEU_P: Projected total port throughput for years 2004.

EFF: DEA scores with inputs and outputs 2004. *Source: CIY 2005.*

EFF_{t-1}: DEA scores with inputs and output 2003. *Source: CIY 2005.*

OWN: Type of port ownership, defined as one of four categories

- 1 = ***PUB_t***: “Public Port”
- 2 = ***MIX_t***: “Mixed Port”
- 3 = ***$LORD_t$***: “Landlord Port”
- 4: “Non-Government Operating Port”

Source: surveyed and compiled for chapter 3

CORP: Dummy variable. “0” means not a corporate port; “1” means a corporate port.
Source: surveyed and compiled for chapter 3

HA: Hinterland Accessibility Index
Sourced: designed and calculated in chapter 5

CHINA: Dummy variable. “0” means not a Chinese port’ “1” means a Chinese port.
Source: CIY 2005.

CON: Port Connectivity. Number of direct-call liner service providers. *Source: CIY 2005.*

DEP: Average berth depth. Source: *CIY 2005.*

WHR: Hours of working (i.e., 7/24 vessel services): “0” means none of the terminals has 7/24 vessel services; “0.5” means some terminals, but not all of them, have 7/24 vessel services; “1” means all of the terminals have 7/24 vessel services.
Source: CIY 2005 and Port Websites.

FTZ: Whether or not the port has, or is within, a free trade zone. “1” means there is a free trade zone; “0” means there is none.
Source: US Department of State, Port Websites, and Literature survey.

CTYP: Number of population in the city in which the port is located.
Source: www.citypopulation.de, UNHABITAT, and Web survey.

GLB: The percent of TEU handled by global terminal operators in a port’s container production
Source: Drewry, 2004.

INF: The Surface Infrastructure Index is an average of three standardized indices that consider infrastructure levels and capital investment aggressiveness of rail infrastructure, road infrastructure, and communication infrastructure. The formal concept is presented below.

Source: World Bank's World Development Indicators. When the WDI data are missing for some countries, the data are supplemented from *Central Intelligence Agency's World Fact Books*. If there is a discrepancy in methods and units between two sources, reasonable treatments were done to match the measurement methods and units.

Infrastructure Index = Average {*Normalized RailIndex*, *Normalized RoadIndex*, *Normalized TelIndex*}

Where $RailIndex_J = (\frac{Rail\ km_J}{percap\ GDP_J} X \frac{Rail\ km_J}{surface\ land\ area_J})$,

$$RoadIndex_J = (\frac{Paved\ Road\ km_J}{percap\ GDP_J} X \frac{Paved\ Road\ km_J}{surface\ land\ area_J}),$$

$$TelIndex_J = (\frac{Telephone\ main\ lines_J}{percap\ GDP_J} X \frac{Telephone\ main\ lines_J}{surface\ land\ area_J})$$

$$Normalized\ Index_J = \frac{Index\ of\ Country\ \ j - Minimum\ Index}{Maximum\ of\ Index - Minimum\ Index} X 1000$$

1000 was multiplied for the legibility convenience.

Six island countries are missing from the data sources: Taiwan, Hong Kong, Canary Island, Guadeloupe, Brunei, and Aruba. Their indices are projected based on averages of countries with similar conditions: *Taiwan and Hong Kong* (= -0.83): average of Singapore and Korea, *Canary Island* (= -4.36): average of Ivory Coast, Togo, Cameroon, and Senegal in West Africa, *Guadeloupe and Aruba* (= -4.43): average of Jamaica, Dominica, and Trinitad and Tabacco in the Caribbean, and *Brunei* (-1.67): average of Malaysia, Singapore, and Indonesia.

REG: Dummy variable for "far regions" The far regions are located remotely from the major economic areas and shipping routes in the North. 1" means that the port is located in one of the following regions: Australasia, Southern Africa, West Africa, North Africa, East Africa, and Scandinavia/Baltic; "0" means that the port is not located in one the above regions.
Source: based on the definition of regions in CIY (2005).

Appendix 7.4 Review of Selected Important Studies for Determinants of Port Efficiency

7.4.1 Models, Determinants, and General Conclusions from the Selected Studies

Author	Data / Sources	Model / Estimation	Dependent or Output / Determinant or Input variables	Main assumption and conclusion	Note
Roll and Hayuth (1993)	cross-section, hypothetical data	DEA	Output: TEUs handled, billing for services, service level, no of ships arrivals, Input: Labor, Capital, Time trends	DEA can be useful in assessing the relative effectiveness of various ways of organizing port services when limited data are available.	Initial application of DEA analysis for port efficiency estimation.
Tongzon (1995)	cross- section, 30 container ports selected -Survey questionnaires requesting 1991 data on port performance and efficiency -Data from port of Melbourne in-house study (1992) -Australia's Bureau of Industry Economics study (1993) -Lloyd's ports of the world (1993) -CIY (1992)	TSLS Log-linear Efficiency scores (%) not derived from the model	Output: total throughput (TH) Determinants of throughput: Location (LOC), Frequency of ship calls (FS), Port charges (CH), Level of economic activity w/in a country (EA): GDP, Terminal efficiency (E) Determinant of terminal efficiency: Proportion of 40-foot containers (CONMIX), Delays during stevedoring (BRLWT, GWLN) , Crane efficiency (CHWH, TEUCH), Vessel size and cargo exchange (CE)	Assumption: ports are throughput maximizers. Terminal efficiency is a vital component of improving port performance and efficiency.	The focus of research is on defining a set of determinants of port performance rather than inter-port efficiency measurement and comparison.
Liu (1995)	panel, 28 UK ports '83~'90	SPF-translog Model 1: OLS, MLE Model 2: within GLS, MLE	Output: Billing for services Input: labor, capital, ownership (private) Other factors: port size, location, ownership, capital intensity, time fixed effect	Examine technical efficiency There is no significant advantage to private or public ownership when the policy environment is competitive.	Two approach: 1.derive efficiency estimates from SPF, and then use OLS with other variables 2.SPF with ownership dummy

Coto et al. (2000)	panel, 27 Spanish ports '85-'89	SCF-translog, within	Output (Y): total throughput Price of labor (W1): the ratio of total labor cost to the number of workers Price of capital (R1): divide the amortization of the period by the lengths of docks TC = f (Y, W1, R1, Intermediate Input price, Time trends)	The most efficient Spanish ports were those which were smaller in size and had adopted a far more centralized management than those that showed greater management autonomy.	
Tongzon (2001)	Four Australian and twelve other international ports • survey from shipping lines plus secondary sources • Australian Bureau of Transportation & Communications Economics survey data (1996) • CIY and Lloyd's Port of the world (1998)	DEA Software: developed by Center for Cybernetic Studies, U of Texas	Output: TEU handled, Ship rate Input: • Capital: Number of cranes, no. of container berths, no. of tugs, terminal area • Labor: Number of port authority employees, delay time	A port's operational efficiency does not depend sorely on its size and function (hub vs. feeder) Sources of inefficiency: under-utilization of labor, container berths, and terminal area	Relative efficiency measures derived from the two DEA models (CCR and Additive) based on the assumption of returns to scale (constant or variable)
Song et al. (2001)	Two container terminals in Port of Busan in Korea and three container terminals in the UK. Annual reports and financial accounts published by each container port	• SPF • *Model 1.* Cross sectional stochastic frontier (log linear cobb-douglas based on MLE) • *Model 2.* Panel stochastic frontier • Software: LIMDEP 7.0	Output: Annual turnover derived from container terminal services Input: L1: total remuneration of directors or executives for managerial services L2: total wages and salaries paid to employees K1: net book value of fixed equipments, buildings, land utilized for the purpose of terminal operations K2: net book value of mobile and cargo handling equipment including container cranes, yard tractors and fork lifts	Hypothesis: the greater private participation in terminal operation, the more efficient. (Felixstowe > Southampton > Tilbury > PECT > BCTOC). Greater private participation does not seem to be a crucial factor in influencing efficiency levels, at least w/in Korean and UK ports.	In the model 1, Ln Y(it) = ln f (L1(it), L2(it), K1(it), K2(it); b) + v(it) – u(it), u(it) is a time variant inefficiency. In the model 2, Ln Y(it) = ln f (L1(it), L2(it), K1(it), K2(it); b) + v(it) – u(i), u(i) is a time invariant inefficiency.

Estache et al. (2002)	13 Mexican ports over '96-'99	SPF (1) translog and (2) cobb-douglas based on MLE Software: FRONTIER	<u>Output:</u> The volume of merchandise handled (in tons) <u>Input:</u> Labor: the no. of workers in independent port administration Capital: the length of docks concessioned by government to the port administration	Reforms promoting its autonomous management in a competitive environment can generate large short-term improvements in the performance. The ranking of efficiency scores is likely to be more robust than the specific efficiency estimates.	Model 1 and 2 do not produce much difference in the results.
Turner et al. (2003)	26 US and Canadian container ports -American Association of Port authorities (AAPA) -CIY -National Research Council (1993) -US Corp of Engineers Port series -US Maritime Administration	DEA to create efficiency scores Tobit regression is used to examine the determinants of port productivity	**For DEA model:** <u>Output:</u> total TEU <u>Input:</u> total terminal land; total quayside gantry cranes; total container berth length **For regression:** Infrastructure Productivity (DEA scores) = f (total TEU handled, average terminal size in tons, dedicated terminal leasing, mean vessel size, mean vessel size squared, intermediacy in the region, double stack capability, Class I railroad, mean draft of entering vessels above 90^{th} percentile – berth depth, proportion of terminal area out of total port area, strike days, roll-on/roll off, feeder service, mean quayside gantry cranes' reach)	-Larger ports are more efficient. Size matters. -Railroad is a significant determinant of port productivity -Strike days is not significant -Port-specific fixed effect are found -Leasing is not significant	

Author	Data / Sources	Model / Estimation	Dependent or Output / Determinant or Input variables	Main <u>assumption</u> and conclusion	Note
Fink et al. (2000)	Waterborne Trade Database by US DOT US Merchandise Imports Database by US DOC BP Marine (Private consultant) Federal Maritime Commission (1998) EU Market Access Database WTO (1994) and a variety of WTO and GATS, APEC, OECD policy reviews and more *(See the appendix of the paper for more specific sources of data)*	Log-linear OLS with several different data selections to capture the effects of different circumstances and policy changes	Concept: constant elasticity pricing scheme that can be derived from "Cournot" competition. Pijk = MC (i,j,k)Φ(i,j.k) Pijk = US dollar price of shipping product k from foreign port i to U.S port j. MC = marginal cost of the service Φ = markup (function of demand elasticity) – *think Learner Index* MC(ijk) = f (Aj, Bk, Tijk, Dij, Qij, CRi, PS1i, PS2i) Φ (ijk) = g (Uk, CRi, A1ij, A2ij) Aj: US customs district specific effect capturing differences across customs districts in port and other services Bk: Product specific effect capturing properties of goods (size, weight etc.) Tijk: Share of good shipped in containers (technological effect) Dij: Shipping distance b/w i and j Qij: total value of import from i to j CRi: dummy for cargo reservation policy of exporting countries affecting trade with US PS1i: index about barriers in exporting countries to the foreign supply of cargo handling services PS2i: index of the extent to which port services are mandatory for	Conclusion: Cargo reservation policies are no longer an important barrier to trade Restrictions on the provision of port services, and private practices continue to exercise a significant influence on maritime transport prices. Private anti-competitive practices have a stronger influence on prices than public restrictions -*competition important* : these results challenge the notion that collusive carrier arrangements have lost their significance over the past decade in the maritime shipping and port sector. There is a need to both	The emphasis of this paper is on maritime shipping policy and competition issues in relation to transport cost, while Clark et al. (2001), following the line of this research, focus more on the relationship between port efficiency and transport cost.

			incoming ships Uk = Product specific effect capturing demand elasticities across sectors A1ij: price fixing collusive agreements among liner companies on routes b/w i and j A2ij: cooperative working agreements	eliminate excessive policy restriction and to deal with the private anti competitive practices of international maritime cartels.	
Clark et al. (2001)	US Import Waterborne Databank by US DOT Fink et al. (2000) World Bank The Global Competitiveness Report (1996 – 2000)	OLS and instrumental variable	Follow closely the line of Fink et al. (2000) Determinants of transport cost: Mariginal Cost (ijk) = f (Aj, Bk, Vijk, Tijk, Dij, Qij, PEi) Markup Φ (ijk) = g (Uk, A1ij, A2ij) Vijk: value per weight for product k transported from i to j PEi: Port efficiency of port i, using proxy variables such as GDP per cap, index constructed by using other infrastructure, or the level of country's port service surveyed by Global Competitiveness Report Other variables: same as Fink et al. (2000) Determinants of port efficiency: Port efficiency = f (country's infrastructure level, cargo handling restriction, cargo handling restriction squared, mandatory port services, mandatory port services squared, organized crime)	Important determinant of transport cost is seaport efficiency. Seaport efficiency is not just a matter of physical infrastructure. Organized crime has an important negative effect on port services, increasing transport costs. Some level of regulation increases port efficiency, but excessive regulation can be damaging.	

7.4.2 Variables, Data Sources, Hypothesis, and Specific Results from the Selected Studies

Author	Observation, Model, Estimation	Factors and meaning	Variables	Hypothesis and Results	Note and implications for my analysis
Tongzon (1995)	No. of observations: 23	<u>Output:</u> Total throughput (TH)	No. of containers handled / yr	Ports as throughput maximizers	* g.w.t. = from the time stevedoring labor goes on board to the time labor leaves the vessel on completion of cargo handling
	30 ports sampled for survey of 1991 data 23 responded	<u>Determinants of throughput:</u> Location (LOC)	Dummy for transshipment or FTZ around port	Statistically insignificant due to collinearity with FS	** berth time – gross working time: Delays caused by industrial disputation and award conditions s/a high rates of penalty and shift allowances
		Frequency of ship calls (FS)	Total no. of ship visits	Statistically significant at 5%	
	TSLS Log-linear	Port charges (CH)	Average port charges	Statistically insignificant (port charges are small portion of total transport costs)	
		Level of economic activity w/in a country (EA)	Respective countries' GDP	Statistically significant at 5%	*** gross working time – net working time: Delays that interrupt the stevedoring operation due to meal breaks, equipment breakdown, weather, ship problems, etc.
	Adj. R2 for the models = 0.83 ~ 0.86	Terminal efficiency (E)	Efficiency scores measured from the first stage model using the following variables	Statistically significant at 1%	
		<u>Determinant of terminal efficiency:</u> Container mix (CONMIX)	Proportion of 40-foot containers	Statistically significant at 5%	
		Work practice: Delays in stevedoring BRLWT	The difference b/w the berth time & gross working time*,**	Statistically significant at 5%	
		GWLN	The difference b/w gross working & net working time***	No data available	
		Crane efficiency CHWH	Average crane hr / working hr	No data available	
		TEUCH	Total no. of containers lifted / crane hr	Statistically significant at 10% and economically most important in determining E	
		Vessel size and cargo exchange (CE)	Containers loaded plus containers unloaded / ship	Statistically significant at 10%	
Liu (1995)	Annual data from 1983 to 1990 for 28 UK ports (N=224 ?)	<u>Output:</u> Billing for services	Turnover which consists of the amount of receivable in respective of port services provided to thirty parties**		* two different approaches: a) ownership is included in SPF, b) ownership as a dependent var. of efficiency estimates

	SPF- translog Model 1: OLS, MLE Model 2: within GLS, MLE	Input: Labor Capital Other: Ownership* Port size Capital intensity Location Time fixed effect	The value of total wage paym't The net-book value of fixed capital assets including land, building, dredging, dock structures, roads, plant, and equipment Private, Trust, Municipal*** Dummy for size*4 Ratio of the net-book value of capital to the value of total wage payment Dummy for the East/West coast	Insignificant in determining efficiency Statistically significant, but the impact is small Too little influence West is 11% less efficient	** excluding property sale *** Nationalized ports are excluded as there is only one. *4 two types of classification by the British Ports Federation
Coto et al. (2000)	SCF-translog, Within TC = f (Y, W1, R1, Intermediate Input price, Time trends)	Output (Y): total throughput Input: Price of labor (W1): the ratio of total labor cost to the number of workers Price of capital (R1): divide the amortization of the period by the lengths of docks Price of intermediate input Time fixed effect			
Tongzon (2001)	No. of observations = 16 ports in **1996** **Dataset is available in the paper** DEA	Output: TEU handled Ship working rate (as a proxy of the level of port service) Input: Capital: No. of cranes No. of container berths No. of tugs Terminal area Labor:	Total no. of containers loaded and unloaded (TEU) No. of containers moved / working hr / ship	Since the no. of observations is small, no statistical technique except descriptive analysis is applied to analyze the relationship b/w productivity and other physical, institutional port characteristics. Sources of inefficiency can be identified. e.g. some input variables. Suggest that for further	* data a/ no. of stevedoring labor is not available, but the no. of port authority employees is usually published in the annual reports of some ports ** criticized as an output by Turner et. al. (2003) *** these delay could be due to labor disputes, work practice such as meal breaks, equipment breakdown, port congestion, ship

		No. of port employees* delay time**	no. of port authority employee The difference b/w total berth time plus time waiting to berth and the time b/w the start and finish of ship working***	analysis, ports can be classified based on size, facilities, and function (hub vs. feeder).	problems, bad weathers, etc. Other variable in the data set: "Cane prod" – Crane productivity which measures the no. of containers moved per crane per working hour
Song et al. (2001)	Total no. of observations = 65 for two Korean container terminals and three UK terminals. Data availability is different from 1978 to 1996 depending on the terminals SPF	Output: Billing for services Input: Labor 1 Labor 2 Capital 1 Capital 2	Annual turnover derived from container terminal services total remuneration of directors or executives for managerial services total wages and salaries paid to employees net book value of fixed equipments, buildings, land utilized for the purpose of terminal operations net book value of mobile and cargo handling equipment including container cranes, yard tractors and fork lifts	Five terminals are different in terms of ownership, so the author tries to compare the different port productivity estimates depending on different types of ownership and levels of autonomy, and finally concludes that it is difficult to find any relationship between ownership and productivity.	Model 1: Cross sectional stochastic frontier (log linear cobb- douglas based on MLE) Model 2: Panel stochastic frontier
Estache et al. (2002)	52 observations, 13 ports from 1996 to 1999 SPF (1) translog and (2) cobb-douglas based on MLE Model settled -> four-year trends of efficiency scores estimated Software: FRONTIER	Output: total throughput Input: Labor: Capital:	The volume of merchandise handled (in tons) The no. of workers in independent port administration The length of docks concessioned by gov't to the port administration	Mexican port reform, promoting autonomous management in each port in a competitive environment, have generated short-term improvement of port productivity, since the annual average technical efficiency increased from 49.5% in 1996 to 54.5% or 58.5% in 1998. The reform is achieved through decentralization and privatization of services, not necessarily of infrastructure.	Interesting is to compare why some ports' efficiency scores or average annual efficiency growth rate increased overtime while others decreased in general and since the port reform. Especially, ranking or changes of ranking is useful for analysis and robust as criteria for yardstick competition, given that the international cross-sectional comparison among world ports is difficult.

Turner et al. (2003)	No. of observation is 360 for 26 continental US and Canadian container ports from 1984 to 1997 **based on two regulatory changes** (the Shipping Act of 1984 and the Ocean Shipping Reform Act of 1998) The maximum sample size for Tobit model: 242	**For DEA model:** Output: Total TEU Input:* Total terminal land Total container berth length Total quayside gantry cranes **For regression:** Dependent: Infrastructure productivity Independent: Total TEU handled (c) Average terminal size in tons(c) Dedicated terminal leasing (p) Mean vessel size (o) Mean vessel size squared (o) “Intermediacy”: 3 var. on inter-modal services: (s) a)Double stack railcars entering terminal area b)Class I railroads c)On-dock rail connections Channel and berth depth (s) Longshore labor action (s) Types of vessels: 2 var. (co) roll-on/roll off feeder services-barge operation	Annual TEU (from AAPA**) Hectare (from CIY) Meters of quay (from CIY) No. of container cranes (directly from the researcher supplying CIY, Andrew Foxcroft, London) DEA Scores Annual TEU units*** Annual TEU / No. of container terminals*** Dedicate quay / total quay TEU slot capacities / total ship arrivals per yr (from MARAD and CIY)*4 Binary (from NRC, 1993)*5 Binary (from NRC, 1993) Terminal ha with immediate access to on-dock rail / total terminal ha Mean draft of entering vessels at or above 90^{th} percentile (derived from MARAD) Total no. of strike days % of ro-ro arrivals out of total ship arrivals (from MARAD) % of barge arrivals out of total arrivals (from MARAD)	(+) -> significant (+)(p<0.001) (+) -> significant (+) (p<0.001) (-)*6 -> insignificant (p=0.999) (-)*7 -> significant (+)*8 not linear -> significant (-)*9 (p=0.01) insignificant (p=0.248) significant (+) (p<0.001) significant (-) (p=0.009) insignificant (p=0.13) insignificant (p=0.76)– may be captured in port specific effect since the impact could be local insignificant (p=0.12) (+) insignificant (p=0.27)	* Longshore labor was omitted as input b/o the assumption that differences in labor productivity b/w North American seaports are minimal. ** American Association of Port Authorities *** To measure the presence of returns to scale and density *4 The US Maritime Administration *5 *Landside Access to US Ports* (National Research Council, Transportation Research Board, 1993) *6 Hypothesis: large carriers often seek dedicated terminal leases requiring substantial port authority investment in terminal capacity. This may increase the port’s cost by requiring investments in excess of economically efficient level and reduces the impact of returns to scale by creating “smaller ports” out of the larger whole. *7 Hypothesis: as average vessel size increases, berth occupancy rate may declines (more idle capacity) and lead to productivity decline. *8 In reality, more efficient ports may attract larger vessels owing to the diseconomies of scale these large vessels experience in port. *9 The significant (-) sign for the squared vessel size notes that diseconomies of scale, as the result of an increase in capacity to handle larger ships, set in for very large ships *10 if the model includes the no. of cranes, the reach variable turns out

		quayside gantry cranes (co) – improvement of crane tech. Time specific effect Port specific effect	mean reach of all quayside gantry cranes (from Andrew Foxcroft, London) binary binary	(+) -> significant (-) (p<0.001) – may be correlation b/w the reach and the no. of cranes*10 all insignificant capture port specific effects	to be insignificant. *11 see later for more new literatures on port productivity (c)Containerport structure (p)Port authority conduct (o)Ocean carrier conduct (s)Situation (co)Control
Clark et al. (2001)	OLS and instrumental variable No. of observation = 41	<u>Dependent:</u> Port efficiency <u>Independent:</u> Country's infrastructure level Cargo handling restriction* (Cargo handling restriction)^2 Mandatory port services* (Mandatory port services) ^2 Organized crime	One-to-seven index ranking port efficiency (from GCR)** Three normalized indices that take into account the country level of telephones, paved roads, railroads, & airports*** Zero-to-one index that captures restrictions and special requirements imposed to foreign suppliers of cargo handling services (from Fink et al, 2000) Zero-to-one index that captures the extent to which port services – pilotage, towing, tug assistance, navigation aid, berthing, waste disposal, anchorage, etc – are mandatory for incoming ships (from Fink et al, 2000) One-to seven index ranking "organized crime as not been a problem" (1= strongly disagree, 7 = strongly agree)*4	 Significant at 1% Insignificant Insignificant Significant at 5% Significant at 5% Significant at 1%	Port efficiency = f (country's infrastructure level, cargo handling restriction, cargo handling restriction squared, mandatory port services, mandatory port services squared, organized crime) * **both indices represent restrictions at port level that could limit "competition" (data is in Appendix B)** – the data may be useful to define the level of competition for my analysis (See variables) ** Global Competitiveness Report ***from WDI 2000 by the WB and The World Fact 2000 by CIA *4 from GCR 1996~2000

7.4.3. Potential factors that can influence port efficiency

<u>Acronyms</u>
CIYs – a series of Container International Yearbook/ Drewry – Drewry Shipping Consultant/ Lloyds – a series of Lloyd's port of the world / Lloyd's p&t – Lloyd's port and terminal guide / WPI – Lloyd's world port index

Category	Sub-category	Examples of variables or proxy variables	Data sources	Note
Output	Throughput	Total TEUs handled (probably minus empty TEU)	CIYs	The most recent one (2004) with 2002 stat.
Input	Labor	No. of stevedoring workers, or	difficult to acquire	No study using this variable so far
		No. of port authority employees, or (may be more proper to look at port authorities' productivity)	APC* (Tongzon 2001) Try Lloyd and other consultants for more ports	*Australian Productivity Commission
		Total wages for stevedoring workers	Only for several ports	
	Capital	No. of cranes, or	Directly from Andrew Foxcroft in CIY (Turner 2003), Try Lloyds	
		Total capacity of cranes		
		No. of container berths, or	APC* Tongzon (2001) CIYs (Turner 2003)	
		Total length of docks, or container berths		
		No. of tugs	Try Lloyds	
		Terminal area (Hectare)	CIYs (Turner 2003)	

Geographical, Institutional, and Other variables as determinants:

Category	Sub-category	Examples of variables or proxy variables	Data sources	Note
Geography	Location Locational advantage	Latitude, Longitude Dummy based on criteria (e.g. FTZ, hub)	Lloyds' WPI	
Physical characteristics	Depth Weather Size	Mean gantry cranes' reach Actual depth (of berths)	 Lloyd, (CIYs) WPI	

Market / Industry Structure	Level of inter-port competition Market size	 GDP, Population of hinterland area	Dummy Dummy	
Legal structure	Customs procedures and practices Anti-competitive policy and practices	- median # of days to clear customs		
Institutional / Organizational structure	Ownership Management/ Corporate Structure	-Dummy for ownership -Dummy for strategic management	Possibly Drewry Construct by examining the port documents	Drewry has a recent research paper on this.
Accessibility to port	Rail Road congestion Queuing time		Partly by examining Lloyd.	
Other characteristics	Crime rate Port Charges Turnaround time Capital intensity Proportion of 40-foot container Vessel size Double stack rail Ro/ro Port service	 Degree of containerization Mean vessel size (squared) Maximum 24 hour 7 day service	 ISL port database, Lloyd Lloyd's p&t Partly by examining Lloyd Partly by examining Lloyd	 Technology economies of scale
Fixed effect	Time Port Country	Time-specific dummy Port-specific dummy Country-specific dummy	Dummy Dummy Dummy	When the numbers of observations are large enough

REFERENCES

Chapter 1

ADB (Asian Development Bank). 2000. *Developing Best Practices for Promoting Private Sector Investment in Infrastructure: Ports*. Manila, Philippines.

Australian Bureau of Industry Economics. 1995. *International Performance Indicators: Waterfront 1995*. Report 95/16, AGPS, Canberra.

APEC (Asia Pacific Economic Cooperation). 2002. *Trade Facilitation. A Development Perspective in the Asia Pacific Region*. October.

Campbell, Scott. 1993. "Increasing Trade, Declining Port Cities: Port Containerization and the Regional Diffusion of Economic Benefits" In Noponen, Graham, and Markusen, eds., *Trading Industries, Trading Regions*. New York: The Guilford Press.

Cass, S. 1996. *Port Privatization: Process, Players, and Progress*. London: IIR Publications.

Clark, Ximena, Dollar, David, and Micco, Alejandro. 2002. *Maritime Transport Costs and Port Efficiency*. Washington, D.C.: World Bank Group.

Clark, Ximena, Dollar, David and Micco, Alejandro. 2004. "Port Efficiency, Maritime Costs, and Bilateral Trade." *Journal of Development Economics*. 75 (2): 417-50.

DSC (Drewry Shipping Consultants). 1998. *World Container Terminals: Global Growth and Private Profit.* London.

DSC (Drewry Shipping Consultants). 2002. Feature Pieces of *Global Container Terminals – Profit, Performance, and Prospects*. October. From the Drewry website: *http://www.drewry.co.uk/frame2.phtml?loc=info/mr066.phtml*

DSC (Drewry Shipping Consultants). 2002. Global Container Terminals: Profit, Performance, and Prospects.

Howes, Candace and Ann R. Markusen. 1993. "Trade, Industry, and Economic Development." In Noponen, Graham, and Markusen, eds., *Trading Industries, Trading Regions*. New York: The Guilford Press.

Johnson, Malcolm. 2005. *On the Water Front.* New York: Chamberlain Bros. A Member of Penguin Group (USA) Inc.

Meyrick & Associates and Tasman Asia Pacific. 1998. *Measures to Promote Effective and Efficient Container Port Practices*. Report Prepared for Marine and Port Groups of the Australian Transport Council. October.

Trujillo, Lourdes and Gustavo Nombela. 2000. "Seaports." In Estache and Rus (eds.), *Privatization and Regulation of Transport Infrastructure: Guidelines for Policymakers and Regulators*. Washington, D.C.: WBI Development Studies.

UNCTAD (United Nations Conference for Trade and Development). 2003. *Efficient Transport and Trade Facilitation to Improve Participation by Developing Countries in International Trade*. Commission on Enterprise, Business Facilitation and Development. Note by the UNCTAD secretariat. February. Geneva.

UNCTAD (United Nations Conference for Trade and Development). 2002. *Review of Maritime Transport, 2002*. New York and Geneva.

UNCTAD (United Nations Conference for Trade and Development). 2001a. *Review of Maritime Transport, 2001*. New York and Geneva.

UNCTAD (United Nations Conference for Trade and Development). 2001b. *Transport and Development*, Issue Note by Transport Round-table in Brussels, Belgium. May. New York and Geneva.

World Bank. 2001. *World Bank Port Reform Toolkit Modules 1-8*. Washington, DC.

Chapter 2

ADB (Asian Development Bank). 2000. *Developing Best Practices for Promoting Private Sector Investment in Infrastructure: Ports*. Manila, Philippines.

Airriess, C.A. 2001. "Regional production, information-communication technology, and the developmental state: the rise of Singapore as a global container hub" *Geoforum* 32: 235-254.

Aldrich, Howard E. 1979. *Organizations and Environments*. Englewood Cliffs, NJ: Prentice-Hall.

Baird, A. 1995. "UK port privatization: In context." In *Proceedings of UK port Privatization Conference*.

Baird, A. 1997: "Port privatization: An analytical framework." In *Proceedings of International Association of Maritime Economist Conference*.

Baird, A.J., 2000. “Port privatization: objectives, extent, process, and the UK experience.” *International Journal of Maritime Economics* 2 (3): 177–194.

Baird, A. 2002. “Privatization trends at the world’s top-100 container ports.” *Maritime Policy and Management*, 29(3): 271–284.

Barzel, Y. 1989. *Economic Analysis of Property Rights*. New York: Cambridge University Press.

Boschken, Herman L. 1988. *Strategic Design and Organizational Change: Pacific Rim Seaports in Transition*. Tuscaloosa and London: The University of Alabama Press.

Campbell, Scott. 1993. “Increasing Trade, Declining Port Cities: Port Containerization and the Regional Diffusion of Economic Benefits” In Noponen, Graham, and Markusen, (eds.), *Trading Industries, Trading Regions*. New York: The Guilford Press.

Coto-Milla´n, P., Banos-Pino, J., Rodrı´guez-Alvarez, A., 2000. “Economic efficiency in Spanish ports: some empirical evidence.” *Maritime Policy and Management: An International Journal of Shipping and Port Research* 27 (2), 169–174.

Cullinane, K., Song, D.W., Gray, R., 2002. “A stochastic frontier model of the efficiency of major container terminals in Asia: assessing the influence of administrative and ownership structures.” *Transportation Research Part A* 36: 743–762.

Cullinane, Kevin, Ping Ji, and Tengfei Wang. 2005. “The relationship between privatization and DEA estimates of efficiency in the container port industry.” Journal of Economics and Business 57 (5): 433-462.

De Monie, G. 1996. “Privatization of Port Structures.” In Bekemans and Beckwith, (eds.), *Ports for Europe: Europe’s Maritime Future in a Changing Environment.* Brussels: European Interuniversity Press.

Denning, Michael. 1985. “Structure, Policies and Performance: Public Ports as Public Enterprise,” paper presented at *the 1985 Annual Meeting of the American Political Science Association*.

Erie, Steven P. 2004. *Globalizing L.A.: Trade, Infrastructure, and Regional Development.* Stanford, CA: Stanford University Press.

Erie, Steven P. and Henry Kim. 2002. “Southern California Infrastructure: Growth and Governance Challenges.” Paper Presented at a conference on Reform, Los

Angeles Style: The Theory and Practice of Urban Governance at Century's Turn. September.

Estache, A., Gonza´lez, M., and Trujillo, L., 2002. “Efficiency gains from port reform and the potential for yardstick competition: lessons from Mexico.” *World Development* 30 (4), 545–560.

Gómez-Ibáñez, Jose. 2003. *Regulating Infrastructure.* Cambridge, MA and London, Harvard University Press.

Goss, R. O. 1990. “Economic policies and seaports. Part 3: Are Port Authorities Necessary?” *Maritime Policy and Management*, 17(3), 257–271.

Gulick, J. 1998. “It’s all about market share: competition among US West Coast Ports for Trans-Pacific Containerized Cargo.” In Ciccantell, PS and Bunker, SG (eds.) *Space and Transport in the World System.* Greenwood Publishing Group.

Hall, Peter. 2002. *The Institution of Infrastructure and the Development of the Port-Regions.* Ph.D. Dissertation, University of California, Berkeley, CA.

Haarymeyer, D. and Yorke, P. 1993. *Port Privatization: An International Perspective.* Los Angeles: Reason Foundation.

Heaver, T. 1995. “The implications of increased competition among ports for port policy and management.” *Maritime Policy and Management*, *22*(2), 125–133.

Heikkila, EJ, Gordon, P and Richardson, HW. 1991. “Leading ahead: the Ports of Los Angeles and Long Beach embark on ambitious course – the 2020 plan,” *Portus* Vol. 6, No.2: 14-20.

Hyman, Leonard. 1995. *The Privatization of Public Utilities.* Public Utilities Reports. Vienna, VA.

Iheduru, O. 1993. “Rethinking Maritime Privatisation in Africa.” *Maritime Policy and Management*. Vol. 20, No. 1: 31-49.

Jasinski, P. and G. Yarrow. 1996. "Privatization: An Overview of the Issues." In Yarrow, G. and Jasinski, P. (eds.), *Privatization: Critical Perspectives on the World Economy.* London: Routledge.

Leibenstein, H. 1996 “Allocative efficiency vs. *x*-efficiency”, *American Economic Review*, Vol. 56: 392-413.

Liu, Zinan. 1992. *Ownership and productive efficiency: With reference to British ports.* (Ph.D. dissertation). Queen Mary and Westfield College, University of London.

Liu, Zinan. 1995. “The comparative performance of public and private enterprises: the case of British ports.” *Journal of Transport Economics and Policy*. September: 263-274.

Martin and Associates. 1995. *The Economic Impacts of the Port of Oakland’s Maritime Division.*

Miles, Robert H. 1982. *Coffin Nails and Corporate Strategies*. Englewood Cliffs, NJ: Prentice-Hall.

Notteboom, T., Coeck, C., Van Den Broeck, J., 2000. “Measuring and explaining the relative efficiency of container terminals by means of Bayesian Stochastic Frontier Models.” *International Journal of Maritime Economics 2*: 83–106.

OECD (Organisation for Economic Cooperation and Development). 1991. *Urban Infrastructure: Finance and Management*. Paris, France.

OECD (Organisation for Economic Cooperation and Development). 1998. *User Charging for Government Services: Best Practice Guidelines and Case Studies.* Public Management Occasional Papers No. 22. Paris, France.

Olson, David J. 1988. “Public Port Accountability: A Framework for Evaluation,” in Marc J. Hershman (ed.), *Urban Ports and Harbor Management: Responding to Change Along U.S. Waterfronts.* New York: Taylor & Francis.

Oram, R. B. and C.C.R Baker, 1971, *The Efficiency Port*. Oxford, New York, Toronto, Sydney, Braunschweig: Pergamon Press.

Parker, D. 1994. “Nationalisation, Privatisation, and Agency Status within Government: Testing for the Importance of Ownership.” In Jackson, P. and Price, C. (eds.), *Privatisation and Regulation: A Review of the Issues*. Longman Group Ltd, Esel. p.149-169.

Posner, M. 1984. “Privatisation: the Frontier between Public and Private,” *Policy Studies*. Vol. 5: 22-23.

Primeaux, W.J., 1977. “An assessment of *x*-efficiency gained through competition”, *Review of Economics and Statistics*, Vol. 59: 105-108.

Ramaswamy, K. 2001. “Organizational Ownership, Competitive Intensity, and Firm Performance in Emerging Economies: An Empirical Study of the Indian Manufacturing Sector.” *Strategic Management Journal* 22: 989-998.

Ramaswamy, K. & Renforth, W. 1996. “Competitive Intensity and technical efficiency in public sector firms: evidence from India.” *International Journal of Public Sector Management* 9 (3): 4-17.

Song, D-W, Kevin Cullinane, and Michael Roe. 2001. *The Productive Efficiency of Container Terminals: An application to Korea and the UK*. Aldershot, Burlington, Singapore, Sydney: Ashgate.

Tongzon, Jose and Wu Heung. 2005. "Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals)." *Transportation Research Part A* 39, no. 5: 405-424.

Turnbull, P., and Weston, S. 1993. "Co-operation or control? Capital restructuring and labour relations on the docks." *British Journal of Industrial Relations 31* (1): 115–134.

UNCTAD (United Nations Conference of Trade and Development). 1995. *Comparative Experiences with Privatization: Policy Insights and Lessons Learned*. New York.

World Bank. 2001. *World Bank Port Reform Toolkit Modules 1-8*. Washington, DC.

Chapter 3

Aigner, D. and Chu, S. 1968. "On Estimating the Industry Production Function." *American Economic Review,* Vol. 58, No. 4: 826-839.

Afriat, S. 1972. "Efficiency Estimation of Production Function," *International Economic Review*, Vol. 13, No. 3: 568-598.

Australian Bureau of Industry Economics. 1993. *International Performance Indicators in the Waterfront*, Research Report 47.

Australian Productivity Commission. 1998, *International Benchmarking of the Australian Waterfront*, Research Report, AusInfo, Canberra, April.

Australian Productivity Commission. 2003, *International Benchmarking of Container Stevedoring*, Commission Research Paper, July.

Australian Transport Advisory Council, 1992. *Port Performance Indicators.*

Burton, M., Phimister, E., 1995. "Core journals: a reappraisal of the diamond list." *Economic Journal* 105: 361-373.

Cooper, William W. Lawrence M. Seiford and Joe Zhu. 2004. *Handbook on Data Envelopment Analysis*. Boston / Dordrecht / London: Kluwer Academic Publishers.

Cullinane, Kevin and Song, DW. 2002. "A stochastic frontier model of the efficiency of major container terminals in Asia: assessing the influence of administrative and ownership structures," *Transportation Research Part A* 36: 743–762.

Cullinane, Kevin, Song, DW, Ji, Ping and Wang, Teng-Fei. 2004. "An application of DEA Windows analysis to container port production efficiency." *Review of Network Economics* 3, no. 2: 184-206.

De Borger, B., Kerstens, K. and Costa, A. 2002. "Public Transit Performance: What does One Learn from Frontier Studies," *Transport Reviews*, 22: 1-38.

Devine, P., Lee, N. and Jones, R. 1985. *An Introduction to Industrial Economics*. London, UK: George Allen and Unwin.

Estache, A., Gonza´lez, M., Trujillo, L., 2002. "Efficiency gains from port reform and the potential for yardstick competition: lessons from Mexico." *World Development* 30 (4), 545–560.

Marlow, Peter B. and Ana C. Paixao Casaca. 2004. "Measuring lean ports performance." *International Journal of Transport Management* 1/4: 189-202.

Parker, D. 1994. "Nationalisation, Privatisation, and Agency Status within Government: Testing for the Importance of Ownership." In Jackson, P. and Price, C. (eds.), *Privatisation and Regulation: A Review of the Issues*, Longman Group Ltd, Esel. p.149-169.

Porter, Michael. 2002. *On Competition*. Cambridge, MA: Harvard Business School Press.

Roll, Y. and Hayuth, Y.1993. "Port performance comparison applying data envelopment analysis (DEA)." *Maritime Policy and Management* 20 (2), 153–161.

Singh, H., J. Motwani, A. and Kumar. 2000. "A review and analysis of the state of the art research on productivity measurement" *Industrial Management and Data Systems*, vol. 100: 234-241.

Sink, D.S. and T.C. Tuttle. 1989. *Planning and measurement of in your organisation of the future*. Norcross, U.S.A: Industrial Engineering and Management Press, chapter 5, p.170-184.

Song, DW, Cullinane, Kevin, and Roe, Michael. 2001. *The Productive Efficiency of Container Terminals: An Application to Korea and the UK*. Aldelershot/ Burlington, US/ Singapore/ Sydney: Ashgate.

SCRCSP (Steering Committee for the Review of Commonwealth/State Service Provision). 1997. *Data Envelopment Analysis: A Technique for Measuring the Efficiency of Government Service Delivery*, AGOS, Canberra.

Tangen, S. 2002. *A Theoretical Foundation for Productivity Measurement and Improvement of Automatic Assembly Systems*. Licentiate Thesis, Stockholm: Royal Institute of Technology. Ch 3. p.19-30.

Tongzon, Jose. 1995. "Determinants of port performance and efficiency." *Transportation Research Part A* 29A, no. 3: 245-252.

UNCTAD (United Nations Conference of Trade and Development). 1975. *Port Performance Indicators*, TD/B/C.4/131. Geneva, Swiss.

Zhu, Joe. 2003. *Quantitative Models for Performance Evaluation and Benchmarking*. Boston / Dordrecht / London: Kluwer Academic Publishers.

Chapter 4

ADB (Asian Development Bank). 2000. *Developing Best Practices for Promoting Private Sector Investment in Infrastructure: Ports*. Manila, Philippines.

Australian Department of Infrastructure. 2001. *The Next Wave of Port Reform in Victoria: An Independent Report to the Minister for Ports.*

Baird, A. 1999. "Analysis of private seaport development: the port of Felixstowe." *Transport Policy* 6: 109-22.

Baird, A. 2000. "Port privatization: Objectives, extent, process, and the UK experience." *International Journal of Maritime Economics*, 2 (3): 177–194.

Baird, A. 2002. "Privatization trends at the world's top-100 container ports." *Maritime Policy and Management*, 29 (3): 271–284.

Beresford, Q. 2000: *Governments, Markets and Globalisation.* Allan & Unwin NSW.

Chlomoudis, C. and Pallis, A. 2002. *European Union Port Policy: The Movement Towards a Long-Term Strategy*. Cheltenham, UK and Northampton, MA: Edward Elgar.

CI (Containerisation International). 2005. *Containerisation International Yearbook 2005*. London. Informa Group.

Corbett, D. 1996 *Australian Public Sector Management*. Allen & Unwin NSW.

Cullinane, Kevin, D. W. Song, Ping Ji and Teng-Fei Wang. 2004. "An application of DEA Windows analysis to container port production efficiency." *Review of Network Economics* 3, no. 2: 184-206.

Cullinane, Kevin, and D. W. Song. 2001. "The administrative and ownership structure of Asian container ports." *International Journal of Maritime Economics*, 3(2): 175–197.

Erie, Steven P. and Henry Kim. 2002. *Southern California Infrastructure: Growth and Governance Challenges*. Paper Presented at a conference on Reform, Los Angeles Style: The Theory and Practice of Urban Governance at Century's Turn. September.

Everette, Sophia. 2005a. "Effective corporatisation of ports is a function of effective legislation: Legal issues in the existing paradigm." A paper presented in the Annual Conference of the International Association of Maritime Economists, Cyprus 2005.

Everette, Sophia. 2005b "Developing a government-owned business: A more effective model for corporatised ports" A paper presented in the Annual Conference of the International Association of Maritime Economists, Cyprus 2005.

Hoffmann, J. 2001. "Latin American ports: Results and determinants of private sector participation." *International Journal of Maritime Economics*, 3 (2): 221–241.

Ircha, M. C. 2001. "North American port reform: The Canadian and American experience." *International Journal of Maritime Economics*, 3 (2): 198–220.

Juhel, M. H. 2001. "Globalisation, privatization and restructuring of ports." International *Journal of Maritime Economics*, 3 (2): 139–174.

Liu, Zinan. 1992. *Ownership and productive efficiency: With reference to British ports* (Ph.D. dissertation). Queen Mary and Westfield College, University of London.

Liu, Zinan. 1995. "The comparative performance of public and private enterprises: the case of British ports." *Journal of Transport Economics and Policy*. September: 263-274.

Lloyd's Register Fairplay, Ltd. 2005. *Ports and Terminals Guide 2005.*

Meryick and Associates and Tasman Asia Pacific. 1998. *Measures to Promote Effective and Efficient Container Port Practices.* Final report prepared for the Marine and Ports Group of the Australian Transport Council. October.

Notteboom, T. E., and Winkelmans,W. 2001. "Reassessing public sector involvement in European seaports." *International Journal of Maritime Economics*, 3(2): 242–

259.

Phang, Sock-Young. 2003. "Strategic Development of Airport and Rail Infrastructure: the Case of Singapore." *Transport Policy* 10: 27~33.

Quiggin, J. 2002. "Economic governance and microeconomic reform" in Bell S (ed) *Economic Governance and Institutional Dynamics*. Oxford University Press South Melbourne.

Saxena, K. B. G. 1996. "Re-engineering Public Administration in Developing Countries." *Long Range Planning*, Vol. 29. No. 5: 703~711.

TFE (Technum Flanders Engineering). 2002. *Public Final Report: Analysis of the Cost Structures of the Main TEN Ports*. February.

Trujillo Lourdes and Gustavo Nombela. 2000. "Seaports," chapter 4 in *Privatization and Regulation of Transport Infrastructure: Guidelines for Policymakers and Regulators.* (eds.) Estache, Antonio and Gines de Rus. WBI Development Studies. The World Bank. Washington, D.C., p.113-170.

UNCTAD (United Nations Conference of Trade and Development). 1998. *Review of Maritime Transport, 1998*. New York and Geneva.

UNCTAD (United Nations Conference of Trade and Development). 2002. *Review of Maritime Transport, 2002*. New York and Geneva.

Wang, James J. Adolf Koi-Yu Ng Daniel Oliver. 2004. "Port governance in China: a review of policies in an era of internationalizing port management practices." *Transport Policy* 11: 237-50.

World Bank. 2001. *World Bank Port Reform Toolkit. Modules 1-8*. Washington, D.C.

Chapters 5

Ashar, A. 1997. "Counting the Moves." *Port Development International* 13: 25-29.

Aivazian, Varouj A Ying Ge and Jiaping Qiu. 2005. "Can corporatization improve the performance of state-owned enterprises even without privatization?" *Journal of Corporate Finance* 11, no. 1-2: 277-91.

Banker, R. D., Charnes, A. and Cooper, W. W. 1984. "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis," *Management Science*, 30: 1078-1092.

Banker, R.D., Conrad, R.F., Strauss, R.P., 1986. A comparative application of DEA and translog methods: an illustrative study of hospital production. *Management Science* 32 (1), 30-44.

Banker, R., and Johnston, H., 1994. "Evaluating the impacts of operating strategies on efficiency in the US Airline Industry." In *Data Envelopment Analysis: Theory, Methodology, and Application.* Boston, MA: Kluwer Academic Publishers.

Bendall, H. and Stent, A. 1987. "On Measuring Cargo Handling Productivity." *Maritime Policy and Management*. Vol. 14. No. 4. p.337-343.

Charnes, A. and Cooper, W.W. 1962. "Programming with linear fractional functionals," *Naval Research Logistics Quarterly* 9, 181-185.

Charnes, A., Cooper, W.W., Clark T., Golany, B., 1985. A developmental study of data envelopment analysis in measuring the efficiency of maintenance units in the US Air Forces. *Annals of Operations Research.* 95-112.

Charnes, A., Cooper, W. W. and Rhodes, E. 1978. "Measuring the efficiency of decision making units," *European Journal of Operational Research*, 2: 429-444.

Charnes, A., Galleous, A., and Li, H., 1996. "Robustly efficient parameter frontiers: an approximation via the multiplicative DEA model for domestic and international operations of the Latin American airline industry." *European Journal of Operational Research* 88: 525-536.

CI (Containerisation International). *Containerisation International Online*, London. Date accessed: September 2004 – December 2004.

CI (Containerisation International). *Containerisation International Yearbook 1990, 1991, 1992, 2003, 2004, 2005*. London: Informa Group.

Cooper, William W. Lawrence M. Seiford and Joe Zhu. 2004. *Handbook on Data Envelopment Analysis*. Boston, Dordrecht, and London: Kluwer Academic Publishers.

Cook, Wade D. and Joe Zhu. 2005. *Modeling Performance Measurement: Applications and Implementations Issues in DEA.* New York: Springer.

Cullinane, K., Song, D.W., Gray, R., 2002. "A stochastic frontier model of the efficiency of major container terminals in Asia: assessing the influence of administrative and ownership structures." *Transportation Research Part A* 36: 743–762.

Cullinane, K., Song, D.W., Ji, Ping and Wang, Teng-Fei. 2004. "An application of DEA

Windows analysis to container port production efficiency." *Review of Network Economics* 3, no. 2: 184-206.

Cullinane, K., Ji, Ping, and Wang, Tengfei. 2005. "The relationship between privatization and DEA estimates of efficiency in the container port industry." *Journal of Economics and Business* 57 (5): 433-462.

De Monie, G. 1987. *Measuring and Evaluating Port Performance and Productivity*, UNCTAD Monograph No. 6 on Port Management, Geneva.

Deprins, D., Simar, L., Tulkens, H., 1984. "Measuring labor-efficiency in post offices." In: Marchand, M., Pestieau, P., Tulkens, H. (Eds.), *The Performance of Public Enterprises: Concepts and Measurement*. Elsevier, North-Holland, p.243-267.

Dowd, T. J. and T. M. Leschine. 1990. "Container terminal productivity: A perspective." *Maritime Policy and Management* 17: 107-112.

Farrell, M. J. 1957. "The measurement of productive efficiency." *Journal of Royal Statistic Society A* 120: 253-281.

Kalmar. "Capital Markets Day," Presentation by Granskog, Christer. March 21. 2006. New York.

Kumbhakar, S.C. and Lovell, C. 2000. *Stochastic Frontier Analysis*, Cambridge: Cambridge University Press.

Lewin, A.Y., Morey, R.C., Cook, T.J., 1982. "Evaluating the administrative efficiency of courts." *Omega*. 401-411.

Le-Griffin, Hanh Dam and Murphy Melissa. 2006. Assessing Container Terminal Productivity: Experiences at the ports of Los Angeles and Long Beach. A paper presented *National Urban Freight Conference 2006*. Feb. 1-3. Long Beach, CA.

Lloyd's Register Fairplay, Ltd. (2005): "Ports and Terminals Guide 2005."

Marconsult. 1994. *Major Container Terminals Structure and Performances Report*, Genova.

Marlow, P. and Paixao, A.C. 2004. "Measuring lean ports performance," *International Journal of Transport Management*. 1/4: 189-202.

Martinez-Budrı´a, E., Diaz-Armas, R., Navarro-Ibanez, M., and Ravelo-Mesa, T., 1999. "A study of the efficiency of Spanish port authorities using data envelopment analysis." *International Journal of Transport Economics* 26 (2): 237–253.

Nicholson, W. 2004. *Microeconomic Theory: Basic Principles and Extensions*. Dryden Press, New York.

Notteboom, T. C. Coeck and J. van den Broeck. 2000. "Measuring and Explaining the Relative Efficiency of Container Terminals by Means of Bayesian Stochastic Frontier Models." *International Journal of Maritime Economics* 2: 83-106.

Oum, T., Yu, C., 1994. "Economic efficiency of railways and implications for public policy." *Journal of Transportation Economics and Policy*. May: 121-138.

Ray, S.C., 1991. "Resource-use efficiency in public schools: a study of Connecticut data." *Management Science* 37 (12): 1620-1628.

Roll, Y. and Y. Hayuth. 1993. "Port performance comparison applying data envelopment analysis (DEA)." *Maritime Policy and Management* 20 (2): 153–161.

Roux, Helene. 2006. "Container Revolution," *Engineering News*, Volume 26. No.24. June 30-July 6. p.16-17.

SCRCSP (Steering Committee for the Review of Commonwealth/State Service Provision). 1997. *Data Envelopment Analysis: A Technique for Measuring the Efficiency of Government Service Delivery*, AGOS, Canberra.

Talley, W.K. 1988. "Optimum throughput and performance evaluation of maritime terminals." *Maritime Policy and Management* 15 (4): 327-331.

Tabernacle, J.B. 1995. "A Study of the Changes in Performance of Quayside Container Cranes." *Maritime Policy and Management*. 22: 115-124.

Tongzon, Jose. 2001. "Efficiency measurement of selected Australian and other international ports using data envelopment analysis." *Transportation Research Part A*: 113–128.

Tongzon, Jose and Wu Heung. 2005. "Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals)." *Transportation Research Part A* 39, no. 5: 405-424.

Tulkens, H. and van den Eeckaut, P. 1995. "Nonparametric efficiency, progress and regress measures for panel-data: Methodological aspects." *European Journal of Operational Research*, *80* (3), 474–499.

Turner, Hugh, Windle, Robert and Dresner, Martin. 2004. "North American containerport productivity: 1984-1997." *Transportation Research Part* E 40, no. 4: 339-356.

UNCTAD. 2006. UNCTAD *Transport Newsletter No. 33 Third Quarter 2006*. UNCTAD/SDTE/TLB/MISC/2006/4 Geneva.

Valentine, V. F. and Gray, R. 2001. "The Measurement of Port Efficiency Using Data Envelopment Analysis," *Proceedings of the 9th World Conference on Transportation Research*, 22-27 July, Seoul, South Korea.

Wang T., Song, D.W.. and Cullinane, K. 2002. "The Applicability of Data Envelopment Analysis to Efficiency Measurement of Container Ports," *Proceedings of the International Association of Maritime Economists Conference*, Panama, 13-15 November.

WorldCargo News. 2005. "Crane price surge – demand pull and supply push." November. p. 44.

World Cargo News Online, "WCN's 13th Annual Ship-to-Shore Crane Survey." March 17, 2007.

Zhu, Joe. 2003. *Quantitative Models for Performance Evaluation and Benchmarking*. Boston, Dordrecht, London: Kluwer Academic Publishers.

Chapter 6

Cooper, William W. Lawrence M. Seiford and Joe Zhu. 2004. *Handbook on Data Envelopment Analysis*. Boston, Dordrecht, London: Kluwer Academic Publishers.

Estache, Antonio, Beatriz Tovar de la Fe, and Lourdes Trujillo. 2004. "Sources of efficiency gains in port reform: a DEA decomposition of a Malmquist TFP index for Mexico." *Utilities Policy* 12: no. 4: 221-30.

Fare, R. S. Grosskopf and C. A. K. Lovell. 1994. *Production Frontiers*. Cambridge: Cambridge University Press.

Grifell, E. and C. A. K. Lovell. 1993. *Deregulation and productivity decline: the case of Spanish saving banks*. Department of Economics Working Paper 93-02. University of North Carolina.

Nishimizu, M. and J. Page. 1982. Total factor productivity growth, technological progress and technical efficiency change: dimensions of productivity change in Yugoslavia, 1965-78. *Economic Journal* 92: 920-936.

Notteboom, T. E., and Winkelmans,W. (2001): "Reassessing public sector involvement in European seaports." *International Journal of Maritime Economics*, 3(2), 242–259.

Turner, Hugh, Windle, Robert and Dresner, Martin. 2004. "North American containerport productivity: 1984-1997." *Transportation Research Part* E 40, no. 4: 339-356.

Zhu, Joe. 2003. *Quantitative Models For Performance Evaluation And Benchmarking*. Boston / Dordrecht / London: Kluwer Academic Publishers.

Chapters 7 and 8

Bird, J. and Bland, G. 1988. "Freight Forwarders Speak." *Maritime Policy and Management*. Vol. 15, No.1: 35-55.

Carroll, Glenn R. and Hannan, Michael T. 2000. *The Demography of Corporations and Industries*. Princeton, NJ: Princeton University Press.

CI (Containerisation International). 2005. *Containerisation International Yearbook 2005*. London. Informa Group.

Clark, Ximena, David Dollar and Alejandro Micco. 2002. *Maritime Transport Costs and Port Efficiency*. Washington, D.C.: World Bank Group.

Cullinane, K., Ji, Ping, and Wang, Tengfei. 2005. "The relationship between privatization and DEA estimates of efficiency in the container port industry." *Journal of Economics and Business* 57 (5): 433-462.

DSC (Drewry Shipping Consultants). 2004. *Annual Review of Global Container Terminal Operators.* July. London.

Everette, Sophia (2005a): "Effective corporatisation of ports is a function of effective legislation: Legal issues in the existing paradigm." A paper presented in the Annual Conference of the International Association of Maritime Economists, Cyprus 2005.

Fageda, X. (2005). *Load centres in the Mediterranean port range: Ports hub and ports gateway*. Public Policies and Economic Regulation Research Unit, University of Barcelona.

Jenness, Jeff. 2005, Distance and Azimuth Matrix v.2 Extension for ArcView 3.2 (Software)

Loo, Becky P. Y., and Hook, Brian. 2002. "Interplay of international, national and local factors in shaping container port development: A case study of Hong Kong."

Transport Review 22 (2): 219–245.

Maddala, G., 1983. *Limited-dependent and Qualitative Variables in Econometrics.* Cambridge University Press.

Pindyck, R. and Rubinfeld. 1991. *Econometric Models and Economic Forecasts*. McGraw-Hill: New York.

Slack, B. 1985. "Containerization, Interport Competition and Port Selection." *Maritime Policy and Management*. Vol. 12, No. 4: 293-303.

Tobin, J., 1958. "Estimation of relationships for limited dependent variables." *Econometrica* 26 (1), 24–36.

Tongzon, Jose and Wu Heung. 2005. "Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals)." *Transportation Research Part A* 39, no. 5: 405-24.

Tongzon, Jose L. 1995. "Determinants of port performance and efficiency." *Transportation Research Part A* 29A, no. 3: 245-52.

UN ESCAP. 2005. *Free Trade Zone and Port Hinterland Development*. New York.

Windle, R., Dresner, M., 1995. "A note on productivity comparisons between air carriers." *The Logistics and Transportation Review* 31 (2), 125–134.

Other Readings on Infrastructure Privatization and Asset Management:

Baietti, Aldo. 2001. Private Infrastructure in East Asia: Lesson Learned in the Aftermath of the Crisis. Technical Paper No. 501. Washington, D.C.: World Bank.

Bahl, Roy and Johannes F. Linn. 1992. *Urban Public Finance in Developing Countries*. New York: Oxford University Press.

Bauman, Duane D., John J. Boland and W. Michael Hanemann. 1997. *Urban Water Demand Management and Planning*. New York: McGraw-Hill.

Bond, Patrick and the Infrastructure Research Team. 1998. "Infrastructure Investment and The Integration of Low-Income People into the Economy". In *The Impact of Infrastructure on Poverty Reduction and Human Development*. Development Bank of Southern Africa.

Burns, Penny, David Hope and Jeff Roorda. 1999. "Managing Infrastructure for the Next Generation." *Automation in Construction 8*. p.689~703.

California Department of Finance. 2002. *2002 California's Five Year Infrastructure Plan*. Sacramento: DOF.

Crump, Kelvin. 2002. *Promoting and Disseminating Good Practice in the Planning and Management of Educational Facilities: Capital Investment Strategic Planning - A Case Study, Gold Coast Institute of TAFE, Queensland, Australia*. Paper presented at OECD Programme on Educational Building International Seminar on Educational Infrastructure. 24 - 27 February 2002.

Deakin, Elizabeth. 1988. The Politics of Exactions. In Rachelle Alterman ed., *Private Supply of Public Services.* pp 96-109. New York: New York University Press.

Deakin, Elizabeth. 1989. "Toll Roads: A New Direction for U.S. Highways?" *Built Environment* 15 (3/4): 185-194.

Dornan, Daniel. L. 2002. "Asset Management: Remedy for Addressing the Fiscal Challenges Facing Highway Infrastructure" *International Journal of Transport Management* 1. p.41~54.

Dowall, David. E. 1996. "An Overview of Private Sector Financing of Urban Infrastructure Services: A Developing Countries Perspective," *Public Works Management and Policy* 1 (1) (July): 76-87.

Dowall, David E. 2000. *California's Infrastructure Policy for the 21st Century: Issues and Policy Options*. San Francisco: Public Policy Institute of California.

Erie, Steven P. 1996. *International Trade and Job Creation in Southern California: Facilitating Los Angeles/Long Beach Port, Rail, and Airport Development*. A Policy Research Program Report. California Policy Seminar, University of California.

Ehrhardt, David and Rebecca Burdon. 1999. *Free Entry in Infrastructure*. Discussion Paper 2093. Washington, D.C.: World Bank.

Eichengreen, Barry J. 1994. *Financing infrastructure in developing countries : lessons from the railway age.* Institute of Business and Economic Research, Working paper no. 94-230. University of California at Berkeley.

Fink, Carsten Aaditya Mattoo and Ileana Cristina Neagu. 1999. *Trade in interantional maritime services: How much does policy matter?*, The World Bank, Washington, DC .

Garvin, Michael J. 2001. *Challenges of Infrastructure Asset Management*. Institute for Civil Infrastructure Systems (ICIS).

Goldsmith, Stephen. 1999. *The 21st Century City*. Rowan & Littlefield, New York.

Gonzalez, Maria Manuela and Lourdes Trujillo. 2005. Reforms and infrastructure efficiency in Spain's container ports, The World Bank, Washington, D.C.

Guislain, Pierre. 1997. *The Privatization Challenge: A Strategic, Legal and Institutional Analysis of International Experience*. Washington, D.C.: World Bank.

Hyman, Leonard. 1995. *The Privatization of Public Utilities*. Public Utilities Reports. Vienna, VA.

IFC (International Finance Corporation). 1996. *Financing Private Infrastructure. The Lessons of Experience*. Washington, D.C.

Jacobson, Charles D. and Joel A. Tarr. 1996 "No Single Path: Ownership and Financing of Infrastructure in the 19^{th} and 20^{th} centuries," in Ashoka Mody ed., *Infrastructure Delivery: Private Initiative and the Public Good*. Washington, D.C.

Jimenez, Emmanuel. 1995. "Human and Physical Infrastructure: Public Investment and Pricing Policies in Developing Countries," in J. Behrman and T.N. Srinivasan eds., *Handbook of Development Economics*. Vol. 3. New York: North Holland.

Kessides, Christine. 1993b. *Institutional Options for the Provision of Infrastructure*. Discussion Papers 212. Washington D.C.: World Bank.

Kimberley, Paul. 2000. MDF 3: *Voices for change, partners for prosperity: Towards Port Besst Practice. What makes your firm internationally competitive?* Cairo: Egyptian Center for Economic Studies (ECES).

Levy, Sidney M. 1996. *Build, Operate, Transfer: Paving the Way for Tomorrow's Infrastructure*. New York: Wiley and Sons.

McNeil, Sue, P. S. Sriraj, and Shaumik Pal. 2002. *Evaluation of Near-Transportation Private Sector Asset Management Practices*. Midwest Regional University Transportation Center. University of Wisconsin-Madison. November.

Mody, Ahoka (eds.) 1996. *Infrastructure Delivery: Private Initiative and the Public Good*. Washington D.C.: Economic Development Institute of the World Bank.

Narayan, Deepa. 1995. *The Contribution of People's Participation: Evidence from 121 Rural Water Supply Projects.* Environmentally Sustainable Development Occasional Paper Series No.1. Washington, D.C.: World Bank.

OECD (Organisation for Economic Cooperation and Development). 1991. *Urban Infrastructure: Finance and Management*. Paris: OECD.

OECD (Organisation for Economic Cooperation and Development). 1997a. *Contraction out Government Services: Best Practice Guidelines and Case Studies.* Public Management Occasional Papers No. 20. Paris.

OECD (Organisation for Economic Cooperation and Development). 1997b. *Privatization of Utilities and Infrastructure.* Paris.

OECD (Organisation for Economic Cooperation and Development). 1998. *User Charging for Government Services: Best Practice Guidelines and Case Studies.* Public Management Occasional Papers No. 22, Paris: OECD.

OECD (Organisation for Economic Cooperation and Development). 2001. *Asset Management for the Road Sector: Transport.* Paris.

Ostrom, Elinor. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. New York: Cambridge University Press.

Ostrom, Elinor, Larry Schroeder and Susan Wynne. 1993. *Institutional Incentives and Sustainable Development: Infrastructure Policies in Perspective*. San Francisco: Westview Press.

Peattie, Lisa. 1987. *Planning: Rethinking Ciudad Guayana*. Ann Arbor: University of Michigan Press.

Porter Doug et al. 1992. *Special Districts: A Useful Technique for Financing Infrastructure*. Washington, D.C.: The Urban Land Institute.

Rae, David. 2002. *Next Steps for Public Spending in New Zealand: The Pursuit of Effectiveness*. OECD Economics Department Working Papers. No. 337.

Rosen, Harvey S. 2002. *Public Finance*, 6th edition. New York: McGraw-Hill/Irwin.

UNCTAD (United Nations Conference of Trade and Development). 1995. *Comparative Experiences with Privatization: Policy Insights and Lessons Learned*. New York.

UNCTAD (United Nations Conference for Trade and Development) Secretariat. 1998. *Guidelines for Port Authorities and Governments on the privatization of port facilities*, GE.98-51748. United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland.

UNCTAD (United Nations Conference for Trade and Development) 2001. *Interactive thematic session: Infrastructure development.* Third United Nations Conference on the Least Developed Countries United Nations. General Assembly, Brussels, Belgium: United Nations.

US DOT (Department of Transportation). 1999. *Asset Management Primer*. December. Washington, DC.

US GAO (General Accounting Office). 2002. *Water Infrastructure: Information on Financing, Capital Planning, and Privatization*. GAO-02-764. August. Washington, DC.

US GAO (General Accounting Office). 1998. *Executive Guide: Leading Practices in Capital Decision Making*. GAO/AMID-99-32. December. Washington, DC.

US OMB (Office of Management and Budget). 1997. *Capital Programming Guide*. Supplement to OMB Circular A-11, Part 3: Planning, Budgeting, and Acquisition of Capital Assets. July. Washington, DC.

Whittington, Dale. 1992. "Possible Adverse Effects of Increasing Block Tariffs in Developing Countries," *Economic Development and Cultural Change* 41: 75-87.

Wilson, John S. et al. 2002. *Trade Facilitation: A Development Perspective in the Asia Pacific Region*. Singapore: Asia Pacific Economic Cooperation.

World Bank. 1994. *World Development Report 1994: Infrastructure for Development.* New York: Oxford University Press.

World Bank. 2000. *Strategic Municipal Asset Management*. Municipal Finance Background Series. Washington, DC.

Yeo, K.T. 1995. "Planning and Learning in Major Infrastructure Development: Systems Perspective" *International Journal of Project Management,* Vol. 13. No. 5 p.287~293.