THE ANALYSES ON TRANSPORTATION ECONOMICS AND NETWORK MODELING

WINAI HOMSOMBAT

Ph.D

The Hong Kong Polytechnic University

2013

THE HONG KONG POLYTECHNIC UNIVERSITY

Department of Logistics and Maritime Studies

THE ANALYSES ON TRANSPORTATION ECONOMICS AND NETWORK MODELING

WINAI HOMSOMBAT

A thesis submitted in partial fulfillment of the requirements for
the degree of Doctor of Philosophy

September 2012

CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

Signature:

Name of student: Winai HOMSOMBAT

Dedicated to my family,
teachers, and friends

ABSTRACT

The transport and logistics industry is of critical importance to the world's economy. It not only directly contributes to economic growth in terms of employment, tax revenue, and value-adding activities, but also provides essential inputs to other sectors such as trade, tourism, and supply chain management. Therefore, it is important for policy makers and industrial practitioners to accurately measure performances of the industrial organizations and examine industrial dynamics in the sector, so that the correct government policy and management strategies can be formulated. This thesis contributes to such an objective by innovatively applying the methods of economic analysis and network modeling to transport and logistics industry. Conceptually, it includes two parts. The first part focuses on the issue of how to evaluate an industrial organization's performance, and how to identify the factors and market dynamics leading to a given performance. This part focuses on the measurement of what actually happened in the market using observed market data. The second part deals with the issue of how to design and evaluate alternative government policies for the transport and logistics industry. This part involves the modeling and prediction of market outcome/equilibrium under alternative policies.

The first part of this thesis consists of three chapters. These chapters, Chapter 2 to Chapter 4, empirically investigate the performance and market dynamics of the aviation industry, from which rich data are available. Chapter 2 benchmarks airline efficiency performance. Chapter 3 investigates the performance and competitive effects of the airlines-in-airlines strategy, in which an airline group operates a full-service airline and a low-cost carrier at the same time. Chapter 4 benchmarks the key performance indicators and competitiveness of the major hub airports in Southeast Asia and Hong Kong, and identifies the key factors behind this development pattern. The second part includes two chapters on policy analysis for the maritime industry. Since industry data are relatively limited in this sector, these studies rely on analytical models and comparative statistics. In particular, Chapter 5 analyzes the effects of regional cooperation on the management of port pollution, by considering the introduction of a market-based policy on pollution control into a region with multiple ports. Chapter 6 investigates the implications of the ongoing process of

production base relocation for major ports in the Pearl River Delta region. The key findings of each chapter are as follows.

Chapter 2 benchmarks airline productivity and cost competitiveness. By examining the changes in these measures over an eighteen-year period, the key factors underlying the changes are then identified. The analysis of the nine major North American airlines during the 1990 to 2007 period indicate that the airlines' productivity levels significantly improved over the study period, although they were clearly influenced by the overall economy and the industrial shocks. In terms of cost competitiveness, significant productivity gains were largely offset by the sharp increase in fuel prices. However, labor costs remained the most important determinant of airlines' cost competitiveness. There is no evidence that airlines' productivity levels were converging, although they served many overlapping markets. Other factors, such as fleet expansion strategies and bankruptcy protection, also had non-negligible impacts on the airlines' operating efficiency.

Chapter 3 analyzes the performance and competitive effects of the airlines-in-airlines strategy by empirically studying airline pricing and network configuration pattern of the Qantas airline group (Qantas Group), which runs a full-service airline (Qantas Airways) and a low-cost carrier (Jetstar Airways) simultaneously. Using data from the Australian domestic market, the fare regression results reveal that when Qantas and Jetstar operate simultaneously on a route, these two airlines are able to charge higher prices, whereas the rival low-cost carrier's price will be reduced. Overall, the average price in the market is increased. The investigation of Jetstar's network configuration shows that there is no significant correlation between an established Qantas route and a new Jetstar's network configuration. However, on a route where Qantas faces competition from other low-cost carriers, there is a significantly higher chance that Jetstar will also serve this route. All these results suggest that Jetstar is designed as a fighting brand in response to low-cost carrier competition. There is also preliminary evidence that Qantas Group derives some quality benefits from this dual-brand strategy. These results provide fresh insights into the competitive effects of the airlines-in-airlines strategy and explain why this strategy is being used by an increasing number of Asian airlines.

Chapter 4 benchmarks key performance measures of the major hub airports in Southeast Asia and Hong Kong so as to identify the key determinants of their competitiveness. The investigation suggests the following. First, Hong Kong airport

is a leader with outstanding performance in several operational measures. Second, Bangkok airport's growth has been constrained by political instability and weak hub airline development; however, the airport has great long-term potential. Third, the development of low-cost carriers has become a major driver for traffic growth, but the implications for airport connectivity are unclear. Fourth, despite limited progress on regional liberalization, intra-Asia routes are clearly contributing to traffic growth and hub airport connectivity. Finally, governments should safeguard airline competition by promoting market liberalization and airport capacity investments.

Chapter 5 attempts to model the government policy. It investigates a market-based policy, namely environmental taxation, to address pollution control in a region with multiple ports where pollution from a port's operation can spread out over a wide region. The investigation reveals that in the absence of inter-port coordination, pollution spill-over and inter-port competition can lead to distorted pollution taxation and emission constraints. As a result, there will be excessive pollution and sub-optimal social welfare. Therefore, despite the potential competition among ports in a region, it is important for them to coordinate their pollution control efforts. The analysis recommends a regional approach to pollution control and suggests areas where inter-port cooperation is needed among competing ports.

Chapter 6 develops an economic model to assess the impacts of production base relocation on intra- and inter-port cluster competition. The study focuses on the major ports in the Pearl River Delta (PRD) region, namely the ports of Hong Kong and Shenzhen, and the competition of these ports with other clusters such as Shanghai in the Yangtze River Delta (YRD). The analysis shows that such a process, in every case, will harm the performance of the port of Hong Kong, but benefit the port of Shanghai. The implication for Shenzhen is more complex as it shares the same transportation corridor to inland China as Hong Kong, but also competes with Hong Kong at the same time. The analytical results suggest that a more competitive port of Hong Kong is in a better position to cooperate with the neighboring port of Shenzhen, and it is important for Hong Kong to improve its cross-border cargo flow.

PUBLICATIONS ARISING FROM THE THESIS

Journal papers:

1. Homsombat, W., Fu, X., Sumalee, A., 2010. Policy implications of airline performance indicators: analysis of major North American Airlines. *Transportation Research Record*, 2177, 41-48.
2. Homsombat, W., Lei, Z., Fu, X., 2011. Development status and prospects for aviation hubs – a comparative study of the major airports in South-east Asia. *The Singapore Economic Review*, 56 (4), 573-591.

Papers submitted for publication (under review):

1. Homsombat, W., Yip, T.L., Yang, H., Fu, X., Regional cooperation and management of port pollution. *Maritime Policy and Management*, under review.
2. Homsombat, W., Ng, A.K.Y., Fu, X., The impacts of production base relocation on port cluster competition: the case of Pearl River Delta (PRD) region. *Growth and Change*, under review.
3. Homsombat, W., Lei, Z., Fu, X., Competitive effects of the airlines-in-airlines strategy – an investigation of airline pricing and network configuration patterns in the Australian domestic market. *Transportation Research Part E*, under review.

Conference papers:

1. Homsombat, W., Fu, X., Sumalee, A., 2009. Airline operating performance indicators towards policy implications: an analysis of major North American airlines. *Proceeding of the 14th International Conference of Hong Kong Society for Transportation Studies (HKSTS),* Hong Kong SAR, China, December 10-12.
2. Homsombat, W., Fu, X., Sumalee, A., 2010. Airline performance indicators towards policy implications: analysis of major North American airlines. *Proceeding of the 89th Annual Meeting of the Transportation Research Board (TRB)*, Washington, D.C., U.S.A., January 10-14.

3. Yip, T.L., Fu, X., Homsombat, W., Yang, H., 2012. Regional pollution management – an economic investigation. *Proceeding of International Forum on Shipping, Ports and Airports (IFSPA) 2012,* Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong SAR, China, May 27-30.
4. Homsombat, W., Yip, T.L., Yang, H., Fu, X., 2012. Regional management of port pollution: game theoretical analysis. *Proceeding of 2012 International Association of Maritime Economists Conference (IAME)*, Inha JRI, CMRI & Kainan University, Taiwan, September 6-8.
5. Homsombat, W., Lei, Z., Fu, X., 2012. Competition effects of the airline group under mixing business models – a case in Australian domestic market. Paper submitted to *the 5th Thailand-Japan International Academic Conference (5th TJIA 2012)*, Tokyo Institute of Technology, Tokyo, Japan, October 20.

ACKNOWLEDGEMENTS

The study in PolyU has opened up my knowledge in several ways. There are many things I have never known, but could experience from here. Throughout my entire study, I have received a great deal of support from many persons. First of all, I would like to express my gratitude to Dr. Xiaowen Fu for being my chief supervisor throughout my study, and Dr. Agachai Sumalee for suggesting me to know the Hong Kong Polytechnic University.

I would like to express my sincere gratitude to my super teacher and advisor, Ajarn Ton, for his generous support, deep understanding, inspiration, and continuous guidance. He is the teacher from his soul and is my role model working in academia.

I am indebted Thai community for their helps during my stay in Hong Kong – P'Chart, P'Nang, P'Lhin, and many others. I would like to thank Thai students in PolyU and HKU for their assistance and friendship.

I am most grateful to all my friends from Thammasat University, in particular. Although we stay apart around the world (Japan, USA, Canada, UK, Sweden, Denmark, Australia, etc.), I do feel so close to you and still receive really nice suggestions and generous supports. Thanks for keeping in touch and sharing your life abroad.

Last but not least, I would like to express my deepest gratitude to my junior sisters and brothers – MooBank, Pui, Bezaki, Tik, Thanin, Eang, Khemmanut, Khemmatat, Boattaman, Ekkachai, Tadjung, and all others – for their love, care, encouragement, and so many things. You are always with me, especially during the down cycle of life, and support no matter what issues or requests. You have never lost faith in me and are the real push throughout my study. Without you, I probably cannot come to this stage and go this far. Thanks all you guys!

TABLE OF CONTENTS

CHAPTER 1

CHAPTER 2

CHAPTER 5

CHAPTER 6

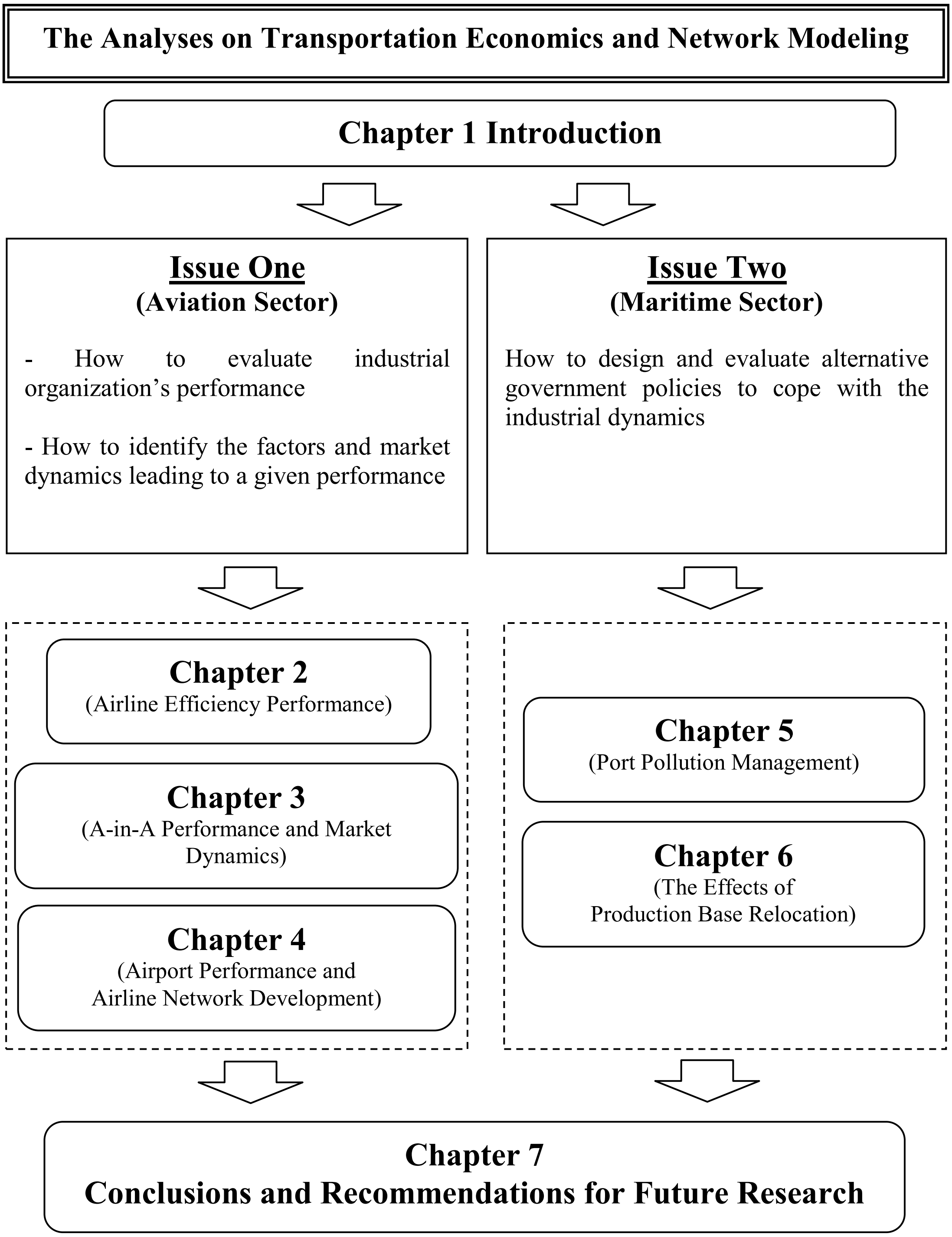
LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

The transport and logistics industry is of critical importance to the world's economy. It not only directly contributes to economic growth in terms of employment, tax revenue, and value-adding activities, but also provides essential inputs to other sectors such as trade, tourism, and supply chain management. Therefore, it is important for policy makers and industrial practitioners to accurately measure performances of the industrial organizations and examine industrial dynamics in the sector, so that the correct government policy and management strategies can be formulated. This thesis contributes to such an objective by innovatively applying the methods of economic analysis and network modeling to the transport and logistics industry. Conceptually, it includes two parts. The first part focuses on the issue of how to evaluate an industrial organization’s performance, and how to identify the factors and market dynamics leading to a given performance. This part focuses on the measurement of what actually happened in the market using observed market data. The second part deals with the issue of how to design and evaluate alternative government policies for the transport and logistics industry. This part involves the modeling and prediction of market outcome/equilibrium under alternative policies.

These two broad issues are often highly integrated: to examine the dynamic effects of government policies, one has to consider individual organizations’ behavior and resultant performance under different policies. Ideally, the formulation of government policies should be based on extensive empirical investigation. However, in practice, it is not always possible to collect all necessary data for the policy formulation. Therefore, analytical models and comparative statistics are often used in such cases, so that some insights on the effects of candidate polices can still be obtained.



- How to evaluate industrial organization's performance
- How to identify the factors and market dynamics leading to a given performance

How to design and evaluate alternative government policies to cope with the industrial dynamics

Figure 1-1 Thesis structure

The structure of this thesis is illustrated by Figure 1-1. The first issue is examined in Chapters 2, 3, and 4. These chapters empirically investigate the performance and market dynamics of the aviation industry, from which rich data are available. Each chapter presents an empirical study of one aspect of the industry. Chapter 2 benchmarks airline productivity and cost competitiveness. Chapter 3 investigates the performance and competitive effects of the airlines-in-airlines strategy, with which an airline group operates a full-service airline and a low-cost carrier at the same time. Chapter 4 benchmarks the key performances and competitiveness of the major hub airports in Southeast Asia and Hong Kong, and identifies the key factors behind this development pattern. The second part consists of two chapters on policy analysis and development in maritime sector. Since industry data are relatively limited in this sector, these studies mainly rely on analytical models. Specifically, Chapter 5 analyzes the effects of regional cooperation on the management of port pollution, by considering the introduction of a market-based policy on pollution control to a region with multiple ports. Chapter 6 investigates the implications of the ongoing process of production base relocation for major ports in the Pearl River Delta region. Chapter 7 summarizes and concludes the thesis.

The thesis starts with performance measurement for the aviation industry. It is well recognized that the airline industry not only contributes to economic growth through employment and service production, but also provides important inputs to related industries such as trade, hotels, tourism, and logistics. Chin and Tay (2001) and Homsombat et al. (2011), among others, showed that a positive relationship exists between air traffic demand and gross domestic product (GDP) growth. It is of crucial importance for a country to have access to efficient and competitive airline services. However, the industry has experienced a large fluctuation in economic conditions and unexpected shocks in recent decades, which in turn have had a large impact on airline operations. Chapter 2 of this thesis attempts to measure and compare the productivity and cost competitiveness of different airlines, with the aim of exploring the change in these two efficiency measures over time and identifying the key factors underlying these changes. The sample data are from nine major North American carriers during the 1990 to 2007 period. This analysis contributes to the literature in three ways. First, since the deregulation in U.S. domestic markets in 1978 and the international liberalization in 1992, the U.S. aviation market has been the most liberal aviation market in the world. Although most previous studies have examined the effects of market liberalization, it is believed that this effect on airline efficiency is likely to gradually decrease over time. Thus, an examination of the new pattern of efficiency growth is needed. Second, by using more recent data, this analysis can evaluate the effects of some major events on the U.S. airline industry, including the September 11, 2001 (9/11) terrorist attacks; the Iraq War since 2003; and the restructuring efforts by major airlines since 2002. Finally, with data covering the 1990 to 2007 period, this study can be used to evaluate the effects of business cycles on the airline industry.

Chapter 2 considers the operating efficiency of the full-service airlines (FSAs) only. Although airlines can improve efficiency, this alone does not guarantee overall performance enhancement and successful operation. Various managerial strategies have been adopted to enhance corporate performances in terms of profitability, revenue, network development, and market share. Since the mid-1990s, there has been a major growth of low-cost carriers (LCCs) globally, often at the expense of their established rival FSAs. In response, many FSAs have established their own low-cost subsidiaries (LCSs), a strategy referred as the "airlines-in-airlines" (A-in-A) strategy. Chapter 3 attempts to capture this dynamic by examining the performance of such a strategy, and investigates the market dynamics leading to such market outcomes. Specifically, the chapter examines the effects of the A-in-A strategy in terms of airline pricing and network configuration. Note this strategy seems to run counter to traditional concepts of efficiency, as considered in Chapter 2, since operating two conflicting business models could result in substantial efficiency loss (Graf, 2005). As a matter of fact, most of the adoptions in North America and Europe have failed (Graf, 2005; Morrell, 2005). However, there are several successful cases in the Asia-Pacific region, notably the Qantas airline group (Qantas Group), which includes Qantas Airways (FSA) and Jetstar Airways (LCS). Chapter 3 investigates the effects of the A-in-A strategy of Qantas Group by empirically studying the pricing and network configuration pattern of the LCS. A better understanding of the A-in-A strategy as it functions in Asia-Pacific will help the major carriers improve their management level, and guide governments and regulators in the region to introduce the right aviation policies. Meanwhile, this analysis may offer new insights for industry practitioners in developed markets to identify the real causes of LCS failures in North America and Europe.

Chapters 2 and 3 contribute to the understanding of airline performance and market dynamics leading to a given performance level. In order to accelerate the fast growth and competitiveness of the aviation industry, efficient and competitive airport hubs are needed in order to support downstream airline operations. Chapter 4 complements this issue by benchmarking the key performances of major hub airports and identifying the factors that determine airports' competitiveness. Four major airports in Southeast Asia and Hong Kong are analyzed, including Singapore Changi International Airport, Kuala Lumpur International Airport, Bangkok-Suvarnabhumi International Airport, and Hong Kong Chek Lap Kok International Airport. This chapter not only provides a comprehensive evaluation of the status quo of aviation hub development in the region, but also identifies key factors influencing the growth pattern of these major airports. It is hoped that this research will help airport managers and government regulators to better understand the industry dynamics, thereby promoting sustained growth of the aviation industry in the region.

In addition to the aviation industry, the maritime sector is one of the focal transport modes for the global economy. It plays a major role in integrating local economies into global shipping and trading networks, and improves social well-being. However, there emerged two crucial challenges to the maritime industry in recent years, which in turn have affected social welfare and competition among the ports. The first challenge is the controlling measure for pollution emissions caused by shipping activities. The second challenge is the ongoing process of the manufacturing base relocation further away from the marine logistics hubs. The second part of this thesis evaluates options / policies which can effectively address such challenges. While the first issue is a global phenomenon, the second issue is more apparent in the port cluster area in the Pearl River Delta (PRD) region of China. Since industry data are relatively limited for the markets analyzed, the investigations in this part mainly rely on analytical models, so that implications of government policy and corporate strategy can be drawn for stakeholders. The two major concerns are examined in Chapter 5 and Chapter 6, respectively.

Chapter 5 develops an economic model for a market-based policy for pollution control in a region with multiple ports. As Talley (2003) discussed, port operations and shipping activities often lead to negative environmental impacts in the port's catchment areas, including vessel oil spills, ballast water disposal, air pollution, anti-fouling pollution, dredging, vessel scrapping, and waste disposal at sea. These practices and events impose additional costs on the local community and have attracted significant attention from regional authorities and governments. Many port authorities have considered/introduced pollution taxes and environmental incentives. However, most of these policies are developed at either the port level or the national level; that is, there is only one decision maker involved (i.e., a local port authority or a central government). In practice, pollution at a port may have some spill-over effects on its neighbours. For instance, if two ports are located close to each other, the effluent of one port may generate negative spill-over effects, or inter-port externalities, for the community in the other port. Unless the two local governments or port authorities behave as a single decision maker, the conclusions reached in previous studies based on a single decision-making body may not hold. This chapter builds on previous studies by taking into account the inter-port externalities and the (possible) regional port cooperation on pollution management. The model further examines the behaviors of ports and port users (i.e. shippers and shipping lines) if certain incentive or disincentive policies are implemented, and suggests areas where inter-port cooperation is needed among the competing ports.

Chapter 6 examines the impact of production base relocation on the port cluster in the Pearl River Delta (PRD) region, specifically the ports of Hong Kong and Shenzhen. The relocation of the manufacturing base to inland China would significantly increase access costs to the PRD ports. As a consequence, *ceteris paribus*, other major Chinese ports, such as Shanghai, might become more attractive to these relocated shippers. This analysis emphasizes the important roles of intra- and inter-port cluster competition, in that the relocation process will not only affect the ports of Shenzhen and Hong Kong, but also ports in other clusters such as Shanghai in the Yangtze River Delta (YRD). Therefore, this chapter proposes an analytical framework to investigate the implications of this process on: (a) port performances in terms of throughputs, service charges, and profits; (b) cooperation and competition within the PRD port cluster (notably between Hong Kong and Shenzhen); and (c) inter-port cluster competition (notably between the PRD and the YRD port clusters). In addition, as Hong Kong and Shenzhen ports share common transportation corridors and infrastructures to the interior of the country, there is likely to be some externality effects on their hinterland access costs, such as those observed by Notteboom (2009a) in European countries. There may be positive externalities from the economy of scale or negative externalities from substantial congestion. Such externality effects are further addressed in this analysis. The chapter provides fresh insight into the gateway-hinterland literature in general and important policy recommendations for stakeholders in the Chinese port industry. Although this chapter focuses mainly on the PRD region, the analytical model can be easily extended to investigate other cases where competing ports experience similar situations and/or major changes in hinterland access costs.

CHAPTER 2

POLICY IMPLICATIONS OF AIRLINE PERFORMANCE INDICATORS[1]

This thesis starts with an important issue in the aviation industry, which is how to evaluate an industrial organization's performance, and how to identify the factors and market dynamics that lead to a given performance. This chapter benchmarks airline productivity and cost competitiveness by using the major North American airlines as a case study. The changes in these two efficiency indicators are examined to identify the key factors underlying such changes. With rich data at market and firm level, comprehensive analysis can be carried out and contribute to useful implications to the aviation industry in general.

The structure of this chapter is organized as follows. Section 2.1 presents background of the study. Section 2.2 introduces the data and methodology used in the research. Then, the calculated total factor productivity (TFP) and the estimated residual total factor productivity (RFTP) are presented in section 2.3. Cost competitiveness and cost function estimation are examined in section 2.4 and 2.5, respectively. The last section concludes the study.

---

[1] The study in this chapter has been published in Transportation Research Record as:

Homsombat, W., Fu, X., Sumalee, A., 2010. Policy implications of airline performance indicators: analysis of major North American Airlines. *Transportation Research Record*, 2177, 41-48.

It has also been submitted for proceeding in the following conferences as:

(1) Homsombat, W., Fu, X., Sumalee, A., 2009. Airline operating performance indicators towards policy implications: an analysis of major North American airlines. *Proceeding of the 14th International Conference of Hong Kong Soceity for Transportation Studies (HKSTS),* Hong Kong SAR, China, December 10-12.

(2) Homsombat, W., Fu, X., Sumalee, A., 2010. Airline performance indicators towards policy implications: analysis of major North American airlines. *Proceeding of the 89th Annual Meeting of the Transportation Research Board (TRB)*, Washington, D.C., U.S.A., January 10-14.

2.1 INTRODUCTION

The airline industry not only directly contributes to economic growth in terms of employment and service production, but also provides important inputs to relevant industries such as trade, hotels, tourism, and logistics. Chin and Tay (2001), among others, showed that a positive relationship exists between air traffic demand and gross domestic product (GDP) growth. Therefore, it is important for a country to have access to efficient and competitive airline services. This research measured and compared the productivity and cost competitiveness of nine major North American carriers during the period 1990 to 2007, with the aim of exploring the change in patterns of productivity and cost competitiveness over that time and identifying the key factors underlying the change.

A large body of literature covers the evaluation and comparison of airline performance. Caves et al. (1981) studied the levels and growth rates of outputs, inputs, and total factor productivity (TFP) for 11 trunk airlines over the 1972 to 1977 period. Other TFP studies on airlines can be found in Bailey (1987), Windle and Dresner (1992), and Oum et al. (2005). Cost competitiveness studies have also been conducted over the years (Windle, 1991; Good and Rhodes, 1991; Baltagi and Griffin, 1995; Oum and Yu, 1995, 1998a). The study in this chapter contributes to this rich literature in three ways. First, most of the previous studies aimed to examine the effects of deregulation and liberalization. With the deregulation in domestic markets started in 1978 and the international liberalization started in 1992, the U.S. aviation market has been the most liberal aviation market in the world. The effect of deregulation or liberalization on airline efficiency is likely to gradually decrease over time. Thus, an examination of the new pattern of efficiency growth is needed. In particular, any productivity changes identified in this study are mostly ascribed to factors other than one major policy change (i.e. the deregulation of the U.S. domestic market), but to a great extent reflecting improvement in management / production of the airlines examined. Second, by using more recent data, this study can be used to evaluate the effects of some major events in the U.S. airline industry, including the September 11, 2001 (9/11) terrorist attacks; the Iraq War since 2003; and the restructuring efforts by major airlines since 2002. Finally, with data covering 1990 to 2007, this study can be used to evaluate the effects of business cycles on the airline industry.

2.2 DATA AND METHOD

2.2.1 Data

This study focuses on the operating performance of nine major North American airlines for the following considerations. First, the United States is the most important aviation market in the world, accounting for more than 30.5% of the total world traffic in 2007. Second, this market has been the most mature and liberal market in the world. The findings from this market will provide important implications in forecasting the performance of other markets. Finally, this market has probably the most complete data set publicly available, which permits rigorous analysis with little data reconciliation. The nine major airlines chosen for the study during the 1990 to 2007 period included American Airlines (AA), Air Canada (AC), Alaska, America West (AWA), Continental (CO), Delta (DL), Northwest (NW), United (UA), and US Air (US). The data came mainly from the International Civil Aviation Organization (ICAO) but were supplemented with data from Avmark, Inc., the Statistical Abstract of the United States, and other sources. Airline annual reports were occasionally referred to if certain data were not available (e.g., fuel consumption for AC).

To measure a firm's productivity, data on output, input, network, and operational attributes were collected. By using an approach similar to one adopted by Windle and Dresner (1992), Oum and Yu (1995, 1998a, 1998b), and Oum et al. (2005), the study considered five output variables and five input variables.

The five output variables were scheduled passenger services, scheduled freight services, mail services, nonscheduled passenger and freight services, and incidental services. Except for incidental services, all other outputs were measured in revenue tonne-kilometer (RTK). In the literature, available tonne-kilometer (ATK) has also been used as an alternative to RTK. In theory, ATK can be regarded as the "capacity" or "inventory" for airlines, while RTK is the true sale that generates revenue. Therefore, RTK was used in this study. In any case, such a choice would have limited impacts on results because load factor was explicitly considered in the investigation. In addition, airlines and international air transport organizations use certain ratios to convert revenue passenger kilometers to RTK. For example, for passengers and their baggage, a standard weight of 200 lb per passenger is used by the U.S. Department of Transportation. This is different from the RTK outputs for cargo operations, which are based on a shipment's actual weight or size (dimensional or volume weight). Such minor inconsistencies would have little effect in the calculation because all airlines have used the same conversion ratio, and there are limited differences in the cargo revenue shares among the studied carriers. Incidental services included a wide variety of nonairline services such as catering, ground handling, aircraft maintenance, and reservation services for other airlines; consulting and hotel business, and the like, which are not the core business of the airlines. A quantity index of the incidental services was computed by deflating the incidental revenue with the U.S. GDP deflator adjusted by purchasing power parity.

The five input variables were labor, fuel, flight equipment, ground property and equipment (GPE), and materials. Labor input was measured by the number of full-time-equivalent employees. Fuel was measured by gallons of fuel consumed. For flight equipment, a fleet quantity index was constructed by aggregating different types of aircrafts with the translog multilateral index procedure proposed by Caves et al. (1982). The leasing prices of each type of aircraft were used as weights in the aggregation. The real stock of GPE was estimated by using the perpetual inventory method. The GPE service price was constructed with the method proposed by Christensen and Jorgenson (1969). Because the GPE cost was relatively small compared with flight equipment cost, these two capital inputs were aggregated into a single capital stock series. The material input was the input excluding all the preceding categories (labor, fuel, and capital). Therefore, the materials cost was the catchall cost category, which covered items such as airport fees, sales commissions, passenger meals, employee travel, consultants, non-labor repair and maintenance expenses, stationery, and other purchased goods and services.

Finally, to obtain a single measure of an airline's overall output (or input) level, the five categories of outputs (or inputs) were aggregated to form multilateral output (or input) index by using the same translog multilateral index procedure.

2.2.2 Methodology

TFP is the ratio of total output to total input obtained by using the translog multilateral index procedure. The multilateral comparison output (or input) index is defined as:

$$\ln Z_k - \ln Z_j = \sum_i \left(\frac{R_{ik} + \overline{R}_i}{2} \right) \ln\left(\frac{Z_{ik}}{\tilde{Z}_i} \right) - \sum_i \left(\frac{R_{ij} + \overline{R}_i}{2} \right) \ln\left(\frac{Z_{ij}}{\tilde{Z}_i} \right) \qquad (2.1)$$

where: - Z_{ik} is the output (input) type i for an airline k;

- R_{ik} is the share of revenues (cost) of output (input) i for airline k;

- $\overline{R}_i$ is the arithmetic mean of the revenue share (cost share) of output (input) i for all observations in the sample; and

- $\tilde{Z}_i$ is the geometric mean of output (input) i over all observations in the sample.

TFP comparison for airline k and j, then, can be written as:

$$\ln TFP_k - \ln TFP_j = \left(\ln Y_k - \ln Y_j\right) - \left(\ln X_k - \ln X_j\right) . \qquad (2.2)$$

TFP is computed by dividing the aggregate output index by the aggregated input index in accordance with the multilateral index procedure developed by Caves et al. (1982). Equation (2.2) compares the gross TFP between two airlines, where Y and X are output index and input index, respectively, obtained from equation (2.1). This method can be applied to the entire data set across all sample airlines and over time.

To decompose the sources of TFP differential among the sample airlines, a set of log-linear regressions was employed. The TFP levels were regressed on a number of output and network control variables. The econometric model is specified as follows:

$$\begin{aligned} \ln TFP_{it} \;=\; & \alpha_0 + \textstyle\sum_t \beta_t T_{it} + \gamma_1 \ln ST_{it} + \gamma_2 \ln LF_{it} + \gamma_3 RoF_{it} \\ & + \lambda_1 \ln FR_{it} + \lambda_2 \ln NoS_{it} + \lambda_3 \ln Inc_{it} \end{aligned} , \qquad (2.3)$$

where T_{it} are dummy variables for time-related effects (base year is 1990); ST_{it} is average stage length; LF_{it} is average load factor; RoF_{it} is rate of fleet adjustment as compared to the industry average and defined in Oum et al. (2005), with positive value indicating fleet expansion rate above industry average and negative value indicating fleet capacity expansion rate below industry average; FR_{it}, NoS_{it}, and Inc_{it} are the portions of revenue shares associated with freight, non-scheduled, and incidental revenue, respectively. A Feasible Generalized Least Square is adopted for the estimation of equation (2.3).

2.3 PRODUCTIVITY AND RESIDUAL PRODUCTIVITY RESULTS

2.3.1 Gross Total Factor Productivity

Table 2-1 reports the TFP calculated for the sample airlines during years from 1990 to 2007. The TFP value measures each airline's productivity level. TFP values were normalized against AA's TFP in 2000; that is, the TFP value of AA in 2000 is normalized to 1.

Although this TFP index reflects overall observed productivity performance, it may not reflect the airlines' "true" managerial level performance. TFP can be affected by many factors that are largely beyond managerial control such as average stage length and overall economic growth rate. Therefore, one should refrain from making inferences about the true managerial efficiency from the gross TFP results. With this caution, the calculated gross TFP levels revealed the following patterns:

Table 2-1 Gross total factor productivity (normalized at AA 2000 = 1.00)

Year	**AA**	**AC**	**Alaska**	**AWA**	**CO**	**DL**	**NW**	**UA**	**US**	**AVE**
1990	0.95	0.83	0.72	0.91	**0.97**	0.88	1.06	1.01	0.71	0.93
1991	0.93	0.75	0.77	**1.02**	**0.97**	0.86	1.03	0.99	0.72	0.92
1992	1.01	0.77	0.78	**0.97**	**1.02**	0.89	1.05	1.03	0.74	0.96
1993	1.01	0.77	0.87	**1.04**	**0.99**	0.96	1.09	1.08	0.75	0.99
1994	1.10	0.85	1.11	**1.09**	1.02	1.03	1.08	1.27	0.83	1.08
1995	1.14	0.87	1.16	1.15	1.04	1.08	1.23	1.26	0.86	1.12
1996	1.14	0.92	1.19	1.14	1.06	1.22	1.25	1.27	0.90	1.16
1997	1.13	0.94	1.18	1.23	1.14	1.24	1.30	1.28	0.97	1.18
1998	1.14	0.84	1.21	1.12	1.17	1.22	1.19	1.27	1.00	1.17
1999	0.99	0.86	1.05	1.07	1.13	1.12	1.18	1.11	0.92	1.07
2000	1.00	0.74	1.03	1.07	1.17	1.10	1.21	1.09	0.89	1.06
2001	0.86	0.96	0.97	1.02	1.14	1.02	1.14	0.99	0.89	0.99
2002	0.93	1.05	0.99	1.10	1.10	1.06	1.20	**1.06**	**0.94**	1.04
2003	1.05	**1.02**	1.08	1.20	1.23	1.15	1.28	**1.14**	**1.03**	1.13
2004	1.21	**1.23**	1.20	1.41	1.28	1.24	1.33	**1.26**	**1.10**	1.24
2005	1.28	1.31	1.26	1.38	1.39	**1.33**	**1.34**	**1.43**	**1.22**	1.34
2006	1.35	1.29	1.21	1.36	1.46	**1.39**	**1.46**	**1.45**	1.33	1.39
2007	1.35	1.40	1.33	1.68	1.46	**1.51**	**1.52**	1.51	1.41	1.45

Note: Average is weighted with revenue share. The bold numbers reflect the periods of those airlines who filed for bankruptcy protection. More details will be presented in later section.

(1) All airlines' productivity levels greatly improved. AWA, which pursued a low-cost business model, achieved the largest productivity growth. While US Airways had been the least productive airline, the carrier achieved tremendous efficiency growth following its merger with AWA in 2005.

(2) The airlines' productivity levels were clearly correlated with the overall economic cycle. The gross TFP levels remained stagnant during the period from 1990 to 1992, immediately following the Gulf War and economic recession. After this period, the steady productivity growth reached its peak in 1997 and 1998, at the height of the boom of the dot.com economy. The TFP levels then declined sharply during the period from 1999 to 2002, reflecting the negative impacts of concurrent factors such as economic recession and the 9/11 terrorist attacks.

(3) Although several major events such as the 9/11 attacks, SARS, and the war in Iraq that began in 2003, imposed significant negative impacts on productivity level, no long-term effect seemed to have resulted. Instead, major productivity growth occurred after 2003 following the restructuring of all the major airlines. Overall, it is apparent that such restructuring brought significant productivity gains. This finding is consistent with Lucas (1988), Bean (1990), and Hall (1991), who highlighted a potential positive effect of the negative event or downturn of the economy in bringing change or improvement to the productivity level. This result is also consistent with the financial stress model proposed by Golaszewski and Sanders (1992), which indicated that the productivity gains among the carriers were more likely to be enhanced during a downturn.

2.3.2 Residual TFP and Sources of Productivity Differentials

Gross TFP levels are influenced by factors beyond managerial control (Jordan, 1982). Therefore, the managerial efficiency should be compared after removing the effects of non-controllable factors. In a manner similar to Caves et al. (1981), Ehrlich et al. (1994), Oum and Yu (1995, 1998a, 1998b), and Oum et al. (2005), here regression analysis as defined in equation (2.3) was conducted to decompose the gross TFP differentials into various sources. The following variables were included in the regression model:

(1) Output scale (size);
(2) Average stage length of flights;
(3) Composition of outputs (freight, non-scheduled services, and incidental services);
(4) Average load factor;
(5) Rate of fleet adjustment; and
(6) Year dummy variables.

Except for fleet adjustment rate and year dummy variables, dependent and all explanatory variables in the model were transformed by using a natural logarithm. Regression analysis was used to identify the potential effects of these variables on gross TFP and to compute the Residual Total Factor Productivity (RTFP) index after removing the effects of the uncontrollable variables. The regression results are summarized in Table 2-2.

Table 2-2 Gross total factor productivity regression results

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient
Constant	0.22 (1.81)	**Rate of Fleet Adj.**	-0.15 (-5.36)	**1997**	0.06 (2.66)	**2004**	0.03 (1.81)
Output	0.02 (4.85)	**1991**	-0.009 (-0.84)	**1998**	0.03 (2.18)	**2005**	0.05 (2.42)
Stage Length	0.06 (4.07)	**1992**	0.008 (0.44)	**1999**	-0.03 (-1.65)	**2006**	0.05 (2.36)
Load Factor	1.31 (22.22)	**1993**	0.04 (2.79)	**2000**	-0.08 (-4.76)	**2007**	0.07 (4.03)
%Freight	-0.03 (-7.15)	**1994**	0.05 (3.53)	**2001**	-0.09 (-4.47)		
%Non-Sch.	0.03 (10.29)	**1995**	0.07 (5.62)	**2002**	-0.07 (-3.77)		
%Incidental	0.01 (1.79)	**1996**	0.07* (4.88)	**2003**	-0.03 (-1.75)		

Note: Number of observations = 162. *T*-statistical values are presented in parentheses, and *Non-Sch* stands for non-scheduled service share.

The estimation results suggest the following:

(1) *Output size*: The positive coefficient of this variable was statistically significant, indicating that larger airlines were expected to achieve a higher gross TFP level. This scale effect, however, was limited due to the small absolute value of the coefficient (0.02). This was consistent with most previous studies such as Doganis (2006), Oum and Yu (1995), and Oum et al.

(2005). This implied that cost savings could be achieved by merger, acquisition, or both in the airline industry but not to a great extent. Therefore, cost savings should not be the main objective or justification for airline merger.

(2) *Fleet adjustment rate* (rate of capacity adjustment): Earlier studies such as Caves et al. (1981) and Oum and Zhang (1991), suggested that capacity inputs should be treated as “quasi-fixed” to reflect the short-term disequilibrium nature of capital input adjustments. Following Oum et al. (2005), this study included the rate of fleet capacity adjustment in the TFP regression. The coefficient for this variable was statistically significant, with a large negative value (−0.15). This implied that the airlines with aggressive fleet expansion tended to suffer efficiency loss. Airlines should pay more attention to their efficiency and profitability level rather than aggressively seeking capacity expansion, scale expansion, or both. A similar observation, based on industry aircraft delivery trend, was made by Jordan (1998).

(3) *Other variables* (such as average stage length, passenger load factor, and output mix): The sign of the coefficients of these variables were intuitive, but the influences of these factors were limited due to the small values of the coefficients. In particular, the average stage length and output mix were dependent on markets served by the airlines, configurations of airlines’ networks and routes, and geographical location of the airlines’ home base operations. These factors were largely beyond managerial control and thus were removed when the RTFP was computed.

To compare the “pure” managerial efficiency of the airlines, the factors beyond the managerial control in the short run (including output size, average stage length, and output mix) were removed from the model. The RTFP levels for each airline were then computed and reported in Figure 2-1.

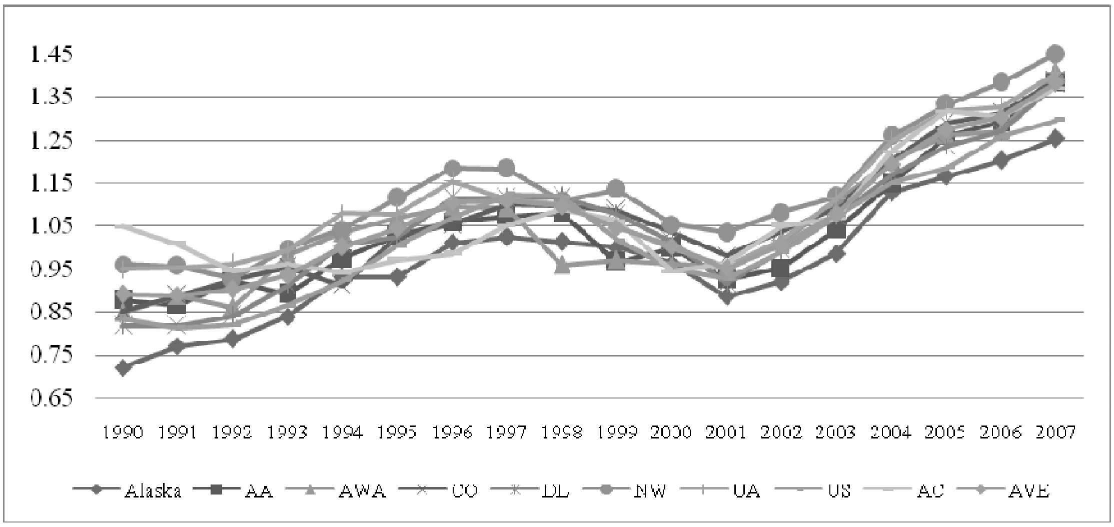


Figure 2-1 RTFP results for the studied airlines

Note: Average is weighted by using revenue share.

The calculated RTFP values suggest that:

(1) The RTFP patterns were overall consistent with the gross TFP. In particular, a significant productivity gain occurred since 2003 after major restructuring. Apparently, the robust recovery of the U.S. economy was another critical contributing factor. Overall, the RTFP pattern confirmed the study's finding that the economic cycle was probably the most important determinant of airline productivity. Therefore, apart from good corporate management, it is important for airlines to forecast industry demand and its trends better.

(2) There was less variation among the airlines' RTFP values when the factors beyond management control were removed. In addition, there were some slight differences between the rankings by gross TFP versus those by RTFP. For example, while AC's gross TFP was slightly below the industry average, it was as efficient as other carriers in RTFP. AWA was still very efficient over the years, but its RTFP level was overtaken by NW's. This implies that external or historical factors, such as market coverage (in the case of AC) or network configuration, still play an important role in shaping airlines' productivity. With deregulation and liberalization, airlines still face some challenges in entering new markets or reconfiguring their networks.

(3) Compared with the productivity results of 1990, the airlines' productivity levels are not converging in either TFP or RTFP. The RTFP of the sample

airlines dropped slightly from 1990 to 1993 but remained consistent afterward. There was no change in the variances of TFP and RTFP during the study period. Intuitively, if airlines serve overlapping markets with similar services and production technology, over time the surviving airlines should have converging productivity levels. Therefore, it is likely that the airlines have adopted product differentiation strategy, or there could be further consolidation in the airline industry. For instance, AWA and Alaska repositioned their services to be close to low-cost carriers. This led to changes in their operating characteristics and cost structures.

Except for AA and Alaska, all other carriers filed bankruptcy protection at least once during the sample period, as summarized in Table 2-3.

Table 2-3 Bankruptcy protection time line

Sample Airlines	Entered	Exited	Duration
AA	-	-	-
AC	April-2003	September-2004	17 months
Alaska	-	-	-
AWA	May-1991	August-1994	39 months
CO	December-1990	April-1993	28 months
DL	September-2005	April-2007	19 months
NW	September-2005	May-2007	20 months
UA	December-2002	February-2006	38 months
US^1	August-2002	March-2003	7 months
US^2 - AWA	September-2004	September-2005	12 months

Source: Various sources, for example, Airlines for America (formerly known as Air Transport Association), BankruptcyData.com, and company reports.

Note: US^1 refers to US first bankruptcy and US^2-AWA refers to second bankruptcy and merger with America West.

Although bankruptcy protection has negative impacts on firm's value, it may provide carriers additional time and opportunity to reorganize their business. Under Chapter 11, a company is granted the authority to cut labor cost aggressively, which would otherwise be difficult or even illegal under normal circumstances. In addition, evidence shows that bankruptcy protection helps firms with high debt ratios to improve operating performance (Kaylay et al., 2007). To examine the bankruptcy effects on productivity level, a paired *t*-test was used to compare the airlines' RTFP improvement after bankruptcy to the industry average RTFP change during the same period. For the eight bankruptcies listed in Table 2-3, on average the airlines involved improved their RTFP by 0.20 throughout the bankruptcy protection periods. During the same periods, the industry average RTFP declined by 0.01. Statistically, there is moderate evidence (*P-value* of 0.0516) that bankruptcy protection allowed the filing airlines to improve their RTFP. Because such a result was obtained with a small sample of bankruptcies, further study is required with data covering more airlines and a longer period.

2.4 COST COMPETITIVENESS

The cost competitiveness of an airline only partially depends on its productivity level. Productivity measures how efficiently airlines can convert inputs to outputs. It does not reflect the effects of input price. If an airline has to pay very high input prices, the carrier may become less cost competitive despite being productive. Therefore, it is important to examine airlines' cost competitiveness, which can be calculated by subtracting the total input price index from the RTFP index. For example, AA's cost competitiveness improved by 6.54% between 2000 and 2007, which was due to a 38.42% increase in productive efficiency (RTFP) and a 31.88% increase in input price. The results are summarized in Figure 2-2. The cost competitiveness index reported was measured as the percentage above (+) or below (−) the level of AA in 2000. In the figure, the average is weighted by using revenue share. In addition, Figure 2-2 uses ICAO data, which are consistent with U.S. Bureau of Transportation Statistics numbers. However, readers are cautioned about the AWA and US results for 2007, the year when the two airlines implemented a full merger and labor transfer.

The results show that AWA, AC, and NW were the most cost competitive carriers throughout the sample period, whereas US Airways and Alaska were among the worst. Overall, the industry's average level of cost competitiveness improved steadily from 1990 to 1999 due to productivity gains. Such a trend reversed in 2001 due to a sharp drop in RTFP from the 9/11 terrorist attacks and the following economic slowdown. Cost competitiveness improved again in 2002. However, the rapid rise of fuel prices began to outweigh efficiency gains in 2005. As a result, cost competitiveness has been declining in general.

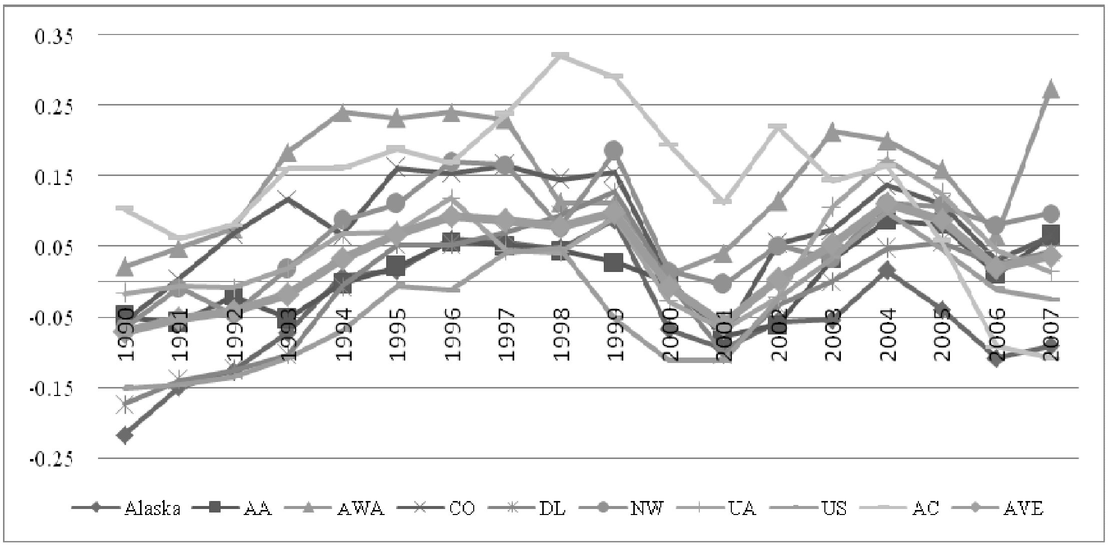


Figure 2-2 Cost competitiveness (percentage above or below AA's value in 2000)

2.5 COST FUNCTION ESTIMATION

Airline cost level is determined by efficiency, input price, and some other factors. This section estimates a variable cost function for the sample airlines in order to examine potential sources affecting cost, which include output scale, input price, network structure, and productivity. Since capital input is always in short-run disequilibrium, it is treated as a quasi-fixed input. Following Caves et al. (1984) and Gillen et al. (1990), a translog variable cost function is specified as follows:

$$\begin{aligned}\ln VC \;=\;& a_0 + \sum_j a_j C_j + \sum_t a_t T_t + b_t \ln Y + \sum_i \delta_i R_i + \sum_i b_i \ln \mathbf{W}_i + b_k \ln(uK) \\ & + b_e \ln E + c \ln Z + \frac{1}{2} d_{yy} (\ln y)^2 + \frac{1}{2} \sum_i \sum_j d_{ij} \ln \mathbf{W}_i \ln \mathbf{W}_j + \frac{1}{2} d_{kk} (\ln(uK))^2 \\ & + \frac{1}{2} d_{ee} (\ln E)^2 + \frac{1}{2} d_{zz} (\ln Z)^2 + \sum_i e_{yi} \ln Y \ln \mathbf{W}_i + e_{yk} \ln Y \ln(uK) \qquad , \quad (2.4) \\ & + e_{ye} \ln Y \ln E + e_{yz} \ln Y \ln Z + \sum_i f_{ki} \ln(uK) \ln \mathbf{W}_i + f_{kz} \ln(uK) \ln Z \\ & + f_{ke} \ln(uK) \ln E + \sum_i g_{ei} \ln E \ln \mathbf{W}_i + g_{ez} \ln E \ln Z + \sum_i g_{zi} \ln Z \ln \mathbf{W}_i\end{aligned}$$

where VC is the cost of variable inputs; Y is the aggregate output index; W_i is a vector of input prices (labor, fuel, and purchased services and materials inputs); K is capital stock which is treated as fixed in the short run; u is utilization rate of capital stock (measured as the weighted load factor); R_i's are the revenue shares of freight and mail, non-scheduled services, and incidental services; Z is average stage length; and E is the efficiency index computed earlier. a_j and a_t are coefficients associated with firm (C_j's) and year (T_t's) dummy variables (to capture the effects of shifts in technical efficiency over time and shifts in firm size). a's, b's, δ's, c, d's, e's, f's, g's are coefficients to be estimated.

With Shephard's lemma applied to the variable cost function in (2.4), the variable input cost share equations can be obtained as follows:

$$S_i = \frac{\partial \ln VC}{\partial \ln \mathbf{W}_i} = b_i + \sum_j d_{ij} \ln \mathbf{W}_i + e_{yi} \ln Y + f_{ki} \ln(uK) + g_{ei} \ln E + g_{zi} \ln Z \,. \qquad (2.5)$$

To improve the efficiency of estimation, the following equation of the shadow value of capital stock (Atkinson and Halvorsen, 1984; Oum and Zhang, 1991; Oum and Yu, 1995) is jointly estimated:

$$\frac{C_k}{VC} = -\frac{\partial \ln VC}{\partial \ln(uK)} = -(b_k + d_{kk} \ln(uK) + e_{yk} \ln Y + \sum_i f_{ki} \ln \mathbf{W}_i + f_{ke} \ln E + f_{kz} \ln Z)\,, \quad (2.6)$$

where C_k is the depreciated capital cost which is approximated by the total capital cost multiplied by utilization rate. Equation (2.6) is basically the first order condition for short-run total cost minimization, which endogenizes the capacity utilization. Equations (2.4), (2.5), and (2.6) are jointly estimated with the iterated Zellner method for seemingly unrelated regressions. The results are reported in Table 2-4. To save space, parameters of firm and time dummy variables are not reported.

The first-order coefficients of input prices indicate that, at mean value, labor and fuel inputs roughly account for 39% and 14%, respectively. This leaves the material input to account for 47% of the total variable cost. The positive first-order coefficient for capital implies a negative shadow value of capital input (Bailey, 1987; Windle, 1991; Gillen et al., 1985, 1990). The stage length's coefficient is negative and statistically significant, indicating that variable cost decreases with longer stage length. The negative coefficients of *%Non-Sch.* and *%Incidental* indicate that, *ceteris paribus*, carriers with a higher proportion of incidental services and non-scheduled services are expected to have lower variable costs, but such effects are rather limited.

Table 2-4 Variable cost function estimation

Parameter	Coefficient	Parameter	Coefficient
Constant (a_0)	0.36 (14.72)	Output × Labor $(Y \times W_l)$	0.14 (1.18)
Output (Y)	0.69 (10.44)	Output × Fuel $(Y \times W_f)$	0.02 (0.3)
%Freight (R_f)	0.02 (1.13)	Output × Capital $(Y \times uK)$	-0.46 (-2.6)
% Non-Schedule (R_n)	-0.02 (-2.92)	Output × Efficiency $(Y \times E)$	0.43 (2.4)
% Incidental (R_i)	-0.01 (-1.48)	Output × Stage $(Y \times Z)$	0.39 (2.78)
Labor Price (W_l)	0.39 (7.73)	Labor × Fuel $(W_l \times W_f)$	0.52 (3.84)
Fuel Price (W_f)	0.14 (3.54)	Labor × Capital $(W_l \times uK)$	-0.17 (-1.71)
Capital (uK)	0.27 (4.68)	Labor × Efficiency $(W_l \times E)$	0.005 (0.03)
Efficiency (E)	-0.03 (-0.26)	Labor × Stage $(W_l \times Z)$	-0.35 (-3.1)
Stage length (Z)	-0.18 (-2.95)	Fuel × Capital $(W_f \times uK)$	-0.10 (-1.4)
Output × Output $(Y \times Y)$	0.32 (1.64)	Fuel × Efficiency $(W_f \times E)$	-0.54 (-3.63)
Labor × Labor $(W_l \times W_l)$	0.19 (1.17)	Fuel × Stage $(W_f \times Z)$	0.09 (1.53)
Fuel × Fuel $(W_f \times W_f)$	-0.20 (-1.98)	Capital × Efficiency $(uK \times E)$	-0.28 (-1.71)
Capital × Capital $(uK \times uK)$	0.48 (2.83)	Capital × Stage $(uK \times Z)$	-0.22 (-1.46)
Efficiency × Efficiency $(E \times E)$	0.64 (1.25)	Efficiency × Stage $(E \times Z)$	-0.20 (-0.91)
Stage × Stage $(Z \times Z)$	-1.11 (-0.47)		
Number of Observations	162		
R-square	0.9885		

Note: All variables are normalized at mean and in natural logarithm form except time dummies. *T*-statistical values are presented in parentheses.

2.6 SUMMARY AND CONCLUSION

This study measured and compared the productivity and cost competitiveness of nine major North American carriers during the period from 1990 to 2007. Productivity level measures how efficiently airlines can use their inputs to produce outputs. Cost competitiveness reflects the combined effects of productivity and input price level on airline costs. Overall, the results of this research suggest the following conclusions:

(1) Overall, airlines' productivity levels, either measured by TFP or RTFP, improved over the years, especially in the late 1990s and during the period from 2003 to 2007. This improvement suggests that the airline industry can maintain its productivity growth with major restructuring efforts after the deregulation.

(2) Airlines' productivity levels were clearly correlated with the overall economic cycle. The Gulf War and the 9/11 terrorist attacks had a clear impact on airlines' productivity in the early 1990s and during 2001 and 2002. However, they had little impact on the overall trend of the productivity change.

(3) Airlines' productivity levels were not converging. This observation suggests that these carriers may have adopted a product differentiation strategy, or there may be further consolidation in the industry. For instance, AWA and Alaska have repositioned their services to be similar to low-cost carriers. This strategy led to changes in their operating characteristics and cost structure.

(4) The labor input price was the most important determinant of the airlines' cost competitiveness during the study period. This result implies that restructuring efforts accomplished by these airlines were necessary and helpful, but a good control of labor cost will also be important in the future.

(5) An aggressive fleet expansion policy was detrimental to the productivity and cost competitiveness of the airlines. Airlines should carefully consider their growth strategy in the future. Better utilization of a conservative fleet is likely to be more effective than an aggressive fleet expansion strategy.

(6) The significant efficiency gains in recent years were largely offset by the sharp increase in fuel prices. Until 2007, the airlines' cost competitiveness levels were almost the same as in 1990s. This situation limits the airlines' ability to stimulate demand growth via substantial price reduction.

(7) Some evidence suggested that bankruptcy protection may allow filing airlines to improve their RTFPs more than the industry average. However, due to the small sample size and relatively high *P-value* obtained in the statistical test, further study is needed on this issue.

Overall, this study provides several important results of the analysis of productivity and cost competitiveness of North American airlines. However, the method adopted in the study may not be able to capture potential quality differentials among these carriers. This is mainly due to the lack of instruments (hedonic measures) in controlling service quality. Future studies should focus on: (a) productivity and cost competitiveness with consideration of quality difference, and (b) cost structure detail of an airline.

CHAPTER 3

COMPETITIVE EFFECTS OF THE AIRLINES-IN-AIRLINES STRATEGY – AN INVESTIGATION OF AIRLINE PRICING AND NETWORK CONFIGURATION PATTERNS IN THE AUSTRALIAN DOMESTIC MARKET[1]

Previous chapter examined full-service airlines' (FSAs) performance in terms of productivity and cost competitiveness. However, efficiency improvement alone does not always lead to successful operations. One major challenge to FSAs in recent years is the rapid expansion of low-cost carriers (LCCs). Many FSAs around the world have utilized various strategies in response and one such method is to establish a low-cost subsidiary (LCS), a strategy referred as "airlines-in-airlines" (A-in-A) in the literature. This strategy seems to run counter to the traditional efficiency measure as discussed in Chapter 2, since it is usually not efficient for one airline to run two distinct business models. Still, there are successful cases, notably the Qantas airline group (Qantas Group) which includes Qantas Airways (an FSA) and Jetstar Airways (an LCC). This chapter investigates the performance and outcome of the A-in-A strategy. In particular, it investigates airline pricing and network configuration pattern using market data in the Australian domestic market.

This chapter is presented as follows. Section 3.1 introduces background of the study. Section 3.2 reviews the recent development of Australian airline market. Section 3.3 examines the effects of the A-in-A strategy on airfares and investigates network configuration patterns of the LCS airline. Summary and conclusion are provided in the last section.

---

[1] The study in this chapter has been submitted for journal publication in Transportation Research Part E: Logistics and Transportation Review, which is under review, as:

> Homsombat, W., Lei, Z., Fu, X., Competitive effects of the airlines-in-airlines strategy – an investigation of airline pricing and network configuration patterns in the Australian domestic market. *Transportation Research Part E*, under review.

It has also been submitted for proceeding in the 5th Thailand-Japan International Academic Conference (5th TJIA 2012) as:

> Homsombat, W., Lei, Z., Fu, X., 2012. Competitive effects of the airline group under mixing business models – a case in Australian domestic market. Paper submitted to *the 5th Thailand-Japan International Academic Conference (5th TJIA 2012)*, Tokyo Institute of Technology, Tokyo, Japan, October 20.

3.1 INTRODUCTION

First adopted by Southwest Airlines in the U.S. in the 1970s, the low-cost carrier (LCC) business model has been employed by airlines in many markets as a competitive alternative to the traditional full-service airline (FSA, also referred to as “legacy carriers” or “network carriers”) business model. In general, LCCs provide low-fare air travel services that eliminate various “frills” such as free meals and in-flight entertainment offered by FSAs. Other main features of the LCC business model include: single, unrestricted, and point-to-point fares; direct and ticket-less sales (supplemented by travel agents); no seat assignments; high flight frequency; single aircraft types and high plane utilization; use of secondary or un-congested airports with 20-30 minute aircraft turnaround times; and competitive employee wages with profit-sharing arrangements. These operational characteristics have enabled LCCs to achieve substantially lower unit costs than FSAs, which has turned LCCs into leading players in many liberalized/developed markets such as Southwest, JetBlue, and Frontier in the U.S., and Ryanair and EasyJet in Europe. In recent years, the low-cost business model has been emulated throughout the Asia-Pacific region, with start-up LCCs being established in many Asian countries (see Appendix A for a list of LCCs). Although the overall industry development in Asia still lags behind those in North America and Europe (Zhang et al., 2008), the Asia-Pacific aviation market offers lucrative opportunities for LCCs with favorable growth factors such as growing groups of middle-income travelers, increasing urbanization, ongoing aviation liberalization and deregulation, and geographic attributes that are favorable for aviation transportation (Centre for Asia Pacific Aviation, 2002).

Morrell (2005) stated that FSAs may respond to LCC competition in the following ways: 1) to reduce the significant costs of their mainline operations without changing their business model or reducing service levels, and/or 2) to establish low-cost, no-frills divisions or “airlines-in-airlines” (A-in-A) that apply all or some of the elements of the low-cost business model. Graham and Vowles (2006) argued that setting up a low-cost subsidiary (hereafter LCS) might provide the following advantages: the airline might be able to force down costs, particularly labor inputs, when competing with LCCs; the LCS service, which is more appropriate for leisure travel or hub-bypass routes, might function as a sophisticated form of market segmentation within a network expansion; the LCS could be used to preempt the market entry of other LCCs; and the LCS could serve as a direct response to other LCCs already operating in the markets.

Indeed, FSAs have been pursuing both of the abovementioned strategies suggested by Morrell (2005). The airlines have also gained significant productivity improvement over the years (Homsombat et al., 2010), which has allowed them to maintain the majority market shares in most markets, especially the trans-continental long-distance routes. Still, many legacy airlines have been forced to reduce a significant amount of their operating costs to compete at the low end of the fare spectrum (Ito and Lee, 2003; Goolsbee and Syverson, 2008). As such, several FSAs have established their own low-cost subsidiaries/offshoots to particularly compete in low-cost segment. Pilling (2004) suggested that FSAs have the following options when creating an LCS: a) to establish a separated brand; b) to maintain some links and coordination between the LCS and FSA brands; and c) to extend the mainline brand to encompass the low-cost segment. The first two options have been widely adopted in practice.

As Table 3-1 summarizes, many LCS airlines have been formed in the North American and European markets. However, these attempts have been largely unsuccessful. In the U.S., many LCS operations have been shut down soon after introduction. Delta and United launched Song and Ted in 2003 and 2004, respectively. Song was reintegrated back into Delta's domestic long-haul operations in 2006 due to poor financial results that led to bankruptcy filing. Later in 2009, Ted was also shifted back into United Airlines, partly due to the crisis caused by high fuel prices. Morrell (2005) concluded that one of the main causes of these failures was labor union restrictions. These subsidiary airlines essentially adopted their parent firms' labor practices, which were usually restrictive and costly. Consequently, having a parallel LCS did not help the parent airlines to achieve cost reduction. Instead, the unit costs of the LCS offshoots were not comparable to those of independent LCCs. Virtually, all LCS attempts in the U.S. failed, with their operations either abandoned or folded back into mainline operations. Similar LCS attempts in Europe were not very successful either. British Airways and KLM eventually sold their LCS brands, GO and Buzz, respectively. Although Basiq Air (Transavia) and Swiss European are still in service, these airlines have not grown into major players in the market due to limited traffic and network expansion over the years.

Table 3-1 LCC offshoots of North American and European network airlines

LCCs	Parent airline	Start of operations	End of operations	Aircraft type
US Markets				
Song	Delta	2003	2006	B757-200
Ted	United	2004	2009	A320
CALite	Continental	1993	1995	DC9 and B737-300
Shuttle	United	1994	2002	B737-500/300
Delta Express	Delta	1996	2003	B737-200
Metrojet	US Air	1998	2002	B737-200
European Markets				
Basiq Air (Transavia)	KLM	1966	-	B737
Germanwings	Lufthansa	2002 (as separate airline)	-	A319
Swiss European	Swiss Int'l Air Lines	2005	-	AVRO 146-RJ100
Go	British Airways	1998	2003 (acquired by EasyJet)	B737-300
Buzz	KLM	2000	2004 (acquired by Ryanair)	B737-300 and BAe146-300

Source: Morrell (2005) and Graf (2005) with supplemented data from the authors.

Running two distinct business models is challenging and risky. Graf (2005) found substantial incompatibilities between the low-cost and network carrier business models within the same airline group, and hypothesized that if parent airlines could effectively control the negative impacts of the two distinct business models and provide sufficient autonomy to the LCS, then the chance of success could be improved. Graham and Vowles (2006) conducted an extensive literature survey of the A-in-A strategy and found that in most cases, even the LCS airlines were established as separate identities, the parent company still paid close attention to market segmentation within a single-delivery platform, such that parent airlines often intervened in the operations of their LCS subsidiaries. Graham and Vowles (2006) cautioned against this strategy – citing the possible dilution of the mainline brand and self-market cannibalization – and suggested that stretching the existing brand might be a more effective alternative for network carriers. Gillen and Gados (2008) examined the potential factors underlying airline groups' operating performances and concluded that failures in running two business models were mostly as a result of LCCs and FSAs moving from vertical to horizontal differentiation (e.g., an increased use of LCCs by business travelers). They argued that there is a chance of success if the airline group can have sufficient market dominance, judicious network planning, and co-ordination between the two models. It appears that some airlines have successfully followed these recommendations. For example, despite being a wholly-owned subsidiary of Lufthansa, Germanwings is not bounded by previous labor union agreements (Graf, 2005). The airline is highly independent and only a few of its routes overlapped with those of Lufthansa. Still, none of the LCS start-ups in Europe and North America have been genuinely successful.

Interestingly, LCS start-ups have also been created in the Asia-Pacific region in recent years and some have achieved good traffic growth and financial returns. For example, Qantas established an LCS, Jetstar Airways, to serve the Australian domestic market in 2003. Jetstar subsequently expanded to include international routes with joint-ventures established in other Asian countries such as Singapore, Vietnam, Japan, and Hong Kong[2]. This strategy has allowed Jetstar to penetrate both the international and domestic markets of many Asian countries despite the relatively tight regulations in the region. Jetstar's performance has been as good as, if not better than, most independent LCCs in the region. Table 3-2 presents the operating statistics of airlines in Qantas Group. The revenue and traffic shares of Jetstar within the airline group have increased rapidly, partially due to its significantly lower costs compared with Qantas (Graham and Vowles, 2006), which allow Jetstar to successfully compete with other LCCs and stimulate more traffic with its lower fares. Jetstar has become a major source of growth for Qantas Group. As Table 3-3 shows, in the first quarter of 2011, Jetstar achieved a seat share of 19.71% in the domestic market, whereas the dominant LCC, Virgin Australia, acquired a seat share of 26.59%. Overall, the airline group controlled over half of the total market. Creedy (2008) concludes that Qantas is probably the most successful airline group in the world currently running parallel full-service and low-cost models. A similar strategy

---

[2] In 2004, Jetstar created Jetstar Asia, which is based at Singapore's Changi Airport. Jetstar Asia offers service to and from Hong Kong, Southeast Asia, Australia, China, and Japan. Jetstar also owns 27% of Jetstar Pacific, which is based in Vietnam. In 2011, it was announced that Qantas Group would establish a joint-venture, Jetstar Japan, with Japan Airlines (Nomura, 2011) and another joint-venture, Jetstar Hong Kong, with China Eastern Airlines (Fickling and Wang, 2012). The latter two airlines are expected to start offering services in late 2012 and 2013, respectively.

has been adopted by an increasingly number of FSAs in other Asian countries, including Singapore[3], Thailand, Korea, and Japan.

Table 3-2 Summary operating statistics of Qantas Group (Unit: Million)

Airlines	**Operating Revenue (US$)**		**ASK**		**RPK**	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**
Qantas	9,067	9,733	30,013	29,795	23,781	24,092
Jetstar	1,444	2,016	11,197	11,615	9,060	9,456
% of Jetstar in total	*13.74*	*17.16*	*27.17*	*28.05*	*27.59*	*28.19*

Source: Airline reports.

Note: Jetstar includes Jetstar Airways and Jetstar Asia Airways. Operating revenue data were from all operations (domestic and international). ASK and RPK were compiled exclusively for the Australian domestic market.

Table 3-3 Capacity shares of four major airlines in the Australian domestic market (Based on scheduled seats as of 2011, quarter 1)

2011 Quarter 1	**Qantas**	**Jetstar**	**Qantas & Jetstar**	**Virgin**	**Tiger**	**Total of four major airlines**
Top 50 routes						
Total number of routes	27	31	40	43	16	46
Total scheduled seats (‘000)	5142.93	2923.49	8066.42	4282.02	777.42	13125.86
Top 50 routes – seat share (%)	35.54	20.20	55.74	29.59	5.37	90.70
Top 100 routes						
Total number of routes	36	44	61	52	20	70
Total scheduled seats (‘000)	5401.68	3345.11	8746.79	4485.19	858.06	14090.04
Top 100 routes – seat share (%)	33.27	20.60	53.87	27.62	5.28	86.78
All Australian domestic routes (276 routes)						
Total number of routes	45	47	73	62	26	98
Total scheduled seats (‘000)	5443.35	3395.03	8838.37	4581.42	902.34	14322.14
Seat share (%)	31.60	19.71	51.31	26.59	5.24	83.14

Source: Compiled from OAG data.

With the exception of Jetstar and Tiger Airways, most of the LCS airlines in Asia have only been in the market for a limited time. It is probably too early to make any affirmative assessment with respect to their overall performances. However,

---

[3] Singapore Airlines holds 32.84% of the shares in the LCC, Tiger Airways (as of 31 July 2011), which was jointly established with other investors including the founder of Ryanair. Tiger Airways operates out of Singapore Changi Airport. In 2007, the airline established its subsidiary Tiger Airways Australia, with the operation hubs at Melbourne and Sydney airports. The latter airline becomes one of the major LCCs in Australian domestic markets.

considering the poor outcomes of other LCS airlines in North America and Europe, the ongoing development in Asian markets is somewhat puzzling. A better understanding of the LCS airline business model as it functions in Asia-Pacific will help the major carriers improve their management level, and guide governments and regulators in the region to introduce the right aviation policies. Meanwhile, this may offer new insights for industry practitioners in developed markets to identify the real causes of LCS failures in North America and Europe. The analysis in this chapter contributes to these objectives through an investigation of the competitive effects of the A-in-A strategy in Asia-Pacific region. In particular, this study examines pricing and network configuration patterns of Qantas Group (i.e., Qantas Airways and Jetstar Airways) in Australian domestic market. The study focuses on fully deregulated Australian domestic market because the restrictive regulations present in international routes might complicate an empirical analysis with unknown biases. Although a large body of literature has examined the consequences of LCC entry (Strassmann, 1990; Windle and Dresner, 1995; Dresner et al., 1996; Windle and Dresner, 1999; Morrison, 2001), this study is novel in that it first empirically investigates the competitive effects of an airline group consisting of both FSA and LCC.

3.2 LCC DEVELOPMENT IN AUSTRALIAN DOMESTIC MARKET

The LCC segment in Australia has grown rapidly in recent years. As of 2011, low-cost services accounted for more than half of the market in terms of number of seats provided. As Figure 3-1 shows, the LCC penetration rate in Australia was ranked third in Asia-Pacific as of early 2011, second only to Philippines and Malaysia. The extremely high LCC market share in Philippines is mainly due to the country’s small overall aviation market, whereas Malaysia is the home market for AirAsia, the most successful independent LCC in Asia. At present, three LCCs dominate Australia’s domestic market, namely Virgin Australia (formerly Virgin Blue), Jetstar Airways, and Tiger Airways Australia.

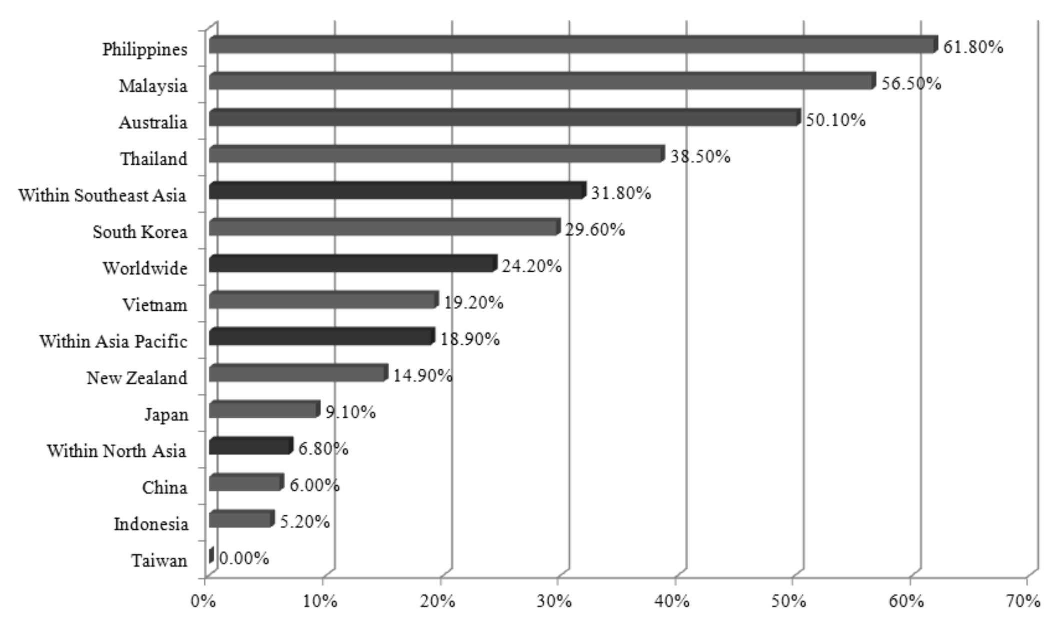


Figure 3-1 Asia-Pacific domestic LCC penetration by capacity (seats): Jan-Jul, 2011

Source: Centre for Asia Pacific Aviation (CAPA) and OAG Facts, (www.centreforaviation.com/analysis/jetstar-jal-lcc-to-commence-service-by-dec-2012-reports-57090).

The development of LCCs began in Australia in 1990 along with the deregulation of the domestic markets. Prior to this, the domestic market was dominated by two incumbent carriers, Qantas and Ansett (Forsyth, 2003). The deregulation opened the market and allowed new entrants to compete in all domestic routes (Forsyth, 1998). Several LCCs were established, which most failed within a short period of time. The first group of entrants included Compass Airlines and Compass Mark II. The former airline commenced its operations in 1990. Only a year later, the airline needed to cease operations as a result of intense price wars and financial difficulties (Nyathi et al., 1993). Compass Mark II entered in 1992, but lasted for only six months due to a liquidity problem. Forsyth (2003) concluded that although there were several favorable factors facilitating LCC services (e.g., a number of dense routes and some leisure markets within the domestic markets), these were largely offset by head-on competition by the incumbents, financial and marketing problems, and insufficient infrastructure accessibility.

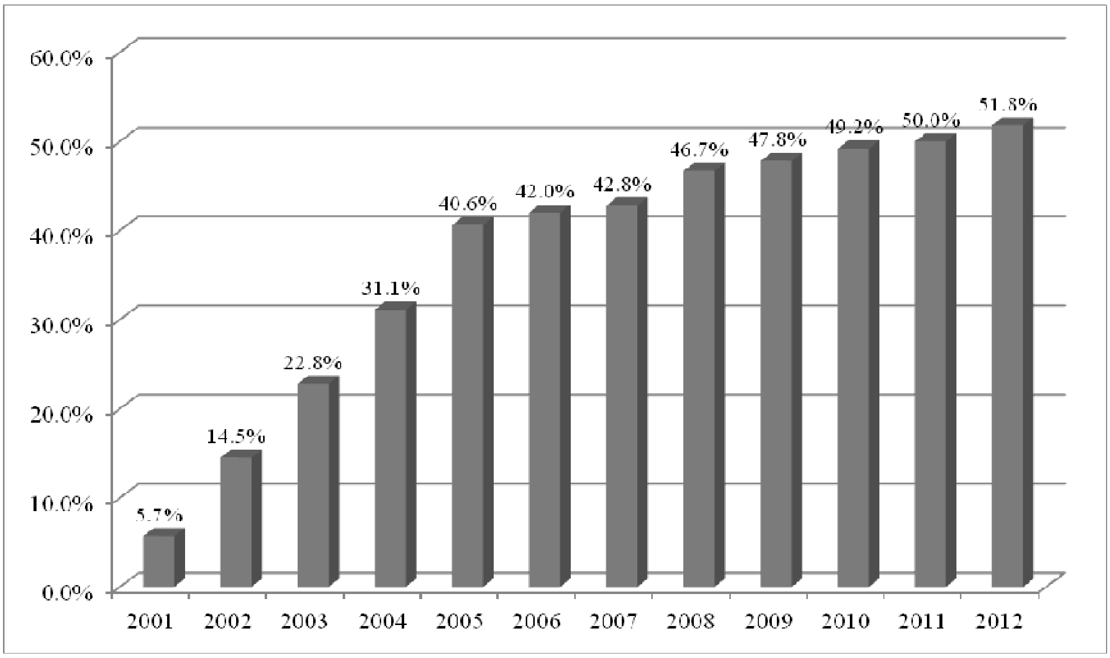


Figure 3-2 Australia (domestic) LCC capacity share (%) of total seats: 2001 – 2012
Source: CAPA-Centre for Aviation with data provided by OAG, a UBM Aviation business, (http://www.centreforaviation.com/profiles/hot-issues/low-cost-carriers-lccs#lcc).

Note: The number as of 2012 is based on total scheduled seats from January to July.

The second phase of LCC entry began in 2000, when Impulse Airlines and Virgin Blue Airlines were formed. Again, Impulse Airlines encountered a serious cash flow problem in early 2001 and was later taken over by Qantas Airways. Virgin Blue turned out to be the only “native” independent LCC that survived in Australia. The airline operated a somewhat different business model compared to previous LCCs. For example, it offered connecting services, engaged in code sharing with major airlines, and was able to maintain airfares substantially lower than those of Qantas (Francis et al., 2006). Most importantly, the collapse of Ansett in 2001 significantly benefited Virgin Blue. The markets previously served by Ansett, which accounted for more than 40%, have been largely acquired by Virgin Blue and Qantas. This allowed Virgin Blue to capture more than 30% of the domestic market share as of early 2003 (Easdown and Wilms, 2002). In response to Virgin Blue’s aggressive growth, Qantas established Jetstar Airways in 2003, a similar approach that adopted by FSAs in North America and Europe. It was used to replace some of the previous QantasLink’s operations and later expanded to include international services. Driven by the healthy growth of Virgin Blue and Jetstar, the low-cost segment has been growing rapidly in recent years. As Figure 3-2 reveals, the market share of LCCs grew sharply in 2002 following the entry of Virgin Blue. Such growth momentum was maintained following the formation of Jetstar in 2003 and has more or less stabilized since 2005, when LCCs jointly claimed more than 40% of the total market.

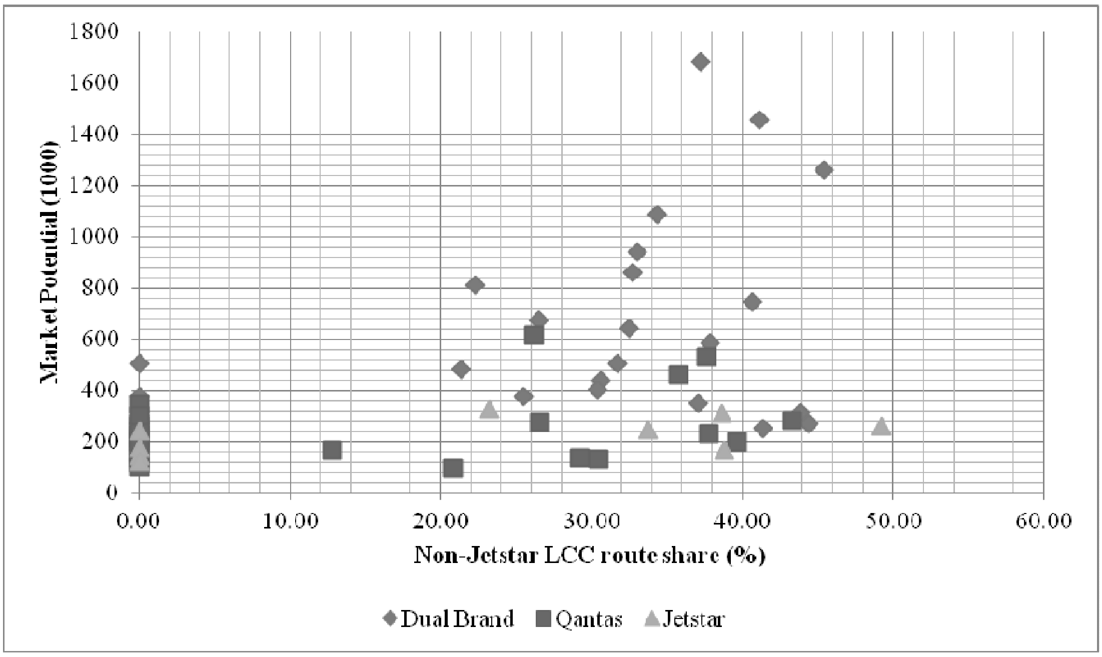


Figure 3-3 Qantas and Jetstar's operating routes with respect to the market potential measure and (non-Jetstar) LCC capacity share (%) as of June 2011.

Source: Compiled from OAG.

Note: Market potential is measured by $\sqrt{TCAP_i \times TCAP_j}$, where *TCAPs* are total scheduled seats of the airport pair.

Qantas Group appears to be using Jetstar as a "fighting brand" to deal with competition from other LCCs in the market with potentially large traffic volume. Based on the OAG schedule data for June 2011, Figure 3-3 classifies the domestic routes served by Qantas and/or Jetstar into the following groups: (1) "Dual-brand" routes in which both Qantas and Jetstar offer services; (2) "Qantas" routes exclusively with Qantas flights; and (3) "Jetstar" routes exclusively with Jetstar flights. These routes are plotted with respect to two dimensions. The vertical axis reports the "market potential" measure, which is defined as the average scheduled seats of the Origin-Destination (OD) airports. Such measure is used because the actual traffic volume in a route is significantly affected by airlines' entry decisions or "endogenous" to airline entry patterns. The horizontal axis reports the market share of rival LCCs (i.e., non-Jetstar LCCs). It is clear that in "thin" markets, Qantas

Group is more likely to use one brand, either Qantas or Jetstar, to serve the market regardless of rival LCCs' market shares. However, in routes with substantial market potential, the services of Qantas and Jetstar are always introduced simultaneously. Such a strategy appears to work well. In all routes with Qantas Group's services, the rival LCCs never get more than half of the market[4].

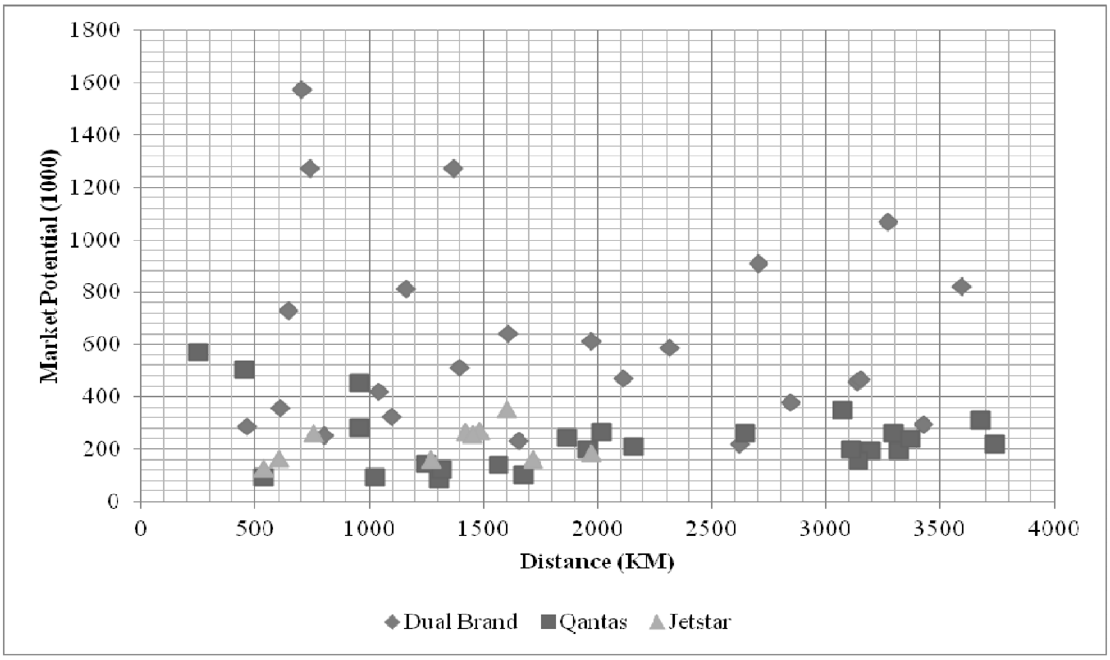


Figure 3-4 Qantas and Jetstar's operating routes with respect to market potential measure and stage length (km) as of June 2011.

Source: Compiled from OAG.

Note: Market potential is defined as $\sqrt{TCAP_i \times TCAP_j}$, where *TCAPs* are total scheduled seats of the airport pair.

The "dual-brand" strategy is used in routes of various distances. As Figure 3-4 illustrates, Qantas and Jetstar work together to serve OD airports from less than 500 km to more than 3,500 km. Again, the main difference from other routes served by either Qantas or Jetstar is potential market size. The single brand is mostly used in small- to medium-sized routes, whereas virtually in all routes that link to major

---

[4] The preliminary finding on Jetstar's average yield reveals that the use of dual brand strategy enables Jetstar to compete against Virgin Australia and/or Tiger Airways without a significant fare reduction. With data from January 2009 to November 2011, it is found that the average yield of Jetstar's routes with the presence of Qantas is statistically higher than those without Qantas (with p-value = 0.000). Details on this issue will be further investigated by regression analysis in next section.

destinations, the dual-brand operation is always observed. Another notable pattern is that an exclusively Jetstar operation is only used in thin routes of short distances (500-2000 km). This is probably due to the fact that Jetstar operates narrow-body aircrafts, which are more cost effective in such markets.

3.3 MARKET COMPETITION ANALYSIS

Qantas faced sharp competition upon the entry of Virgin Blue (later renamed as Virgin Australia) and thus created Jetstar as a "fighting brand" in response. As previously discussed, such a strategy is nothing new and had not proven success in North America and Europe. No study in the public domain has quantitatively analyzed the competitive effects of such a strategy. Its implications for the implementing carrier (in this case, Qantas Group) and rival airlines (in this case, all airlines competing with Qantas and Jetstar) remain unclear. The following subsections examine these issues empirically by investigating: (1) its implications on airline pricing, and (2) the network configuration patterns of the LCS airline and underlying driving factors.

3.3.1 Airline Pricing

The empirical work first analyzes the effects of the Qantas Group's dual-brand strategy on average fares of various airlines in Australian domestic market, using monthly data from January 2009 to November 2011. A market or route is defined as a non-directional airport pair, thus the average of both directions is used for all variables in the estimation. Such effect on airline fares is examined by the following reduced-form price equation[5]:

$$\begin{aligned} \ln P_{ijt}^{k} = \;& \alpha_0 + \alpha_1 \ln Dist_{ij} + \alpha_2 \ln \sqrt{TCAP_{it} \times TCAP_{jt}} + \alpha_3 \ln FREQ_{ijt} \\ & + \alpha_4 \ln MinAPHHI_{ijt} + \alpha_5 \ln MaxAPHHI_{ijt} + \alpha_6 NFSA_{ijt} \\ & + \alpha_7 NLCC_{ijt} + \alpha_8 DualBrand_{ijt} + \sum\nolimits_m \gamma_m Quarter_m + \sum\nolimits_n \lambda_n Year_n \end{aligned} \quad , \quad (3.1)$$

---

[5] Alternatively, one can consider including route HHI in the estimation. However, Fu et al. (2011a) found that there is substantial product differentiation between FSAs and LCCs, thus using the numbers of FSAs and LCCs within a market (i.e., variables $NFSA_{ijt}$ and $NLCC_{ijt}$) will achieve better estimation results. In robustness check, alternative fare regressions with and without route HHI are tested. There is little change in key estimation results, but using the specification in (3.1) provided a slightly better fit for the data.

where the dependent variable P_{ijt}^{k} is the average fare for economy class tickets of airline k in the route linking airports i and j at time t. The explanatory variables include the following. $Dist_{ij}$ is the great circle distance in kilometer of the city-pair markets. $\sqrt{TCAP_{it} \times TCAP_{jt}}$ represents "market potential" or potential market size, which is calculated as the geometric mean of the airport throughput $TCAP$ (measured in total scheduled seats) at the two-endpoint airports. $FREQ_{ijt}$ is the total frequency of all airlines in the route, measured by number of scheduled departures in a month. This is used to control for service quality in a route because higher flight frequency will lead to reduced schedule delays. $MinAPHHI_{ijt}$ and $MaxAPHHI_{ijt}$ are the minimum and maximum Herfindahl-Hirschman Index (HHI) of the two airports. These are included because it is well known that the market concentration indices at OD airports are likely to influence airline's pricing. $NFSA_{ijt}$ and $NLCC_{ijt}$ are the numbers of FSAs and LCCs serving the route with non-stop flights[6]. $DualBrand_{ijt}$ is a binary variable capturing the possible effects of dual-brand operation by Qantas Group on fare, and taking value of 1 if Qantas and Jetstar operate simultaneously in the market, and 0 otherwise. $Quarter_{m}$ and $Year_{n}$ are quarterly and yearly dummy variables. Fare data were retrieved from Passenger Intelligence Services (PaxIS), a database developed by IATA Business Intelligence Service. Frequency and capacity data were compiled from the Official Airline Guide (OAG) database.

To investigate the implications of dual-brand operations on market average fares, group airlines' fares, and rival airlines' fares, the regression analysis specified in equation (3.1) is estimated by using different fares as the dependent variable P_{ijt}^{k}. The following price equations are specified:

(P1) *Market Average*: the dependent variable is the average fares from all airlines in the market;

(P2) *Qantas Airways*: Qantas' average fare is used as the dependent variable;

(P3) *Jetstar Airways*: Jetstar's average fare is used as the dependent variable; and

---

[6] In the data set, there are three major LCCs in the Australian markets: Jetstar Airways, Tiger Australia, and Virgin Australia. Apart from Qantas, all other non-LCC airlines are treated as FSAs, most of which include niche market carriers such as Airlines of Tasmania, Brindabella Airlines, Regional Pacific Airlines, and Skytrans.

(P4) *Virgin Australia*: the average fare offered by Virgin Australia, the largest LCC in the domestic market, is used as the dependent variable.

That is, models (P2) and (P3) measure the effects of dual-brand operations on the airline group's fare levels, while models (P1) and (P4) capture the respective effects on the overall market and rival airline's price levels. In all four specifications, only economy fares are considered because business and first class services are very different products that are not always offered by all carriers. The independent variables have the same values except for the numbers of FSAs and LCCs (i.e., variables $NFSA_{ijt}$ and $NLCC_{ijt}$), which do not include the airline itself or other airlines in the same group. Such a specification ensures that when estimating an airline's pricing behavior, $NFSA_{ijt}$ and $NLCC_{ijt}$ correctly measures the degree of competition faced by each particular carrier. Summary statistics of the variables used in this analysis are reported in Table 3-4. As evidenced by the number of FSAs and LCCs in a route, the sample covers a wide range of market structures that range from close to perfectly competitive markets (where the total number of FSAs equals to 9 and the total number of LCCs equals to 3) to monopoly markets. There are also large variations in terms of distance, frequency, and potential market size. All of these suggest that the sample data include diversified routes that allow these models to provide important insights into very general market conditions.

Table 3-4 Summary statistics of variables used in alternative fare models

Variables	**Market Average** (Number of observations = 14899)				**Virgin Australia** (Number of observations = 2568)			
	Mean	**Std.**	**Min**	**Max**	**Mean**	**Std.**	**Min**	**Max**
Fare (US$)	213.27	109.41	36.20	1241.96	152.36	75.73	52.11	1241.96
Distance (KM)	1148.76	895.47	31.00	3740.00	1532.32	937.53	251.00	3740.00
Market potential	285.39	345.02	0.17	1809.82	373.99	303.35	49.35	1809.82
Frequency	371.32	681.53	8.00	4464.00	423.63	619.78	8.00	4464.00
Min airport HHI	2555.93	1924.50	1565.86	10000	1992.92	386.05	1565.86	3937.18
Max airport HHI	5085.04	2868.26	1686.61	10000	3410.29	1018.06	1686.61	8564.91
Number of FSAs$^{1/}$	1.4926	1.0649	0	9	1.3037	0.9222	0	9
Number of LCCs$^{1/}$	1.2169	1.1436	0	3	0.9295	0.7079	0	2
Variables	**Qantas Airways** (Number of observations = 4884)				**Jetstar Airways** (Number of observations = 1889)			
	Mean	**Std.**	**Min**	**Max**	**Mean**	**Std.**	**Min**	**Max**
Fare (US$)	268.29	111.26	53.79	716.23	133.62	81.98	36.20	843.00
Distance (KM)	1196.45	902.11	92.00	3740.00	1564.46	848.85	386.00	3740.00
Market potential	238.03	267.72	0.87	1809.82	425.70	325.44	37.82	1809.82
Frequency	282.10	484.20	8.00	4464.00	456.72	685.26	8.00	4464.00
Min airport HHI	2190.82	964.94	1565.86	10000	2007.67	448.80	1565.86	4306.28
Max airport HHI	4860.48	2480.83	1686.61	10000	3463.50	1464.02	1686.61	10000
Number of FSAs$^{1/}$	0.3991	0.7700	0	8	0.3785	0.9760	0	8
Number of LCCs$^{1/}$	0.6560	0.7066	0	2	1.2107	0.5805	0	2

Note: 1/ Numbers of FSAs and LCCs were not included the airline itself or other airlines in the same group.

Table 3-5 summarizes the estimation results of the airline pricing models specified above. The key variable of interest is dual-brand, which is statistically significant in all specifications. This suggests that such a strategy does have important implications for all the airlines involved. The variable has a positive sign in the estimation with dependent variables being the average fare of the whole market, exclusively Qantas fares, and exclusively Jetstar fares. When Qantas and Jetstar operate simultaneously in a route, the average market price is pushed higher. This differs from the services of independent LCCs, which typically see a reduction in their market price levels (Bailey et al., 1985; Strassmann, 1990; Windle and Dresner, 1995; Dresner et al., 1996; Windle and Dresner, 1999). It shall be noted that the estimation results are also consistent with previous studies in that the number of LCCs in a route, $NLCC$, reduces the fare of the market average and the fare levels of LCCs.

Table 3-5 Fare regression estimation results

Fare	P1: Pooled data estimation			P2: Qantas Airways			P3: Jetstar Airways			P4: Virgin Australia		
	Coef.	**Std**	**P>|t|**	**Coef.**	**Std**	**P>|t|**	**Coef.**	**Std.**	**P>|t|**	**Coef.**	**Std**	**P>|t|**
Distance	0.3954	0.0056	0.0000	0.4098	0.0044	0.0000	0.6002	0.0156	0.0000	0.5260	0.0073	0.0000
Market potential[1/]	-0.0112	0.0054	0.0370	0.0268	0.0053	0.0000	-0.0373	0.0241	0.1230	-0.0067	0.0086	0.4370
Frequency	-0.0114	0.0035	0.0010	-0.0154	0.0022	0.0000	-0.0728	0.0100	0.0000	0.0027	0.0038	0.4800
Min airport HHI	0.1226	0.0125	0.0000	0.1610	0.0150	0.0000	0.5509	0.0629	0.0000	-0.1109	0.0198	0.0000
Max airport HHI	0.0489	0.0107	0.0000	0.0684	0.0064	0.0000	-0.0976	0.0250	0.0000	-0.0611	0.0141	0.0000
Number of FSAs[2/]	**0.0790**	0.0042	0.0000	**-0.0144**	0.0026	0.0000	**0.0420**	0.0063	0.0000	**0.0121**	0.0085	0.1570
Number of LCCs[2/]	**-0.1883**	0.0071	0.0000	**0.0021**	0.0040	0.6080	**-0.0013**	0.0122	0.9160	**-0.0135**	0.0073	0.0620
Dual-brand	**0.0264**	0.0141	0.0610	**0.0147**	0.0064	0.0210	**0.1817**	0.0319	0.0000	**-0.0407**	0.0089	0.0000
Dummy 2010	0.1832	0.0076	0.0000	0.2513	0.0046	0.0000	0.2071	0.0140	0.0000	0.1903	0.0067	0.0000
Dummy 2011	0.4118	0.0077	0.0000	0.4949	0.0051	0.0000	0.3793	0.0147	0.0000	0.4094	0.0074	0.0000
Dummy quarter 2	0.0665	0.0087	0.0000	0.0881	0.0054	0.0000	0.0215	0.0149	0.1500	0.0477	0.0082	0.0000
Dummy quarter 3	0.1398	0.0086	0.0000	0.1387	0.0057	0.0000	0.1163	0.0158	0.0000	0.0950	0.0086	0.0000
Dummy quarter 4	0.2148	0.0088	0.0000	0.2113	0.0062	0.0000	0.2500	0.0166	0.0000	0.1446	0.0099	0.0000
Constant	1.2025	0.2191	0.0000	0.3203	0.1979	0.1060	-2.5640	0.7256	0.0000	2.3308	0.2691	0.0000
Number of observations	*14899*			*4884*			*1889*			*2568*		
F-statistics	*0.0000*			*0.0000*			*0.0000*			*0.0000*		
R-squared	*0.4529*			*0.8854*			*0.7605*			*0.8569*		

Note: 1/ Market potential is measured by $\sqrt{TCAP_{it} \times TCAP_{jt}}$, where *TCAPs* are total scheduled seats of the airport pair at time t .

2/ Number of FSAs and LCCs do not include the airline itself or other airlines in the same group.

Specifically, the dual-brand operation's effect is separated in addition to the effects of LCC competition. More interestingly, such effects differ between Qantas Group and the competing airlines. It increases the fares of Qantas and Jetstar, yet reduces the price of rival LCC, Virgin Australia. This may be ascribed to several possible factors. First, the service levels of both Qantas and Jetstar might be improved because their total frequency increases, which reduces travelers' schedule delays and allows them to conveniently switch to other flights in the event of irregular operations such as delays and cancelations. Second, while the investigation only considers domestic markets, both Qantas and Jetstar have extensive international services. Dual-brand operation may allow these two airlines to jointly offer better connection services. These possible effects can be referred to as the "quality effects" of a dual-brand strategy. Finally, while Jetstar and Qantas provide differentiated services, the fact that they jointly control a larger market share implies that they have more market power, which can be reflected in pricing. In addition, because Jetstar provides an almost identical service to that offered by Virgin Australia to price-sensitive travelers, Qantas does not have to price low to capture these travelers with its FSA services. This allows Qantas to focus on quality-sensitive travelers with high-quality and high-price services. In contrast, more competitive operations of Qantas and Jetstar can put more competitive pressure on Virgin Blue, which would reduce its fare. These are the "competitive effects" of a dual-brand strategy. A natural question arising from these two types of effects is which one is dominant? A preliminary conclusion can be obtained by comparing the magnitudes of the coefficients in all models. Note that the impact on Jetstar's fares is much more significant than that on those of Virgin Australia (the absolute coefficient values are 0.18 vs. 0.04). Intuitively, the competitive effect should be more or less symmetric for the two players of similar sizes. This indicates that the quality effect is probably more significant than the competitive effect. Of course, due to the limited explanation power of reduced-form regression, such a hypothesis would be better tested using a structural model analysis.

Fu et al. (2011a) concluded that due to product differentiation, the competition between the same type of carriers (i.e., LCCs vs. LCCs or FSAs vs. FSAs) is much stronger than the competition between FSAs and LCCs. This explains the negative sign of variable $NFSA$ in model (P2) of the Qantas fare regression. The positive sign of $NFSA$ in specifications (P1), (P3), and P4 is a bit puzzling. This is mainly due to the definition of $NFSA$, which includes all airlines other than the major LCCs (Jetstar, Virgin Australia, and Tiger Airways). These airlines are really small niche carriers focused on mostly regional markets with typically high fares. The interpretation of $NLCC$ is straightforward. Other than the positive but insignificant estimate in the Qantas regression, more LCCs in a route reduces the market average fare and the price levels of other LCCs. Dummy variables of 2010 and 2011 are all positive, suggesting that compared to 2009, the aviation market in Australia recovered from the economic crisis year significantly. The sign of route distance is also of expected, because fares are higher in longer routes.

3.3.2 Network Configuration Pattern

The price equations estimated above reveal airlines' pricing behavior given the market structure in a route. However, they provide little information regarding the key factors that lead to an airline's decision to serve a route in the first place. For example, it is unclear whether the presence of Qantas in a route will increase or reduce the chance of Jetstar's operation in the same market. Although the dual-brand strategy may offer possible benefits such as the quality and competition effects defined previously, it may also lead to higher operational costs because Qantas and Jetstar follow two distinct business models and have different operational practices/requirements. In addition, their decisions about whether to serve a route may or may not be influenced by other factors including route characteristics, such as distance, and airport characteristics, such as market concentration at origin and destination airports and the presence of other airlines.

A number of studies have investigated airline's entry patterns in the U.S., including Berry (1992), Sinclair (1995), Boguslaski et al. (2004), Dixit and Chintagunta (2007), Yan et al. (2008), and Liu (2009). These studies defined an entry as an "event" when an airline starts to serve a market. The characteristics associated with this route and OD airports at the time of entry are often used as explanatory variables for an airline's entry decision. One problem with this approach is the possible endogenity associated with airline's inter-dependent decisions about entering and/or leaving a route. This may not be a critical issue for very large markets with many competing airlines, given that in such cases one airline's decision may not radically change the market structures in the routes it enters. However, it is likely to be problematic when analyzing the leading airlines' behaviors in the Australian markets, where four leading brands (i.e., Qantas, Jetstar, Virgin Australia, and Tiger Airways Australia) compete in less than 200 routes. The potentially significant multi-market contact effects on competition and inter-dependent entry decisions among a small group of airlines could lead to serious endogenity problems in empirical estimation. In addition, if only "new" entries are considered in this relatively small market, the number of entries will be small unless one uses data from an extended period. Even if data are available for an extended period, the long-term coverage could introduce additional challenges because changes in regulations, airline competition, and market demand are likely to be substantial, which would require more control variables.

Therefore, rather than tracing the event of new airline entries into routes, this study analyzes the static network configuration pattern of Jetstar in the first quarter over the 2005 to 2012 period. A simple probit model is used to characterize Jetstar's decisions about whether to serve a route. Let D_{ijt} indicate the observed service pattern of Jetstar in a route that links airports i and j in period t. If Jetstar offers substantial flight frequency in this route during period t (defined as more than 24 flights in a quarter, or at least 2 flights a week), then the airline is regarded as being determined to serve the route, or $D_{ijt} = 1$. Otherwise, if Jetstar offers no flights or less than 24 flights (e.g., seasonal or charter services), then the airline is regarded as having decided not to serve the route, or $D_{ijt} = 0$. Following an approach similar to those of Sinclair (1995), Yan et al. (2008), and Liu (2009), the probit model is specified as follows:

$$\begin{aligned} D_{ijt}^{JQ-Entry} = {} & \gamma_0 + \gamma_1 Dist_{ij} + \gamma_2 \sqrt{TCAP_{i,t-1} \times TCAP_{j,t-1}} + \gamma_3 MinAPHHI_{ij,t-1} \\ & + \gamma_4 MaxAPHHI_{ij,t-1} + \gamma_5 NoQan\_FSA_{ij,t-1} \\ & + \gamma_6 NoJet\_LCC_{ij,t-1} + \gamma_7 Qantas_{ij,t-1} + \gamma_8 MaxJQRoute_{ij,t-1} \\ & + \gamma_9 FightingBrand_{ij,t-1} + \gamma_{10} D2009 \end{aligned} \quad , \qquad (3.2)$$

where

- $NoQan\_FSA_{ij,t-1}$ and $NoJet\_LCC_{ij,t-1}$ refer to the number of non-Qantas FSAs and non-Jetstar LCCs, respectively. These two variables are used to investigate the effects of airline rivalry on Jetstar's network formation.

- $Qantas_{ij,t-1}$ is a binary variable that takes the value of 1 if the market was previously served by Qantas. It is used to examine whether Jetstar would be introduced to compete and/or complement its mother company's services.
- $MaxJQRoute_{ij,t-1}$ is the maximum number of Jetstar routes out of origin and destination airports. This variable is expected to give Jetstar the competitive advantage when deciding to start new services that are complementary to its own network.
- $FightingBrand_{ij,t-1}$ is the product of Qantas' route and number of non-Jetstar LCCs variables, defined as $Qantas_{ij,t-1} \times NoJet\_LCC_{ij,t-1}$. This variable is used to test Qantas' strategic decision regarding whether to use Jetstar to function as a direct response to other LCC competition.

The remaining variables are as described in the price regressions. Variable $D2009$ is a dummy used to account for the impact of the 2009 economic crisis, taking the value of 1 for the year 2009 onward. Because the network configuration analysis is based on OAG schedule data from 2005 to 2012, this parsimonious specification is adopted instead of using a group of yearly dummies for each year.

To avoid potential endogenity problems, this analysis uses the route and airport characteristics in the last period $t-1$ as independent variables. The "last period" is defined as one year in advance. That is, Jetstar's network configuration in 2012 is explained by using the route and airport characteristics from 2011. To obtain a larger sample without sacrificing model robustness, two data sets are used: (E1) includes all possible routes in Australian domestic market, and (E2) includes operating routes with two-way frequencies larger than 180 as of the first quarter of 2008. Specifically, (E1) investigates all routes, whereas (E2) ignores very thin markets. Because the variable $FightingBrand$ is the product of $Qantas$ and $NoJet\_LCC$ variables by definition, two models are estimated: specification (M1) includes only the variables $Qantas$ and $NoJet\_LCC$, but not $FightingBrand$; while specification (M2) includes the variable $FightingBrand$, but not $Qantas$ and $NoJet\_LCC$. The estimation results are summarized in Table 3-6.

Table 3-6 Estimation results for Jetstar's network configuration analysis

Entry[1/]	**E1: All domestic markets**						**E2: Markets with two-way frequencies larger than 180**					
	Model: (M1)			**Model: (M2)**			**Model: (M1)**			**Model: (M2)**		
	Coef.	**P>|z|**	**Marginal Effect**	**Coef.**	**P>|z|**	**Marginal Effect**	**Coef.**	**P>|z|**	**Marginal Effect**	**Coef.**	**P>|z|**	**Marginal Effect**
Distance (in '000 km)	-0.0632	0.6540	-0.0021	-0.3815	0.0020	-0.0236	-0.0580	0.6990	-0.0102	-0.2759	0.0370	-0.0568
Market potential (in '000)[2/]	0.2143	0.1360	0.0070	0.6650	0.0000	0.0412	0.1561	0.2820	0.0276	0.5939	0.0000	0.1222
Min airport HHI (in '000)	-0.5972	0.0000	-0.0195	-0.3457	0.0030	-0.0214	-0.7260	0.0000	-0.1282	-0.4604	0.0000	-0.0948
Max airport HHI (in '000)	-0.2128	0.0000	-0.0069	-0.2917	0.0000	-0.0181	-0.1762	0.0000	-0.0311	-0.2679	0.0000	-0.0551
No of non-Qantas FSAs	**-0.4742**	0.0000	-0.0155	**-0.6311**	0.0000	-0.0391	**-0.4369**	0.0000	-0.0772	**-0.5939**	0.0000	-0.1222
No of non-Jetstar LCCs	**0.8819**	0.0000	0.0288				**0.8720**	0.0000	0.1540			
Qantas' route	**-0.1441**	0.3800	-0.0045				**0.0439**	0.7960	0.0078			
Fighting Brand				**0.1670**	0.0730	0.0103				**0.1995**	0.0400	0.0411
MaxJQRoute	**0.0753**	0.0000	0.0025	**0.0770**	0.0000	0.0048	**0.0843**	0.0000	0.0149	**0.0791**	0.0000	0.0163
Dummy after year 2009	-0.1538	0.2290	-0.0048	-0.1764	0.1470	-0.0105	-0.2418	0.0790	-0.0411	-0.2380	0.0680	-0.0474
Constant	1.3339	0.0060		1.6270	0.0000		1.4170	0.0060		1.8160	0.0000	
Number of observations	*1408*			*1408*			*976*			*976*		
Wald chi2	*720.74*			*652.58*			*526.9*			*466.07*		
Prob > chi2	*0.0000*			*0.0000*			*0.0000*			*0.0000*		
Pseudo R2	*0.5281*			*0.4782*			*0.4699*			*0.4157*		

Note: 1/ Total route markets are 176 and 122 for models (E1) and (E2), respectively.

2/ Market potential is measured by $\sqrt{TCAP_{i,t-1} \times TCAP_{j,t-1}}$, where *TCAPs* are total scheduled seats of the airport pair at time $t-1$.

The estimation results are consistent across different market specifications, implying that the findings are solid and not sensitive to alternative sample selections. Most coefficients are statistically significant and of predicted sign. The main variables of interest are $Qantas$ and $FightingBrand$. The variable $Qantas$ is not significant, whereas the variable $FightingBrand$ is positive and significant. As such, the fact that Qantas served this route in the previous year does not significantly increase or decrease the chance of Jetstar providing service. However, in markets where Qantas faces competition from other LCCs, there is a significantly higher chance that Jetstar will also offer the services. These empirical findings clearly suggest that Jetstar is indeed designed as a head-on fighting brand against other LCCs.

The interpretations of other variables are relatively straightforward. The coefficient of $MaxJQRoute$ is statistically significant in all specifications, which indicates that the probability of Jetstar serving a route is positively associated with the number of network connections at the airports served. The significant effects of $NoQan\_FSA$ and $NoJet\_LCC$ indicate that Jetstar tends to serve routes with an LCC presence, but is less likely to compete with other non-Qantas FSAs in Australian domestic market, which host mostly niche market players. This is consistent with the airlines' pricing analysis in previous section, in that an airline is more aggressive when competing with the same types of carriers. In addition, the estimates of potential market size ($\sqrt{TCAP_i \times TCAP_j}$), $MinAPHHI$, and $MaxAPHHI$ reveal that Jetstar is more likely to serve large routes, but tries to avoid routes linked to highly concentrated airports.

3.4 SUMMARY AND CONCLUSION

In response to aggressive competition from LCCs, many FSAs have adopted the airlines-in-airlines (A-in-A) strategy to establish the low-cost subsidiary (LCS) airlines. Such attempts in the U.S. and Europe have been mostly unsuccessful. Most of the LCS airlines in those markets were unable to compete with the standalone LCCs and appeared to be incompatible with the mainline FSA business model within the same airline group (Graf, 2005). However, an increasing number of Asian airlines have begun to experiment with this strategy in recent years. In particular, the

Qantas Group’s LCS, Jetstar, has achieved very promising results in terms of traffic volume growth and financial returns. It is unclear why the same strategy has achieved different outcomes in the Asia-Pacific region. Investigating LCS airline’s business model as it functions in Asia-Pacific would provide better knowledge of the A-in-A strategy, which would help the major carriers improve their management levels and guide governments and regulators in the region to introduce the right aviation policies. Meanwhile, it also offers new insights to industry practitioners in developed markets regarding the real reasons behind LCS failures in North America and Europe.

This study investigates the implications of the use of the A-in-A strategy in Asia-Pacific through an empirical analysis of the competitive effects of LCS operations, with a focus on the Qantas Group’s operations in Australian domestic markets. First, airline pricing models were estimated to capture the airlines’ pricing behavior in the presence of LCS operation. Jetstar’s network configuration pattern was subsequently analyzed.

The fare regression results suggest that when Qantas and Jetstar operate in the same markets, these two airlines are able to charge higher prices, which increases fare level of the market as a whole. However, the rival airline, such as Virgin Australia in this study, must lower its price accordingly. Although Qantas and Jetstar’s higher price level can be explained through both quality and competitive effects, fare reduction of the competing airline clearly suggests that the presence of the A-in-A is an effective competition strategy in Australian domestic market. The investigation of Jetstar’s network configuration pattern offers consistent insights. Qantas’ exclusive operation in a route does not significantly increase/decrease the chance that Jetstar will offer its services in that route. This may be due to the fact that these two airlines have focused on different market segments (Knibb, 2005). Jetstar targets price-sensitive leisure passengers, whereas Qantas targets higher-yield, quality-conscious travelers (Gillen and Gados, 2008). The two brands are differentiated and therefore their network formations are not strongly dependent. However, in a market where Qantas faces competition from other LCCs, there is a significantly higher chance that Jetstar will also be introduced. Given this, Jetstar is indeed designed as a head-on fighting brand against other LCCs.

In conclusion, Qantas Group has demonstrated the successful use of the A-in-A strategy. LCS airlines can bring significant benefits to an airline group in terms of (fare) yield and network configuration, which explains why an increasing number of Asian airlines have introduced their own LCS brands in recent years. However, the implications for competition policy remain rather ambiguous. On the one hand, the A-in-A strategy has an anti-competition flavor in that it raises market fare levels. On the other hand, the fighting brand strategy has been routinely used in other industries and the dual-brand operation in the airline industry may have both quality and competitive effects. Although the investigation reveals the dynamics of a successful A-in-A operation in Australian domestic market, it does not explain why such a strategy repeatedly failed in North America and Europe. Further investigations with the estimation of structural models may offer additional insights into this important issue. In addition, given the strong presence of Jetstar in international routes, it is of great value to investigate how the international presence of Jetstar will contribute to the Qantas Group's expansion overseas. However, as much of the Asian markets are still heavily regulated, one needs rich data in order to separate the effects of regulation vs. A-in-A strategy. It is hoped that such challenges can be addressed in future study when rich data in the international routes and detailed information of existing Air Service Agreements (ASAs) are available.

CHAPTER 4

DEVELOPMENT STATUS AND PROSPECTS FOR AVIATION HUB – A COMPARATIVE STUDY OF THE MAJOR AIRPORTS IN SOUTH-EAST ASIA[1]

Previous two chapters (Chapter 2 and 3) contribute to the measurement of airline performance and the market dynamics leading to a given performance. Successful operations of airline, however, also depend on airport services, particularly their hub airports. Efficient and competitive hub airports are thus of critical importance to the aviation industry. This chapter complements the empirical investigations in Chapter 2 and 3 by benchmarking the performances of the major hub airports and identifying the factors that determine airport's competitiveness. The major airports in Southeast Asia and Hong Kong are used as a case study.

The structure of this chapter is as follows. Section 4.1 presents the introduction of the study. Section 4.2 provides a brief overview of the development of the aviation industry in the region. Section 4.3 benchmarks airports' performances, with a focus on their network connectivity and traffic growth pattern. Section 4.4 investigates the role of dominant airlines at each airport and the way they have been contributing to these airports' hub status. Policy implications and management strategy recommendations are discussed in the last section.

4.1 INTRODUCTION

It is well recognized that the air transport industry plays an important role in the economy. It not only directly contributes to economic growth via increased employment, tax revenue, and service production, but also provides essential inputs to other sectors such as trade, tourism, logistics, and high-tech manufactures. Efficient and competitive hub airports are thus of critical importance to the economy. Hub airports benefit local travelers in terms of increased frequency and extensive

---

[1] The study in this chapter has been published in The Singapore Economic Review as: Homsombat, W., Lei, Z., Fu, X., 2011. Development status and prospects for aviation hubs – a comparative study of the major airports in South-east Asia. *The Singapore Economic Review*, 56 (4), 573-591.

network coverage (Kanafani and Ghobrial, 1985; Morrison, 1997), as well as more direct flights originating from hub airports (Oum and Tretheway, 1990). In addition, hub airports usually provide better location choice for distribution centers, and promote the growth and concentration of efficient carriers and logistics service providers (Zhang and Zhang, 2002; Zhang, 2003; Ohashi et al., 2005). Yuan et al. (2010) studied the important role of an efficient airport and competitiveness of its air cargo service, and pointed out that the integrated operations among them can help local economy to achieve a competitive air cargo supply chain. Oum and Park (2004) found that among the most important factors for multinational firms to choose the location of distribution centers, "Port, airport and inter-modal transport facilities" is ranked as the third most important factor, whereas "Modern logistics service providers and costs" are also regarded as another key determinant. Therefore, efficient hub airports not only contribute to the growth of service sectors such as trade and tourism, but also high-value added manufacturing industries that are dependent on premium logistics services and global supply chain support. Button et al. (1999) and Button and Lall (1999) examined the contribution of hub locations to the high-technology industry. With sample data covering 321 U.S. metropolitan areas, their studies suggested that the presence of a hub airport had significant positive effects on the employment and growth of the high-tech industry.

With the tremendous benefits associated with hub airport status, governments around the world have been giving great support to the major airports under their jurisdiction. A good example is in the Southeast Asia region where strong supports from governments have seen. Major airports such as Singapore Changi International Airport, Kuala Lumpur International Airport, and Bangkok-Suvarnabhumi International Airport, all developed into world-class hubs in terms of airport facility and traffic volume. Together with the new Hong Kong Chek Lap Kok International Airport, these four airports all have the potential and ambition to become the region's leading aviation hub. In the past few years, competition for transfer passengers has intensified the rivalry among these major hubs. This is because for almost all connecting traffic, there are alternative transfer points (Tretheway and Kincaid, 2010). For example, a passenger travelling from Sydney to London could choose to fly with Thai Airways via Bangkok, Malaysia Airlines via Kuala Lumpur, Singapore Airlines via Singapore, or Cathay Pacific Airways via Hong Kong. It is evident that connecting traffic can easily shift from one airport to another if cheaper, faster, and/or more convenient connections become available (Tretheway and Kincaid, 2010).

Few studies have systematically investigated the airport development and competition in Southeast Asia. Bowen (2000) examined the competition between major airports in this region during the period 1979 to 1997, with an emphasis on the effects of state policies on economic development and air transport growth. Park (2003) measured the competitive strength of major Asian airports using five core factors, namely service performance, demand, managerial, facility, and spatial factors. These two studies offer valuable insights into the development path of the airports under investigation. Yet these early studies have not considered the effects of recent market dynamics such as major airport expansion, efforts toward regional liberalization, and the emergence of low-cost carriers (LCCs). Recently, De Wit et al. (2009) examined network performance of the major hub airports in the Asia-Pacific rim, suggesting Hong Kong International Airport as the leader in the region, followed by Singapore Changi, Bangkok Suvarnabhumi, and Kuala Lumpur airports. This study has focused on the network development status without investigating the driving factors behind it. In addition, all the studies mentioned above have not considered the influences of dominant airlines at those airports. Recent work such as Barbot (2009), Fu and Zhang (2010), and Zhang et al. (2010), all suggests that dominant airlines' performances and their vertical cooperation with the airports will affect the market equilibrium in the airline market, and thus affect hub airports' overall performances and resultant social welfare. Therefore, there is a need to take into account the influences of hub carriers' performances and strategies before a comprehensive evaluation can be obtained in assessing the long-term prospects of the hub airports.

The analysis in this chapter aims to benchmark the key performances of the major hub airports in Southeast Asia and Hong Kong and to identify the key driving factors determining their competitiveness. The four major airports included in the study are Singapore Changi International Airport (airport code SIN), Kuala Lumpur International Airport (KUL), Bangkok-Suvarnabhumi International Airport (BKK), and Hong Kong Chek Lap Kok International Airport (HKG). This study will not only provide a comprehensive evaluation of the status quo of aviation hub developments in the region, but also identify key influencing factors shaping the growth pattern of those major airports. It is hoped that such a study will help airport managers and government regulators to better understand the industry dynamics, thereby promoting sustained growth of the aviation industry in the region.

4.2 AVIATION INDUSTRY DEVELOPMENT AND GOVERNMENT POLICY IN THE REGION

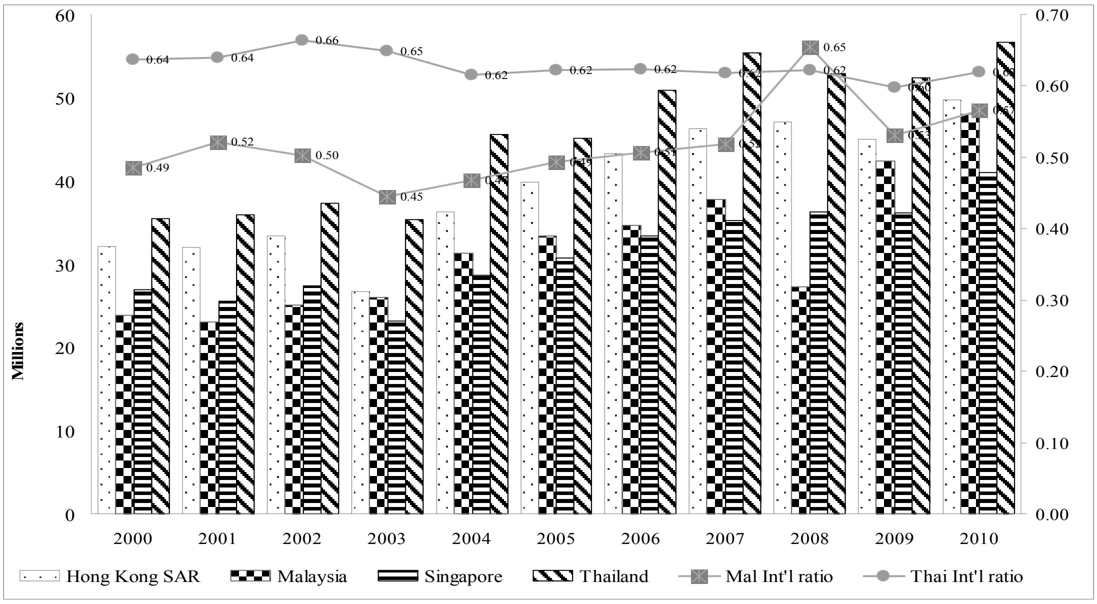


Figure 4-1 Total passengers in the four markets 2000-2010 (Unit: Million)

Source: International Civil Aviation Organization (ICAO).

Note: The airline market size presented is measured by total passengers of airports under the considered countries / regions. The passenger volumes are presented by the bar charts, while the proportion of international traffic is presented by the lines. Note such proportion equals to one for Hong Kong and Singapore as there is no domestic traffic.

Driven by sustained economic growth and large population base, Southeast Asia has become one of the fastest growing aviation markets in recent years. Figure 4-1 reports the total passenger traffic volumes in Hong Kong, Malaysia, Singapore, and Thailand. Over the last decade, all markets have achieved healthy traffic growth, except moderate set-backs in 2003 and 2008 due to SARS and global financial tsunami, respectively. During the period of 2000 to 2010, total passenger volumes have doubled in Malaysia and increased more than 50% in the rest of the three economies. Overall, Thailand has the largest market size. This may be explained by several contributing factors, including the introduction of the new Bangkok airport, large population base, thriving tourism industry, and gradual market penetration by LCCs as a result of domestic deregulation (Zhang et al., 2008). Taking the size of the overall economies into account, Hong Kong appeared to have the most competitive aviation industry, serving a total traffic volume close to Thailand. It is evident that a substantial proportion of traffic growth in the region is ascribed to international market. While Singapore and Hong Kong depend 100% on international services, Malaysia and Thailand derived more than half their passenger volumes from international routes.

Bowen (2000) examined the impacts of regional economic integration and concluded that the aviation industry growth has greatly benefited from the development in three main sectors, namely manufacturing, international business services, and tourism. This is not a surprising result as the region has been the host of some most dynamic and open economies such as Singapore and Hong Kong. Table 4-1 summarizes the key economic indicators for the four economies under investigation. All the countries / regions have achieved fast economic growth; except for Hong Kong, all other three countries have more than doubled total gross domestic product (GDP) measured in US dollars. Singapore has achieved the highest GDP growth during the period, averaging 6% growth rate per year. Despite the recent political instability in Thailand, the country's average GDP growth still reached 4.4% during 2000 to 2010. What is more, all the four economies have either improved or maintained their integration with the global economy. The degree of openness, measured by trade volume divided by GDP, is inversely related to the size of the economy in the region. As a major trade gateway to mainland China, Hong Kong has consistently ranked highest in the region, followed by Singapore, Malaysia, and Thailand. Overall, all of them have maintained very open economies throughout the years by world standards.

Table 4-1 Key economic indicators of selected countries

2002	**Unit**	**Hong Kong**	**Malaysia**	**Singapore**	**Thailand**
GDP	Billion USD	163.78	100.85	90.64	126.88
GDP growth	Percent	1.84	5.39	4.24	5.32
GDP per capita	USD	24,351.11	4,078.33	22,027.88	2,020.34
Export	Billion USD	201.93	94.06	125.18	68.11
Import	Billion USD	207.97	78.67	116.44	64.65
Degree of openness	Percent	250.27	171.28	266.57	104.63
Population	Million	6.73	24.73	4.12	62.80
Unemployment rate	Percent	7.31	3.48	3.55	2.41
2005	**Unit**	**Hong Kong**	**Malaysia**	**Singapore**	**Thailand**
GDP	Billion USD	177.77	138.02	125.43	176.35
GDP growth	Percent	7.08	5.33	7.38	4.61
GDP per capita	USD	25,998.54	5,212.94	28,497.52	2,825.33
Export	Billion USD	292.12	141.62	229.65	110.11
Import	Billion USD	300.16	114.29	200.05	118.16
Degree of openness	Percent	333.17	185.42	342.59	129.44
Population	Million	6.84	26.48	4.40	62.42
Unemployment rate	Percent	5.58	3.53	3.13	1.85
2010	**Unit**	**Hong Kong**	**Malaysia**	**Singapore**	**Thailand**
GDP	Billion USD	225.00	237.96	222.70	318.85
GDP growth	Percent	6.81	7.16	14.47	7.80
GDP per capita	USD	31,590.68	8,423.18	43,116.69	4,991.53
Export	Billion USD	400.69	198.79	300.45	195.31
Import	Billion USD	441.37	164.59	261.67	182.39
Degree of openness	Percent	374.24	152.71	252.41	118.46
Population	Million	7.12	28.25	5.17	63.88
Unemployment rate	Percent	4.29	3.30	2.20	1.04
Average (2000-2010)	**Unit**	**Hong Kong**	**Malaysia**	**Singapore**	**Thailand**
GDP growth	Percent	4.43	5.00	6.00	4.40
Degree of openness	Percent	311.84	172.12	305.23	116.42
Population growth	Percent	0.60	1.96	2.26	0.32
Unemployment rate	Percent	5.41	3.40	2.87	2.02

Source: Data including GDP, GDP per capita, population, and unemployment rate were collected from International Monetary Fund (IMF), World Economic Outlook Database, April 2011. Export and import volumes were supplemented by UN Comtrade Database, United Nations, 2009.

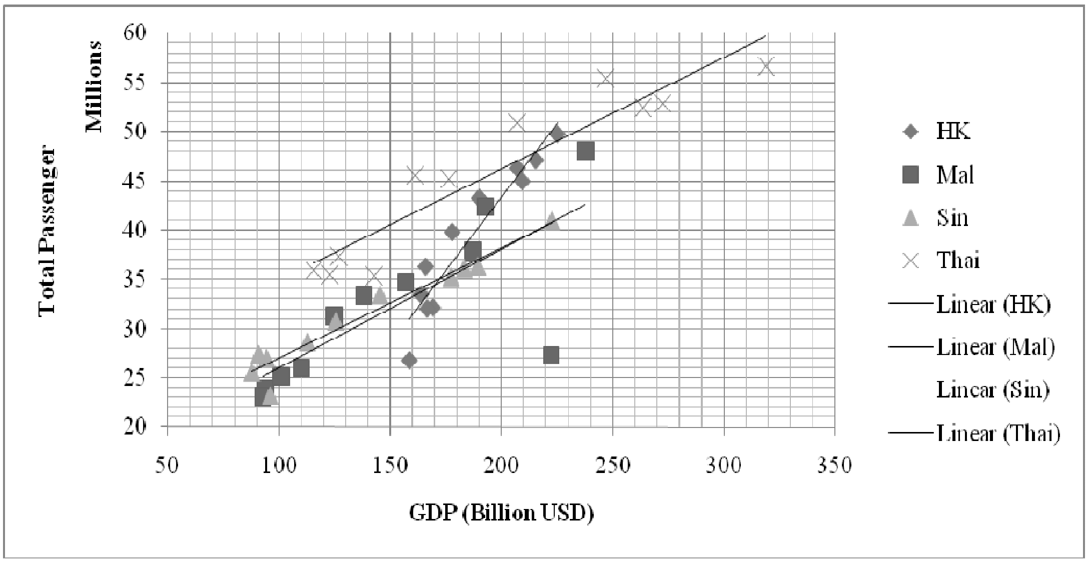


Figure 4-2 Correlation between GDP and passenger volumes, 2000-2010

Source: GDP data were collected from the World Economic Outlook Database of International Monetary Fund (IMF). Passenger data were obtained from the International Civil Aviation Organization (ICAO).

Many studies have suggested that the income elasticity of air transport is more than unity (for example, Gillen et al, 2003). That is, the industry will grow faster than the overall economy. The close correlation between national GDP and passenger traffic volume is evidenced as in Figure 4-2. Although one should be very cautious for any conclusions draw from such a small sample, the figure does suggest something interesting. For the case of Singapore, Hong Kong, and Thailand, the correlation patterns between GDP and traffic growth are remarkably similar. Yet for Malaysia, passenger traffic appeared to grow faster than GDP growth compared to the other three countries. As will be discussed further in the following sessions, such fast market expansion is likely driven by AirAsia, the most successful LCC in Asia.

The fast expansion of the aviation industry in the region has attracted increased investments over the years. Since airports are essential infrastructure for the aviation industry, major investments have been made in recent years. The new Hong Kong Chek Lap Kok International Airport and Kuala Lumpur International Airport were both pressed into service in 1998, followed by Bangkok Suvarnabhumi Airport's opening in 2006. Singapore Changi Airport has subsequently expanded its capacity with the addition of the third terminal in 2008. As of 2009, the capacity and ownership/governance structure of the four airports are presented in Table 4-2.

Table 4-2 Airport capacity and ownership as 2009

Capacity	Number of runways	Terminal space (m^2)
HKG	2	710,000
KUL	2	479,404
SIN	2	1,043,020
BKK	2	563,000
Ownership/governance		
HKG	Airport Authority of Hong Kong (AA), a wholly owned by the Government of Hong Kong SAR	
KUL	Malaysia Airports Holding Berhad (MAHB), a public company with Khazanah National Berhad (a government investment holding) being a majority shareholder (60%)	
SIN	Civil Aviation Authority of Singapore (CAAS), Ministry of Transport	
BKK	Airports of Thailand Public Company Limited (AOT), a public company with the Ministry of Finance being a majority shareholder (70%)	

Source: Airport Benchmarking Report 2010, Air Transport Research Soceity (ATRS).

In addition to the existing airport capacity as shown in Table 4-2, all the airports have proposed the strategic long-term plans for possible capacity upgrading and/or expansion. Hong Kong International Airport in 2010 launched a public consultation for the third runway, as its capacity is expected to hit the limit earliest by 2017. As a matter of fact, the airport has already been running close to the maximum capacity during peak hours. The Malaysian government has proposed several expansion plans for Kuala Lumpur International Airport in its Tenth Malaysia Plan 2011-2015 (The Economic Planning Unit, 2010). The proposal includes a new permanent Low-Cost Carrier Terminal, a new satellite terminal, and increasing the total number of runways to four by 2020. Singapore Changi Airport (SIN) has been implementing major expansion and upgrading projects for its Budget Terminal (completed in mid-2009) and Terminal 1 (expected to be completed in 2012). This would enable the airport to accommodate higher passenger volume with improved customer experiences. Suvanabhumi Airport (BKK) has also made strategic plans to add a new domestic passenger terminal in fiscal year 2010-2013, and a third runway and passenger terminal upgrade in fiscal year 2011-2016. In summary, all the four airports are planning major capacity expansions. However, unlike other airports that have ample capacity, the Hong Kong International Airport has only limited extra runway capacity to accommodate more flights before the third runway to be introduced.

4.3 AIRPORT DEVELOPMENT AND PERFORMANCES

With sustained traffic volume increase and major capital investments on airports in Southeast Asia, the region's aviation industry is expected to grow continuously in the long term. This section benchmarks the four airports' performances with focus on airport traffic, connectivity, and service charges, and whenever possible, identifies the key factors influencing airports' competitiveness.

4.3.1. Benchmarking Airport Traffic

Table 4-3 Traffic volumes and number of airlines serving the airports

2002	**HKG**	**KUL**	**SIN**	**BKK**
Passenger Volume	33,451,466	15,936,882	27,374,329	30,484,781
Cargo Volume	2,504,585	531,980	1,660,404	957,430
Average Daily Aircraft Movements[1/]	567	350	479	542
Number of Airlines Serving the Airport	63	37	62	78
2005	**HKG**	**KUL**	**SIN**	**BKK**
Passenger Volume	39,799,662	22,726,827	30,720,366	37,162,241
Cargo Volume	3,433,351	656,645	1,854,610	1,140,836
Average Daily Aircraft Movements	722	497	559	734
Number of Airlines Serving the Airport	68	47	66	93
2010	**HKG**	**KUL**	**SIN**	**BKK**
Passenger Volume	49,774,902	33,718,562	40,923,716	41,253,893
Cargo Volume	4,165,845	694,295	1,841,004	1,310,139
Average Daily Aircraft Movements	840	669	722	728
Number of Airlines Serving the Airport	74	56	66	91

Source: All the data were collected from International Civil Aviation Organization (ICAO) and compiled with number of airlines serving the airport from Official Airline Guide (OAG).

Note: 1/ Average Daily Aircraft Movements were calculated from total (yearly) aircraft movements divided by 365.

As discussed in previous sections, there have been many favorable factors contributing to the region's traffic growth, including strong economic growth, regional liberalization, prosperous tourism sectors, and new investment on high-tech manufacturing industries. Increased airport capacity and upgraded facilities also allow airports in the region to offer quality services to airlines and passengers. The traffic volumes handled by the four major airports in the last decade are summarized in Table 4-3 .

It is clear that all airports were able to achieve healthy traffic growth, albeit such growth has not been evenly distributed. In terms of both passenger and cargo volumes, Hong Kong has been the consistent leader among the four airports. As a matter of fact, the airport has widened its leadership during this period. As of 2002, Hong Kong's annual passenger volume was about 3 million more than the second follower Bangkok airport. By 2010, such a gap increased to more than 8 million. Many analysts believed that Hong Kong had greatly benefited from a large volume of cross-Taiwan-strait traffic. Before 2008, direct flights between Taiwan and mainland China were forbidden, thus travelers had to route through a third destination, mostly via Hong Kong and Macau. Such restrictions have been gradually removed since the end of 2008, leading to explosive growth in direct flight services between Taiwan and mainland, partly due to the traffic switched from indirect flights via Hong Kong. However, Hong Kong was able to recover quickly in 2010 from the financial tsunami and the re-introduction of direct flights across the Taiwan straits, handling a record of 50 million passengers in 2010. Such a remarkable achievement is likely due to several driving factors. Firstly, Hong Kong's airlines have good access to the fast growing mainland Chinese market. On average, the aviation market in China has been growing at about 17% per year in the last three decades. Therefore, even though the re-introduction of direct flights to cross-Taiwan-strait diverted moderate traffic, the strong growth in the Chinese market more than compensates such one-time loss. Secondly, Hong Kong has better international network compared to the nearby mainland China airports, including Shenzhen and Guangzhou. Therefore, Hong Kong is able to attract substantial traffic across the border. This is more evident in terms of air cargo. In 2002, Hong Kong's annual cargo volume was about 900,000 tons more than the closest follower Singapore. By 2010, such a difference increased to more than 2 million tons. As the world's largest cargo hub, cargo volume handled by Hong Kong was more than the rest three airports combined. Nevertheless, Hong Kong does not have much manufacturing operation: the majority of its cargo volume is originated in / destined to the nearby Pearl River Delta, which is mainland China's key manufacturing base for foreign trade. The air cargo service has well-developed in Hong Kong, making HKG the region's leading logistics center (Centre for Asia Pacific Aviation, 2011).

While Bangkok consistently ranked second among the four airports in terms of airport traffic, it is the only airport whose passenger volume growth was less than 10 million from 2005-2010. From 2002-2005, traffic growth at BKK was on track with other airports in the region. However, the political riots in Thailand, in particular, Thai coup in 2006 and followed by the anti-government protesters' seize of the Bangkok airport in 2008, reduced the demand for air travel. Traffic volume dropped by 6% in 2008 and only gradually recovered since then. Despite of Thailand's large population and thriving tourism industry, Bangkok airport has been losing its competitive edge in the recent years. Still, it has the largest number of airlines operating at the airport. This may be ascribed to Bangkok's ideal hub location connecting Europe and Far East. Overall, it is clear that Bangkok's growth potential has not been fully realized.

Singapore and Kuala Lumpur have maintained healthy passenger traffic growth. However, cargo operations in Singapore had been more or less stagnant – during 2002 to 2010, cargo volume only increased by 10%. Although cargo volume in Kuala Lumpur increased by 30% , its size was relatively small – merely 0.7 million tons as of 2010, equivalent to one-third of the volume in Singapore, or less than 20% of the cargo handled in Hong Kong. Clearly, the limited growth of the manufacturing sector in Singapore and the small size of Malaysia's high-tech industries in the last two decades had not been enough to drive the development of their respective air cargo logistics industry.

4.3.2. Benchmarking Airport Connectivity

Airport's network connectivity is an important indicator of its competitiveness, as the number of possible origin-destination (OD) pairs increases exponentially with the number of destinations connected to an airport. Therefore, airlines tend to favor flying into large hubs thus that there will be more connection opportunities for passengers. The destinations connected to the four airports are classified into major geographical regions, including Asia-Oceania, Europe, and North America as presented in Table 4-4.

Table 4-4 Airport networks and destinations served

2002	**HKG**	**KUL**	**SIN**	**BKK**
Number of Asia-Oceania Destinations	80	61	71	90
Number of European Destinations	8	8	9	14
Number of North American Destinations	8	0	0	0
Other	2	4	5	3
Total	**98**	**73**	**85**	**107**
2005	**HKG**	**KUL**	**SIN**	**BKK**
Number of Asia-Oceania Destinations	82	83	92	105
Number of European Destinations	11	12	11	27
Number of North American Destinations	12	0	2	2
Other	2	2	5	4
Total	**107**	**97**	**110**	**138**
2010	**HKG**	**KUL**	**SIN**	**BKK**
Number of Asia-Oceania Destinations	103	100	101	109
Number of European Destinations	12	10	14	29
Number of North American Destinations	9	0	2	1
Other	2	4	5	6
Total	**126**	**114**	**122**	**145**

Source: Official Airline Guide (OAG). Number of destinations is measured by total non-stop flights to/from the airports.

In terms of total destinations served, Suvarnabhumi Airport (BKK) has the best network coverage, linking 145 destinations as of 2010. Hong Kong, Singapore, and Kuala Lumpur followed closely. It can be seen that all four airports improved network coverage from 2002 to 2010. Hong Kong's network expanded by less than 30 destinations, while all other airports' networks increased by about 40. Kuala Lumpur's network expansion was mostly in Asia-Oceania, while Bangkok substantially increased its network coverage in Europe, linking to 29 European destinations. Hong Kong and Singapore's network expansion was more balanced, but Hong Kong had a clear leadership in North American market. Such expansion patterns may be due to several factors. Firstly, Bangkok has an ideal location as a transit hub for European markets, while Hong Kong is geographically better positioned for North American markets. Hong Kong based airlines can conveniently serve Southeast Asian and Indian markets via 6th freedom operations[2] (e.g., Cathay Pacific's service on route Bangalore – Hong Kong – Vancouver), while foreign

---

[2] Sixth freedom refers to the right of airlines to carry traffic between two other countries but using its home base as a transit point.

airlines can conveniently serve the region via 5th freedom[3] through Hong Kong (e.g., United Airlines' service on route Singapore – Hong Kong – San Francisco). Secondly, Kuala Lumpur's sharp expansion in Asia-Oceania destinations is likely due to the phenomenal growth of AirAsia, the most successful LCC in the region. As LCCs typically serve short to medium distance market, AirAsia's network has mostly been focused in Asia. Finally, it is notable that Hong Kong has developed good network coverage in mainland China after its returning in 1997. Still, its Asian network growth falls behind the other three airports. This suggests that the regional liberalization in ASEAN has achieved limited success. While the network expansion is not as quick as one hoped due to limited progress toward regional liberalization (Tan, 2010); in the long run, liberalization should contribute more substantial growth as witnessed in other markets (Fu et al., 2010), and thus, much more markets/routes will be added.

4.3.3. Benchmarking Airport Service Charges

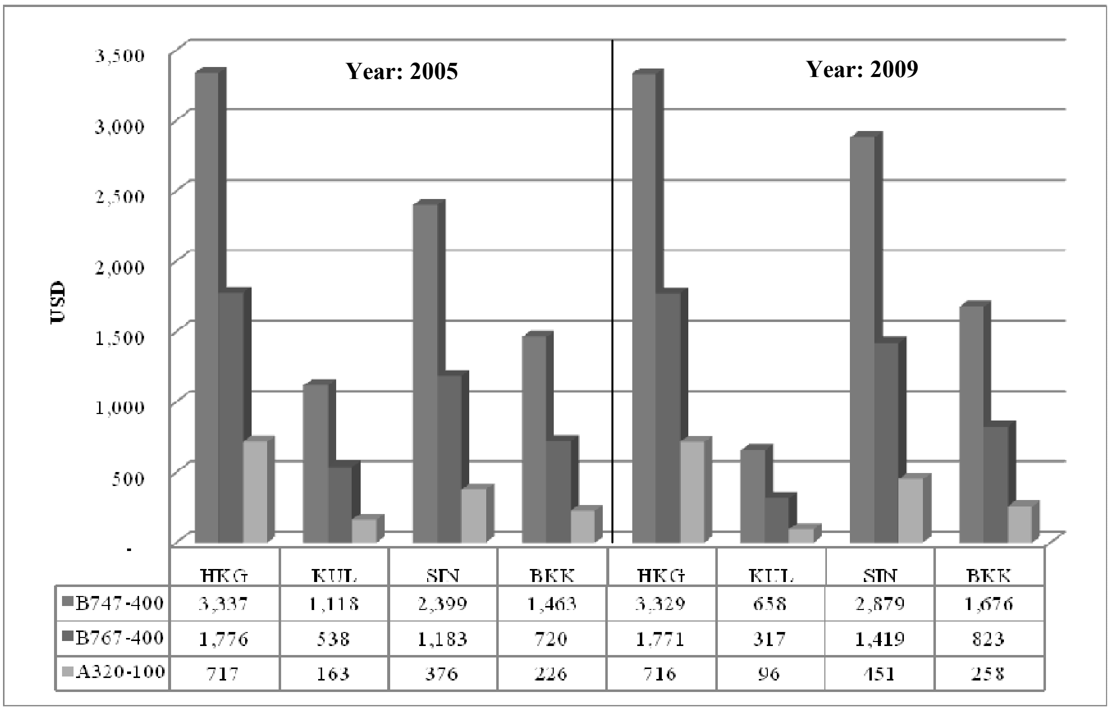
The levels of service charges have significant influences over airport choice by airlines and travelers, especially for LCCs and their customers (Francis et al., 2003). Low-cost airlines in developed markets mostly serve secondary airports, so that they are able to pay much lower average service charges compared to full-service airlines (Barrett, 2004). In most airports, however, there are uniform charges to all types of airlines which may limit the competitiveness of LCCs against traditional full-service airlines (Fu et al., 2006). Due to the high fuel prices since 2006, even full-service airlines are becoming more sensitive to airport charges with much reduced profit margin. Therefore, the levels of service charges are likely to be of increasing importance in the long run. While there is no one simple indictor to benchmark airport pricing level, aircraft landing fee has been extensively used for benchmarking purpose.[4] Figure 4-3 compares the landing charges at the four airports in 2005 and

---

[3] Fifth freedom is the right of airlines to carry traffic via the third country on services starting or ending in its home country.

[4] Airlines typically pay many types of fees according to the airport's charge schedule. The Airport and Air Navigation Charges Manual provided by IATA (2008) suggests the following items: landing charge, parking charge, terminal navigation, lighting, noise tax, power supply, baggage handling, aerobridge, security, check-in counters, ground handling, passenger charge, terminal building charge, airport departure tax, customs, and even minute charges such as TV displays, flight announcements, customs forms and immigration forms

2009, respectively. The landing charge schedule shows a consistent pattern where Hong Kong (HKG) collected the highest fees, and followed by Singapore (SIN), Bangkok (BKK), and Kuala Lumpur (KUL). Hong Kong's higher charges may be at least partially justified by its higher investment costs. Since the new Hong Kong Chek Lap Kok International Airport is built on a man-made island, there were substantial costs associated with land reclamation. The Hong Kong government has been maintaining a "user-pay" policy for transport infrastructures. Therefore, Hong Kong International Airport has to charge a relatively high fee to make a reasonable return out of government investments.



	HKG	KUL	SIN	BKK	HKG	KUL	SIN	BKK
■B747-400	3,337	1,118	2,399	1,463	3,329	658	2,879	1,676
■B767-400	1,776	538	1,183	720	1,771	317	1,419	823
■A320-100	717	163	376	226	716	96	451	258

Figure 4-3 Airport landing charge comparison

Source: Airport Benchmarking Report 2006 and 2010, Air Transport Research Soceity (ATRS).

It is clear that all four airports' service charges had been fairly stable throughout the years, except that Kuala Lumpur strengthened its cost leadership by lowering landing charges in 2009. This is mainly due to the Airline Support Program launched by Malaysia Airport Holdings Berhad (MAHB) in April 2009, which offered a 50% rebate on landing charges for all airlines operating from Malaysian

---

etc. IATA (2005) examined airport charges comparison across major airports in Asia and found that HKG charged the highest fees, followed by SIN, BKK, and KUL. Such a ranking is consistent with the levels of landing fees reported in this paper.

airports for a period of two years. This program gave Kuala Lumpur a clear low-cost edge against its regional competitors.

4.4 THE IMPACTS OF DOMINANT AIRLINES

The performance of hub airlines plays an important role in shaping an airport's competitive position. Fu et al. (2011b) suggest that in order to achieve various network-and-competition-related benefits, a hub carrier has great incentive to dominate an airport instead of sharing its hub with other airlines. As a result, there is usually strong partnership between one hub airline and the airport. Among world's major network carriers, only American Airlines and United Airlines shared a hub at Chicago O'Hare Airport. Therefore, an airport's connectivity, traffic volume, and resultant revenue are greatly influenced by the performances of its hub carrier. Many airports choose to form various vertical relationships with the dominant airlines in order to achieve certain strategic objectives (Barbot, 2009; Fu and Zhang, 2010; Zhang et al., 2010). This section will therefore investigate the hub carriers' operating performances and management strategies that are likely to have important implications to the competitiveness of the four airports in this study.

4.4.1. Performances and Contributions of Hub Carriers

For the airports included in this investigation, key performance indicators of the dominant airlines are summarized in Table 4-5. Cathay Pacific (airline code CX) in Hong Kong had been holding minority shares in DragonAir (KA) in the 1990s. The latter became a wholly-owned subsidiary of Cathay in 2006. Therefore, these two airlines are reported separately, although they are now better treated as one single entity. Similarly, Silk Air is a wholly-owned regional carrier of Singapore Airlines (SQ). The two airlines are reported separately but shall be regarded as one carrier. Malaysian Airlines (MH) and AirAsia (AK) have always been competing with each other with different business models. Malaysian Airlines is a full-service airlines based on hub-and-spoke networks. AirAsia is an LCC targeting point-to-point traffic. In Aug 2011, the two airlines agreed on a share swap, so that each carrier will hold about 20% share of the other airline. This suggests that in the long term, these two airlines are likely to cooperate, rather to compete, with each other. It should be noted that due to data availability, Table 4-5 summarizes mostly those airlines' overall performance indicators such as average stage length and available seat kilometers. In order to measure those airlines' contribution to their hub airports' network connectivity, the numbers of destinations served by those airlines are reported for their respective hubs.

Table 4-5 Summary statistics of dominant carriers in the hub airports

Years	**Hong Kong**		**Malaysia**		**Singapore**		**Thailand**
2003	**Cathay**	**Dragon**	**Malaysian**	**AirAsia**	**Singapore**	**SilkAir**	**Thai**
Average Stage Length (km)	3,818.39	1,461.55	1,548.99	1,098.73	5,492.34	3,386.78	2,049.85
Passengers Carried (million)	10.05	3.07	15.14	1.55	13.32	0.86	16.69
Passengers Kilometers (million)	42,796.68	3,847.94	36,796.75	2,002.72	63,941.67	1,466.02	44,934.18
Available Seat Kilometers (million)	59,323.16	6,482.98	55,134.55	2,853.49	88,631.59	2,348.18	64,282.96
Passenger Load Factor	72.10	59.40	66.70	70.20	72.10	62.40	69.90
Number of Destinations Served	38	28	65	13	57	26	68
Total Number of Destinations Served by Hub Carriers	63		67		81		68
2005	**Cathay**	**Dragon**	**Malaysian**	**AirAsia**	**Singapore**	**SilkAir**	**Thai**
Average Stage Length (km)	3,927.99	1,569.74	1,750.52	1,098.21	5,705.04	3,420.42	2,291.84
Passengers Carried (million)	15.33	5.03	18.28	4.41	16.63	1.14	17.26
Passengers Kilometers (million)	64,456.71	6,484.85	47,303.96	4,880.60	80,906.36	2,048.37	50,040.86
Available Seat Kilometers (million)	82,098.98	10,064.98	65,914.14	6,524.65	108,660.99	3,134.66	70,381.40
Passenger Load Factor	78.50	64.40	71.80	74.80	74.50	65.30	71.10
Number of Destinations Served	39	27	78	27	56	31	72
Total Number of Destinations Served by Hub Carriers	61		87		83		72
2010	**Cathay**	**Dragon**	**Malaysian**	**AirAsia**	**Singapore**	**SilkAir**	**Thai**
Average Stage Length (km)	4,288.05	1,258.45	1,985.17	1,184.00	5,635.90	2,904.58	2,767.55
Passengers Carried (million)	16.37	7.04	13.11	15.12	16.52	2.58	17.61
Passengers Kilometers (million)	75,742.60	9,177.98	37,837.64	16,586.00	83,938.20	3,712.49	55,676.17
Available Seat Kilometers (million)	97,804.55	11,983.86	49,613.06	23,184.00	105,952.86	4,898.48	75,600.24
Passenger Load Factor	77.40	76.60	76.30	71.54	79.20	75.79	73.60
Number of Destinations Served	48	29	67	55	57	36	73
Total Number of Destinations Served by Hub Carriers	70		87		89		73

Source: Compiled from various data sources including International Civil Aviation Organization (ICAO), the Official Airline Guide (OAG). The operating data of AirAsia in 2010 was supplemented by its annual report.

Most of the dominant airlines at the four airports have experienced healthy growth. The only exception is Malaysian Airlines, which has been losing market share to its rival AirAsia, also based in Kuala Lumpur. During 2005 to 2010, passengers carried by Malaysian Airlines dropped sharply from 18 million to 13 million, while AirAsia's traffic volume increased from 4 million to 15 million. It is clear that AirAsia had captured much regional traffic from Malaysian Airlines. In 2006, Malaysian Airlines had to relinquish some of its non-truck routes to AirAsia as part of domestic route rationalization, pushing Malaysian's stage length from 1,750 km in 2005 to 1,985 km in 2010. Malaysian Airlines' destinations out of Kuala Lumpur decreased from 78 in 2005 to 67 in 2010, while AirAsia's destinations increased from 27 to 55. For Kuala Lumpur International Airport as a whole, the destination number had remained constant. This is mixed news to Kuala Lumpur: the success of AirAsia has brought a great deal of newly stimulated traffic. This not only leads to increased revenue to the airport, but also increased flight frequency on many of the regional routes. This would strengthen Kuala Lumpur's competitiveness. However, network downsizing is very destructive to Malaysian Airlines. For network carriers, one less destination not only means losing some O-D traffic on this route, but also numerous connection possibilities. To the airport, such loss may not be fully compensated with services from LCCs. In addition, reduced local feeder network will also hinder Malaysian Airlines' capability in offering more long-distance routes. In the long term, this may reduce Kuala Lumpur International Airport's network coverage. While all other three airports' hub carriers have expanded their network coverage, Malaysian Airlines and AirAsia's total network size remained the same during 2005 to 2010. Of course, if AirAsia's long-distance brand, AirAsia X, can replicate its success in regional market, then Kuala Lumpur's network coverage may be strengthened in the near future. It shall be noted that AirAsia has adopted the multi-hub strategy in Southeast Asia through the joint-venture with local companies to set up Thai AirAsia and Indonesia AirAsia in 2004 (Hooper, 2005). With its high operating efficiency and low cost, AirAsia is likely to continue its aggressive growth in the region (Inamura and Saraswati, 2008). While its impacts on Kuala Lumpur airport's network coverage so far has been unclear, the airline did improve the region's aviation industry development overall.

Cathay Pacific and Singapore Airlines were able to achieve balanced growth with their wholly-owned subsidiaries. Cathay increased its revenue passenger kilometers (RPKs) by 17% from 2005 to 2010, after taking full control of Dragonair in 2006. Such moderate growth mostly came from long-distance routes, as the airline's average stage length increased from 3,928 km to 4,288 km. Regional markets, especially those linking to mainland China, were shifted to Dragonair. Dragonair's output measured by RPK increased by 42%, while average stage length was reduced from 1,570km to 1,258km. A similar pattern has been observed for Singapore Airlines, with much of the growth coming from its subsidiary SilkAir. Traffic volume within Asia has been growing fast due to strong economic growth and regional liberalization. The healthy growth of dominant airlines contributed to their hubs' network connectivity: Cathay Pacific and Dragonair together expanded their network to 70 destinations, while Singapore Airlines and Silk Air expanded their network coverage to 89 by 2010. It is notable that there is clear network complementarity between Singapore Airlines and Silkair, as they only had four overlapping routes in 2010. Thai Airways plays an important role in linking the Bangkok airport to the rest of the world, accounting for more than half of the airport's linked destinations as of 2010. However, the airline had registered little growth since 2005. A series of political riots starting from 2006 in Thailand and the subsequent global financial crisis did take a toll on Thai Airways. In 2010, the airline needed to issue new shares to implement substantial operations restructuring (Szep, 2010).

To sum up, all four airports' network developments much depend on their hub carriers' performances. Hong Kong and Singapore gained competitive edge over the years with their strong hub carriers. While Thai Airways accounts for more than 50% of the total cities linked to Bangkok airport, the airline's sluggish performance since 2005 has contributed little growth to the airport. In Kuala Lumpur, the success of the LCC AirAsia has mixed implications: on the one hand, the airline greatly stimulated traffic with its low fares and increased traffic volume and flight frequency for services out of Kuala Lumpur; on the other hand, the competitive pressure from AirAsia forced Malaysian Airlines to reduce its network size, and the loss of regional feeder network will limit Malaysian Airlines' global network expansion. As a result, the overall impact to Kuala Lumpur airport's network connectivity is not straightforward. However, with strategic alliance between Malaysian Airlines and AirAsia after the share swap, the two airlines are likely to achieve balanced network expansion, thus enhancing Kuala Lumpur airport's overall competitiveness in the long run.

4.4.2. Airline Competition and Hub Dominance

Table 4-6 Market shares of dominant carriers in the four airports

Airport	2002 Market Share of Scheduled Seats			
	No.1 carrier	**No.2 carrier**	**No.3 carrier**	**Top 3 Carriers**
HKG	31.66%	10.68%	8.56%	CX /KA/CI
KUL	68.59%	5.90%	3.48%	MH/SQ/CX
SIN	43.95%	6.48%	4.78%	SQ/QF/MH
BKK	50.44%	4.08%	3.79%	TG/CX/PG
Airport	**2005 Market Share of Scheduled Seats**			
	No.1 carrier	**No.2 carrier**	**No.3 carrier**	**Top 3 Carriers**
HKG	32.37%	13.52%	7.21%	CX /KA/MU
KUL	57.39%	17.73%	3.42%	MH/AK/SQ
SIN	43.22%	5.52%	3.90%	SQ//QF/CX
BKK	39.71%	5.69%	4.33%	TG/PG/FD
Airport	**2010 Market Share of Scheduled Seats**			
	No.1 carrier	**No.2 carrier**	**No.3 carrier**	**Top 3 Carriers**
HKG	35.39%	13.79%	5.87%	CX /KA/CI
KUL	35.20%	34.82%	5.53%	MH/AK/D7
SIN	35.29%	6.51%	6.28%	SQ/MI/TR
BKK	40.93%	11.20%	5.56%	TG/FD/PG

Source: Official Airline Guide (OAG).

Note: AK (AirAsia), CI (China Airlines), CI (China Airlines), CX (Cathay Pacific Airways), D7 (AirAsia X), FD (Thai AirAsia), KA (Dragonair), MH (Malaysia Airlines), MI (SilkAir), MU (China Eastern Airlines), PG (Bangkok Airways), QF (Qantas Airways), SQ (Singapore Airlines), TG (Thai Airways Intl), and TR (Tiger Airways).

While having a strong hub carrier is beneficial to the hosting airport's network development, hub carriers' market dominance may limit competition in the airline market. As a result, airlines may charge higher prices (referred as "hub premium" in the literature) and thus reduce traffic volume. Table 4-6 summarizes the market shares of the top three carriers at each airport. Note in the case of Hong Kong and Singapore, the leading airlines are indeed of the same group. In 2010, Cathay and Dragonair jointly controlled more than 50% market share at HKG, while Singapore Airlines and Silk Air together dominated more than 40% of the market at SIN. If Tiger Airways (TR) is also included into the Singapore Airline group, the combined market share was around 50%.[5] By contrast, the rise of AirAsia saw the rapid shrinkage of Malaysian Airlines's market share at KUL from over 68% in 2002 to 35% in 2010, at the time when AirAsia captured one-third of the market. In addition, the LCC established a subsidiary, Thai AirAsia, in 2004. Within one year, Thai AirAsia got 4% of the market at Bangkok, and became the second largest carrier at the airport by 2010.

In addition to dominant airlines' market shares, a better measurement of market concentration is the Herfindahl–Hirschman Index (HHI), which is reported in Figure 4-4. It should be emphasized that Cathay had been a minority shareholder of Dragonair till September 2006, after which Dragonair became a wholly-owned subsidiary of Cathay. If the two airlines' market shares were summed up, HHI index would have been significantly increased to over 2,100 in 2007 and over 2,500 in 2010.

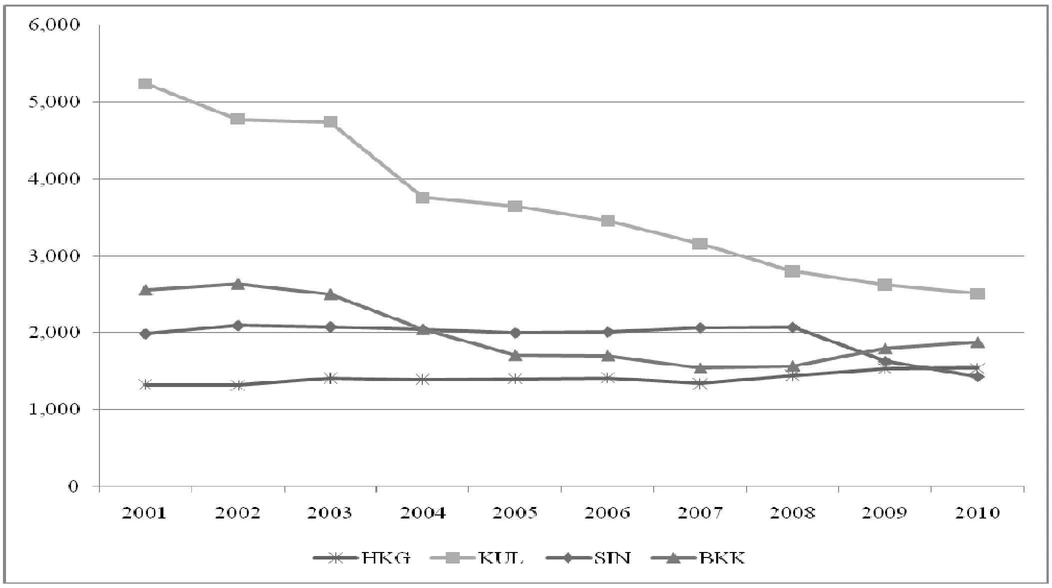


Figure 4-4 Market concentration (HHI index) in the four airports

Overall, most airports had seen reduced market concentration in the last decade. Kuala Lumpur had experienced a substantial increase in competition since AirAsia's operation in 2003. However, AirAsia and Malaysian Airlines agreed on substantial share swap in August 2011. This may significantly reduce, or even

---

[5] SilkAir (MI) is a wholly-owned subsidiary of Singapore Airlines, while Tiger Airways (TR) is partially owned (32.9% of equity held as reported in the 2010/2011 annual report of Singapore Airlines).

eliminate, the competition between these two dominant airlines. Hong Kong was the most competitive market till Cathay acquired Dragonair in 2006. The merger between Cathay and Dragonair allowed them to acquire higher market power, which could reduce the competition level in Hong Kong airport. However, overall, this has likely contributed to the Hong Kong airport's competitiveness for several considerations. First, the aviation market in Hong Kong is fairly open, thus in the long run any major reduction in competition level would attract more airline entrants. Second, Cathay and Dragonair are the hub carriers of Hong Kong airport. Stronger hub carriers are likely to enhance the competitiveness of an airport, especially in terms of network connectivity. While the market concentration in Hong Kong is still comparable to other major hubs in North America and Europe, it is important for Hong Kong to ensure ample airport capacity in the long term, thus that other airlines can enter the market. In Singapore and Bangkok, market concentrations had experienced mild reduction, mainly due to growth of LCCs, in particular AirAsia, Tiger Airways, and Jetstar Asia.

4.5 SUMMARY AND CONCLUSION

This study benchmarks the key performances of the major hub airports in Southeast Asia. The investigation suggests that the development of hub airports in the region has overall been very well due to healthy economic growth, market liberalization, and the development of LCCs. While the first two factors are common to aviation market growth, the contribution of LCC is something new. In developed markets such as North America and Europe, LCCs have mainly led the growth of secondary airports. By contrast, in Southeast Asia, LCCs have gained significant market share at the major hubs. Their presence has reduced the level of market concentration and increased competition in the region.

Among the four major airports studied, overall Hong Kong has been a leader in most of the performance matrices such as network connectivity, traffic growth, hub airline developments, and cargo logistics services. The study revealed that a major source of Hong Kong's competitive advantages is its close link with mainland China, thus enabling it to capitalize on the huge traffic growth generated by China's fast economic development. Moreover, Hong Kong International Airport is well-recognized as one of the most efficient airports in the world (ATRS, 2010), although service provision to passengers may need to be further improved in terms of airport operational time and service charge level (Park, 2003). The potential challenge for Hong Kong in the upcoming years, however, is more likely to be the proliferation of Asian LCCs, because it does not have sufficient or extra capacity for new services. All other rivalry hubs, namely, KUL, SIN, and BKK, have a separated terminal or extra capacity to handle extra traffic likely to be stimulated by LCCs. The completion of the Hong Kong – Zhuhai – Macao Bridge, which is expected to be around 2015-2016, may provide HKG with strategic opportunities to cooperate with Macau Airport which is currently a regional hub for LCCs, to feed air passengers to strengthen its hub position.

For the other three airports in Southeast Asia, Singapore Changi (SIN) and Suvarnabhumi (BKK) airports are competitive in some aspects, while Kuala Lumpur (KUL) lags behind in overall operating performance. One of the SIN's and BKK's comparative advantages lies in their geographical locations: both are strategically situated in the crossroads of traffic flows from European and Far-East Asian countries and inter-regional connections. In the last decade, the development of BKK has posed serious threats to the dominant position of SIN. A particular strength that BKK has possessed is the large tourism sector in Thailand and excellent airport connectivity especially to Europe. However, traffic growth at the airport during 2005 to 2010 was lower than the regional average due to political instability, which also negatively affected its hub carrier Thai Airways. Therefore, the political stability and long-term oriented planning for the aviation and other related industries, in particular the tourism sector, are among the most important factors in fostering BKK towards a world-class aviation hub. As can be seen in the first three months of 2011, when the political situation became more stable and the world economy was promising, Suvarnabhumi Airport (BKK) recorded the highest passenger traffic among the four airports studied (Airport Council International, 2011).

Despite intensive regional rivalry, SIN is still competitive due to Singapore's strong economy with a focal point in global shipping and trading networks as well as a strong presence of hub carrier, Singapore Airlines – all these factors have supported the continuity of its competitiveness (Lohmann et al., 2009). Even though Kuala Lumpur Airport (KUL) has relatively lower performance than the others, the hub position and network connectivity has been largely facilitated by the fast growth of its local LCCs. The steps toward liberalization in ASEAN are expected to benefit further growth of AirAsia in particular the domestic and intra-regional markets.

Despite of limited progress on regional liberalization, intra-Asia routes have clearly contributed to traffic growth and airport connectivity at the hub airports investigated. Together with the fast growth of LCCs in the region, market concentration in general has been moderately reduced. However, major acquisitions and strategic alliances among dominant hub carriers may potentially harm airline competition. Therefore, there may be a need for regulators to safeguard airline competition at these hub airports. Governments can promote further market liberalization and airport capacity investments, which ensure that new entrant airlines can have easy access to aviation hubs. With properly measures adopted, all hub airports in Southeast Asia are expected to achieve sustainable growth in the foreseeable future.

CHAPTER 5

REGIONAL COOPERATION AND MANAGEMENT OF PORT POLLUTION[1]

The second important issue to be examined in this thesis is how to design and evaluate alternative government policies for the transport and logistics industry. Two investigations, Chapter 5 and 6, are devoted for the study in the maritime sector. This chapter starts with the environmental protection challenge. The study develops an economic model to examine the effectiveness of a market-based policy for pollution control in a region with multiple ports, and suggests areas where inter-port cooperation is needed among the competing ports.

The structure of this chapter is laid out as follows. Section 5.1 presents the overview of the study. Section 5.2 describes the basic economic model of port pollution control in a region. Optimal pollution tax derivation is given in section 5.3. Analytical results on market equilibriums are presented in section 5.4. Next section provides managerial and policy implications. The last section concludes the study.

5.1 INTRODUCTION

The growth of international trade and global economy has led to strong demands for the maritime transport services. Meanwhile, the development of maritime services fruitfully brings about economic benefits and social well-being to local industries and residents. However, port activities also generate negative environmental impacts

---

[1] The study in this chapter has been submitted for journal publication in Maritime Policy and Management, which is under review, as:

Homsombat, W., Yip, T.L., Yang, H., Fu, X., Regional cooperation and management of port pollution. *Maritime Policy and Management*, under review.

It has also been submitted for proceeding in the following conferences as:

1. Yip, T.L., Fu, X., Homsombat, W., Yang, H., 2012. Regional pollution management – an economic investigation. *Proceeding of International Forum on Shipping, Ports and Airports (IFSPA) 2012,* Department of Logistics and Maritime Studies, Hong Kong Polytechnic University, Hong Kong SAR, China, May 27-30.
2. Homsombat, W., Fu, X., Yip, T.L., Yang, H., 2012. Regional management of port pollution: game theoretical analysis. *Proceeding of 2012 International Association of Maritime Economists Conference (IAME)*, Inha JRI, CMRI & Kainan University, Taiwan, September 6-8.

to its catchment areas, which impose additional costs associated with pollution emission upon the local community. Ships often burn bunker oil, which is the least refined of the petroleum product. The burning process of bunker oil in ships produces significant amounts of particulate matter (PM), nitrogen oxides (NOx), unburned hydrocarbons (HC), sulphur oxides (SOx), carbon monoxide (CO), and carbon dioxide (CO2). Gradually, ships are regarded as key pollution sources in ports (for example, see Table 5-1).

At present, MARPOL Annex VI[2] is the only international convention that addresses air emissions from ocean-going vessels. However, MARPOL Annex VI is not tight enough to meet the increasing concerns of some ports. Absent of explicit regulation, such as emission standard or pollution tax, the negative externalities and social costs will not be considered in the production process of the marine industry. As a result, the market price and output level of the industry will deviate from social optimum, leading to reduced social welfare.

As discussed by Talley (2003), port operations and shipping activities often lead to certain negative environmental impacts such as vessel oil spills, ballast water disposal, air pollution, anti-fouling pollution, dredging, vessel scrapping, and waste disposal at sea. Alternative economic and regulatory tools can be used in environmental control. For instance, the government may require the shipping firms to adopt abatement technology in order to process pollution effluent before discharge. The Port of Los Angeles has required ships to switch from cheap bunker oil to relatively clean diesel when approaching the port.

In addition to such technical restrictions, policy makers may introduce economic regulations such as taxes on and/or subsidies to the polluters so as to induce shipping outputs to an appropriate level. Among such instruments, pollution tax has been extensively used not only in transport sectors such as aviation and road transport, but also other public utilities such as electricity generation, water supply, and waste processing. One major advantage of pollution tax is that it will reduce the effluent at minimum cost by equating the marginal costs of all the polluters, even if there is a large variation in pollution reduction costs and heterogeneity among the producing firms (Calthrop and Proost, 2003). In recent years, regional and/or

---

[2] See details of MARPOL Annex VI, for instance, from International Maritime Organization (www.imo.org/ourwork/environment/pollutionprevention/airpollution/pages/the-protocol-of-1997-(marpol-annex-vi).aspx).

national carbon taxes have been introduced in countries such as some states of the United States, South Korea, Australia, UK, and Switzerland. Several OECD countries have introduced green tax system reforms since the early 1990s, including Sweden in 1991, the Netherlands between 1971 and 1996, Finland in 1997, Denmark during 1994-1998, and Norway between 1991 and 1998 (OECD, 1999). Ecological tax for energy saving has been implemented in Germany since 1999 and entire European Union since 2003 (Bellido-Arregui, 2003).

In the marine and port sector, many kinds of financial incentives and disincentives have already been introduced (IAPH, 2007). Swedish ports posted incentives (Fairway Dues) for low emission in 1997, whereas Norwegian ports imposed tax on NOx emission in 2007. The Port of Los Angeles and the Port of Long Beach have jointly developed the Clean Air Action Plan in 2006. These two ports provide financial incentives (dockage rate reduction) to vessel operators for slowing down to 12 knots or less within 40 nautical miles from the harbour entrance. The Port Authority of New York and New Jersey developed a Clean Air Strategy in 2009 in which an incentive program was established for switching to low sulphur fuel and to fund the cost differential between the use of low sulphur fuel and conventional bunker fuel. Today, a number of ports have established clean air strategies, including those in the U.S. (Los Angeles, Long Beach, New York, New Jersey, Seattle, and Tacoma), Europe (Rotterdam and Gothenburg), and Korea (Busan).

Table 5-1 Contribution of near port and interport emissions to the total C3 inventory (Calendar Year 2002)

Region	Metric Tonnes								
	NO_X			**PM_{10}**			**PM_{25}**		
	Port	**Interport**	**Total**	**Port**	**Interport**	**Total**	**Port**	**Interport**	**Total**
Alaska East (AE)	833	17,218	18,051	80	1,345	1,425	74	1,237	1,311
Alaska West (AW)	0	60,019	60,019	0	4,689	4,689	0	4,313	4,313
East Coast (EC)	48,313	171,247	219,560	4,126	13,375	17,501	3,796	12,305	16,101
Gulf Coast (GC)	33,637	139,260	172,897	3,169	10,874	14,043	2,916	10,004	12,920
Hawaii East (HE)	2,916	19,684	22,600	251	1,524	1,775	231	1,402	1,633
Hawaii West (HW)	0	31,799	31,799	0	2,498	2,498	0	2,297	2,297
North Pacific (NP)	14,015	12,022	26,037	1,216	938	2,154	1,119	863	1,982
South Pacific (SP)	20,079	84,076	104,155	1,525	6,569	8,094	1,403	6,044	7,447
Great Lakes (GL)	491	14,528	15,019	44	1,135	1,179	41	1,044	1,085
Total Metric Tonnes	*120,285*	*549,852*	*670,137*	*10,413*	*42,945*	*53,358*	*9,580*	*39,510*	*49,089*
Region	**HC**			**CO**			**SO_2**		
	Port	**Interport**	**Total**	**Port**	**Interport**	**Total**	**Port**	**Interport**	**Total**
Alaska East (AE)	27	570	597	66	1,344	1,410	641	9,977	10,618
Alaska West (AW)	0	1,989	1,989	0	4,685	4,685	0	34,786	34,786
East Coast (EC)	1,603	5,674	7,277	3,864	13,367	17,231	45,952	99,072	145,024
Gulf Coast (GC)	1,142	4,615	5,757	3,305	10,864	14,169	24,187	80,665	104,852
Hawaii East (HE)	96	653	749	230	1,535	1,765	1,891	11,291	13,182
Hawaii West (HW)	0	1,053	1,053	0	2,484	2,484	0	18,546	18,546
North Pacific (NP)	540	398	938	1,152	938	2,090	8,329	6,966	15,295
South Pacific (SP)	678	2,786	3,464	1,876	6,561	8,437	11,715	48,728	60,443
Great Lakes (GL)	17	481	498	40	1,134	1,174	346	8,420	8,766
Total Metric Tonnes	*4,103*	*18,219*	*22,322*	*10,533*	*42,912*	*53,445*	*93,062*	*318,450*	*411,512*

Source: United States Environmental Protection Agency (2009).

Note: 1) PM_{25} is estimated from PM_{10} using a multiplicative adjustment factor of 0.92.

2) Port or near port inventories were estimated based on the emissions associated with ship movements when entering or exiting the major U.S. ports.

3) Interport inventory refers to the emission associated with operations to and from the ports in the U.S. within 200 nautical miles (nm) of the U.S. coastline. The vessel operations considered in the calculation include maneuvering to enter or exit a port, cruising near a port, or moving in a shipping lane. Emissions associated with 251 U.S. ports are reported.

Many port authorities have considered / introduced pollution tax and environmental incentives. However, most of these policies considered pollution tax either at port level or national level. That is, there is only one decision maker involved (i.e., a local port authority or a central government). Such an assumption does not always hold in practice as pollution at a port may have some spill-over effects on its neighbours. If two ports are located close to each other, the effluent of one port may generate negative spill-over effects, or inter-port externalities, to the community in the other port. Unless the two local governments or port authorities behave like one single decision maker, the conclusions obtained in previous studies may not hold. For example, pollutants released at Shenzhen Port may cause some damages to industries and residents in the adjacent Hong Kong area, and vice versa. Another example of spill-over to adjacent port areas can be found for the ports in Norway and Sweden, where are very close to each others. In the U.S., the Environmental Protection Agency (2009) estimated ship emission inventory for Category 3 (C3) vessels using C3 engines for propulsion[3]. As summarized in Table 5-1, in calendar year 2002 interport emissions in many cases accounted for over 80 percent of the total inventory. The interport inventory refers to the emission associated with operations to and from the ports in the U.S. within 200 nautical miles of the U.S. coastline. It does not reflect the "spill-over" pollution from one port region to other port regions directly. Still, the magnitudes of interport emissions suggest that operations associated with one port can lead to significant emission and pollution to the regions nearby, and thus there is a need to consider such spill-over effects when regulators design pollution and environmental related policies.

The estimation of pollution emission by region is not an easy task in practice. To precisely model and control spill-over pollution is even more challenging. Still, such an issue has attracted significant attention from regional authorities and governments. For instance, transboundary air pollution has become a serious concern to countries in North-East Asia. China, Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea, and the Russian Federation have been working together toward regional cooperation in environment protection (Kim, 2007; United Nations ESCAP, 2008). The U.S. Department of Commerce (2010) pointed out that oceanic pollution is becoming a serious challenge to the marine industry in China. Indeed, port authorities in the Pearl River Delta, including Guangzhou, Macau, Shenzhen, Zhuhai, and Hong Kong, have worked together toward a regional cooperative agreement on environment protection. Such plan aims to prevent oil spills, reduce air pollution, and greenhouse gas emissions from the marine industry in the region (McKinnon, 2011). These examples testify governments' growing awareness of the need for regional cooperation. Intuitively, cooperation by the governments of rival ports may be desired. Yet few studies, either commissioned by

---

[3] Category 3 engines are specified as having displacement above 30 liters per cylinder (L/cyl).

governments or from academic researchers, have systematically investigated regional cooperation in using economic measures for environmental protection.

Although it has been well recognized that the market structures in the marine shipping and port sector play an important role in determining the price and output levels of the overall marine industry (e.g., Ferrari and Benacchio, 2000; Lam and Yap, 2006; Lou et al., 2010; Ducruet et al., 2011), few studies have explicitly considered the implications of market competition on the choice of optimal pollution tax level. One exception is Yin (2003), who considered corrective taxes under oligopoly market structure. However, this study focused on firm level in a specific market without considering possible regional cooperation. To fill this research gap, this chapter aims to investigate the effects of pollution tax taking into account of (possible) regional port cooperation as well as competition among shipping lines and marine ports. Although this study has explicitly modelled the case of two adjacent ports, the model can be easily extended to other cases such as two adjacent airports or even the case of two power generation plants in adjacent cities.

5.2 AN ECONOMIC MODEL OF PORT POLLUTION CONTROL IN A REGION

Using a similar approach as adopted by Zhang et al. (2010) and Basso and Zhang (2007), this section considers an infinite linear region or port catchment areas where potential shippers (also referred as consumers hereafter) are uniformly distributed with a density of one shipper per unit of length. Two competing ports are located at $z = 0$ (Port 1 in city 1) and $z = 1$ (Port 2 in city 2), and there are n_i symmetric shipping lines at the i^{th} port (see Figure 5-1). At the i^{th} port, the total output is defined as $Q_i = \sum_{k=1}^{n_i} q_{ik}$, where q_{ik} is the output of shipping line k and n_i is the number of shipping lines at the i^{th} port. Also, market price is denoted by P_i. For mathematical tractability, this study considers a symmetric case where shipping lines have the same cost function $C(q_{ik}) = cq_{ik}$, where c is the constant marginal cost per unit of output[4].

---

[4] Without loss of generality, the symmetric condition is imposed in order to obtain results with clear interpretation. Although market equilibriums will be affected if asymmetric

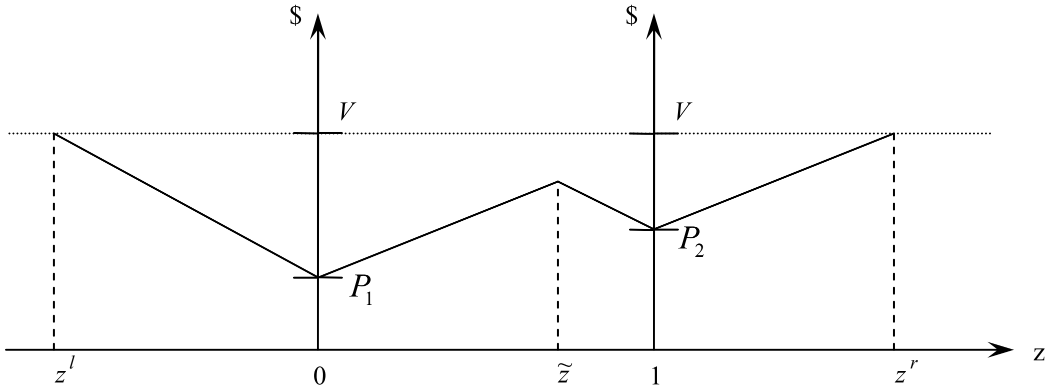


Figure 5-1 Consumer distribution and ports' catchment areas

Consider the catchment areas ($0 \le z \le 1$) between two ports, the total cost for a consumer located at z and going to Port 1 ($z = 0$) is given by $P_1 + (4t)z$, where $4t$ (> 0) represents the consumer's transportation cost per unit of distance in going to a port. The expression $4t$ is used because it is more convenient to work with in subsequent analytical derivation. Such a cost specification may reflect real transportation cost or simply consumers' preference to a particular port. By choosing either Port 1 or Port 2 (but not both), a consumer derives the following respective net utilities:

$$U_1 = V - P_1 - 4tz, \qquad U_2 = V - P_2 - 4t(1-z), \qquad (5.1)$$

where V denotes (gross) benefit from marine shipping. Assuming consumer in the [0, 1] interval consumes, then the indifferent consumer $\tilde{z} \in (0,1)$ is determined by setting $U_1 = U_2$, or:

$$\tilde{z} = \frac{1}{2} + \frac{P_2 - P_1}{8t}. \qquad (5.2)$$

Given that Port 1 also captures consumers at its immediate left side, define z^l as the last shipper on the left side of the region who utilizes Port 1. Similarly, define z^r as the last shipper on the right side of the city who goes to Port 2. With the uniform distribution of shippers, z^l and z^r are computed as:

---

shipping lines are allowed (e.g., as reflected by different operating costs $c_1 \neq c_2$), the key findings and conclusions will not change qualitatively.

$$z^l = -\frac{V - P_1}{4t} \quad , \qquad\qquad z^r = 1 + \frac{V - P_2}{4t}. \tag{5.3}$$

The two ports' demands are computed as:

$$Q_1 = \tilde{z} + |z^l| = \frac{1}{2} + \frac{P_2 - P_1}{8t} + \frac{V - P_1}{4t}, \tag{5.4}$$

$$Q_2 = (1 - \tilde{z}) + (z^r - 1) = \frac{1}{2} - \frac{P_2 - P_1}{8t} + \frac{V - P_2}{4t}. \tag{5.5}$$

From equations (5.4)-(5.5) the inverse demands are given by:

$$P_i(Q_1, Q_2) = (2t + V) - 3tQ_i - tQ_j, \quad i, j = 1, 2, \tag{5.6}$$

which take the linear functional form. Since market demand depends on both Q_i and Q_j, this implies that there are intra- and inter- port competition at the same time.

The shipping and port terminal operations at port i lead to pollution to the residents in city i (local pollution) as well as to the residents in the rival city j (spill-over). The pollution cost to city i is defined as in equation (5.7), where α is the pollution cost associated with per unit shipping volume at its own city, and β represents inter-city externalities. Since pollution to the local community is more severe than the spill-over effects, it is further assumed that $\alpha > \beta > 0$.

$$PC_i = \alpha Q_i + \beta Q_j, \qquad \alpha > \beta > 0. \tag{5.7}$$

The ports' and shipping lines' behaviors are modelled in the following two-stage game: In Stage One, each port chooses respective port service charge w_i to maximize its profit; In Stage Two, shipping lines compete in Cournot to maximize their individual profits. Without loss of generality, it is assumed that the two ports have constant marginal costs which are normalized to zero. A port's profit function is thus specified as below, where $Q_i^* = \sum_{k=1}^{n_i} q_{ik}^*(w_1, w_2)$ denotes the total outputs of all shipping lines at port i.

$$\Pi_i(w_1, w_2) = w_i Q_i^*. \tag{5.8}$$

The profit maximization problem for shipping line k $(k = 1, 2, ..., n_i)$ at port i ($i = 1, 2$) is specified as:

$$Max_{q_{ik}} \pi_{ik} = \left(P_i - c - w_i\right) q_{ik}. \tag{5.9}$$

The theoretical game can be solved in reverse. Shipping lines' output in Stage Two is obtained by solving the system of first-order conditions derived from equation (5.9), such that:

$$q_{ik}^{*}(w_1,w_2)=\frac{(2n_j+3)(2t+V-c-w_i)+n_j(w_j-w_i)}{(8n_in_j+9n_i+9n_j+9)t}. \tag{5.10}$$

Substitute equation (5.10) into equation (5.8), optimal port charges can be obtained by jointly solving two ports' best response functions. The port charges and shipping line outputs at equilibrium are obtained as follows:

$$w_i^{*}(n_1,n_2)=\frac{(14n_in_j+18n_i+15n_j+18)(2t+V-c)}{35n_in_j+36n_i+36n_j+36}, \tag{5.11.1}$$

$$q_{ik}^{*}(n_1,n_2)=\frac{3(n_j+1)(14n_in_j+18n_i+15n_j+18)(2t+V-c)}{(8n_in_j+9n_i+9n_j+9)(35n_in_j+36n_i+36n_j+36)t}. \tag{5.11.2}$$

The pollution cost at each port is therefore calculated as:

$$PC_i=\frac{1}{t}\left[(\lambda_i\alpha+\lambda_j\beta)(2t+V-c)\right], \tag{5.12}$$

where $\lambda_i=\dfrac{3n_i(n_j+1)(14n_in_j+18n_i+15n_j+18)}{(8n_in_j+9n_i+9n_j+9)(35n_in_j+36n_i+36n_j+36)}$, $(i,j=1,2)$.

Clearly $\lambda_i>0$ and so $\partial PC_i/\partial t=-(\lambda_i\alpha+\lambda_j\beta)(V-c)/t^2<0$. When transportation cost increases, there will be lower demand for shipping services and thus pollution cost will be lower. Denote "local" social welfare at city i as SW_i, which is the sum of net consumer surplus at the city, total profits of shipping lines serving its port, port profit, tax revenue of the local government, and the (negative) pollution cost. The social welfare is therefore specified as[5]:

$$SW_i\equiv\varphi_i=\frac{t}{4}\left(7Q_i^2-Q_j^2+2Q_iQ_j\right)+t\left(Q_j-Q_i-1\right)+\left(P_i-c\right)Q_i-PC_i. \tag{5.13}$$

At equilibrium the local social welfare φ_i is thus:

$$\varphi_i=\frac{(2t+V-c)}{4t}\left[(2t+V-c)(4\lambda_i-2\lambda_i\lambda_j-5\lambda_i^2-\lambda_j^2)-4t(\lambda_i-\lambda_j)-4(\alpha\lambda_i+\beta\lambda_j)\right]-t. \tag{5.14}$$

Define the regional social welfare Φ in this region as the sum of the local social welfare in the two ports or $\Phi=\varphi_1+\varphi_2$, it can be derived that at equilibrium:

$$\Phi=\frac{(2t+V-c)}{2t}\left[(2t+V-c)(2\lambda_1+2\lambda_2-2\lambda_1\lambda_2-3\lambda_1^2-3\lambda_2^2)-2(\alpha+\beta)(\lambda_1+\lambda_2)\right]-2t. \tag{5.15}$$

---

[5] For details of social welfare derivation, please refer to the Appendix B.

Without government intervention, pollution costs will not be considered in private firm's output decision. As a result, output and pollution levels are usually above socially optimal level. Government should impose pollution tax or regulate emission to force firms to take into account of the negative externality / pollution costs associated with their operations. However, as discussed in section 5.1, most previous studies only considered the case of single decision maker. The following sections will analyze the cases when pollution taxes are introduced by local city governments in the presence of competition among shipping lines and ports.

5.3 MARKET EQUILIBRIUMS WITH DIFFERENT FORMS OF POLLUTION TAX

Consider the case where the government regulators in the two cities (hereafter "city") impose pollution tax s_i $(i=1,2)$ on shipping lines for each unit of shipping volume. Clearly, the introduction of pollution tax will influence equilibrium output and thus pollution cost. Therefore, the pollution costs can be denoted as $PC_i = \alpha Q_i(s_1, s_2) + \beta Q_j(s_1, s_2)$. In the absence of inter-city coordination, the two cities will independently choose tax levels in order to maximize their respective local welfare. If there is coordination, the two cities will behave like one single identity such that the regional welfare is maximized. The general taxation process thus can be modelled as a three stage game: In Stage One, local city governments decide their respective tax s_i, either independently or with coordination[6]; In Stage Two, each port decides its service charge w_i; In Stage Three, shipping lines compete in Cournot.

With pollution tax, the profit maximization problem of shipping lines is defined as:

$$Max_{q_{ik}} \pi_{ik} = \left(P_i - c - w_i - s_i\right) q_{ik}. \tag{5.16}$$

---

[6] It is possible that the pollution policy may be made by port operators. If service charge and pollution tax are decided simultaneously, the port operators can group the two items as one single port charge. That is, in such a case there is no need of considering separate pollution tax. However, industrial groups may not care about social welfare as much as their own profit/revenue. For example, nine industrial groups in Japan opposed the carbon tax regulations in the COP-15 Copenhagen Climate Conference in 2009, as they claimed that it would harm the economy (Maeda, 2009). Many ports are fully / partially privatized, which may share the same vision of industrial groups instead of government. Therefore, this study considers the case when pollution tax is set by government.

The outputs and port service charges at equilibrium given pollution tax at each port are, respectively:

$$q_{ik}^{*}(s_1,s_2)=3(n_j+1)\left[\frac{(14n_in_j+18n_i+15n_j+18)(2t+V-c-s_i)+3n_j(n_i+1)(s_j-s_i)}{(8n_in_j+9n_i+9n_j+9)(35n_in_j+36n_i+36n_j+36)t}\right], \quad (5.17.1)$$

$$w_i^{*}(s_1,s_2)=\frac{(14n_in_j+18n_i+15n_j+18)(2t+V-c-s_i)+3n_j(n_i+1)(s_j-s_i)}{(35n_in_j+36n_i+36n_j+36)}. \quad (5.17.2)$$

Clearly, pollution tax s_i imposed by port i would reduce the outputs of shipping lines serving its own port i, but increase the outputs of shipping lines serving the rival port j. The intuition is clear: *ceteris paribus*, imposing pollution tax would increase the production costs of shipping lines serving the port, which reduces their competitiveness against liners in the rival port. Such a feature has not been considered in previous studies. Note where there is an identical increase in pollution tax in the two ports, i.e. $ds_1=ds_2=ds$, this reveals that:

$$dq_{ik}^{*}=\left(\frac{\partial q_{ik}^{*}}{\partial s_1}+\frac{\partial q_{ik}^{*}}{\partial s_2}\right)ds=-\left[\frac{3(n_j+1)(14n_in_j+18n_i+15n_j+18)}{(8n_in_j+9n_i+9n_j+9)(35n_in_j+36n_i+36n_j+36)t}\right]ds<0. \quad (5.18)$$

That is, if pollution tax is introduced in both ports, all shipping lines' outputs will be reduced. Then, the following subsections consider the ports' decision on pollution with and without coordination.

5.3.1 Local Pollution Taxation without Regional Coordination

If there is no coordination / cooperation between the two cities, each city will set "local pollution tax" in order to maximize its local social welfare φ_i as specified in equation (5.13). With the new equilibrium outputs and port service charges as defined in equation (5.17.1) and (5.17.2), the first-order conditions for ports' local welfare optimization problem can be obtained by solving $\left[\partial\varphi_i\left(s_1,s_2\right)/\partial s_i\right]=0$. This leads to the following optimal tax:

$$s_i^{LO*}=4te_i-\left(V-c\right)d_i+\alpha a_i-3\beta b_i, \quad (5.19)$$

where $e_i=\dfrac{8n_i^2n_j^2-246n_j^2n_i-42n_jn_i^2-54n_i^2-378n_i-594n_j-621n_in_j-270n_j^2-324}{18n_i(n_j+1)(32n_in_j+35n_i+35n_j+36)}$,

$$d_i=\frac{2076n_j^2n_i+1620n_jn_i^2+837n_i^2+2106n_i+2646n_j+784n_i^2n_j^2+1350n_j^2+4185n_in_j+1296}{18n_i(n_j+1)(32n_in_j+35n_i+35n_j+36)}>0,$$

$$a_i = \frac{1467n_i^2 + 2754n_i + 2826n_i^2 n_j + 5463n_i n_j + 1360n_i^2 n_j^2 + 2706n_i n_j^2 + 1350n_j^2 + 2646n_j + 1296}{18n_i(n_j + 1)(32n_i n_j + 35n_i + 35n_j + 36)} > 0,$$

$$b_i = \frac{80n_i^2 n_j^2 + 154n_i n_j^2 + 82n_i^2 n_j + 90n_j^2 + 141n_i n_j + 90n_j - 18n_i - 3n_i^2}{18n_i(n_j + 1)(32n_i n_j + 35n_i + 35n_j + 36)} > 0 .$$

A somewhat unexpected result is that, without regional coordination, the optimal pollution tax s_i^{LO*} can be negative. That is, instead of reducing port output to socially optimal level, the cities may subsidize shipping lines so as to encourage a higher shipping volume. This new insight is due to the fact that market structure in the liner and port markets is explicitly considered in the study. In particular, the competition between the two ports may be limited if their catchments are sufficiently separated (i.e., large transportation cost t in the model). When there are only a small number of competing lines serving the ports (i.e., small n_i), the liner market is best characterized as oligopoly rather than perfectly competitive. Therefore, the output may be lower than social optimal level due to insufficient competition. More importantly, in the absence of regional coordination, the two-city governments only value the size of local economy but not the spill-over pollution to their neighbours. As a result, the two cities have strong incentive to help their local marine sector in the competition against the rival port. They may subsidize rather than charge the local marine sector, leading to a negative pollution tax s_i^{LO*}. A positive tax will only be introduced when a port's desire to control pollution outweighs the possible incentive of subsidy.

The determination process of pollution tax can be further clarified by checking the comparative statics. It can be shown that:

$$\frac{\partial s_i^{LO*}}{\partial \alpha} = a_i > 0 \qquad \text{and} \qquad \frac{\partial s_i^{LO*}}{\partial \beta} = -3b_i < 0 \ . \qquad (5.20)$$

That is, as the pollution cost / damage to the local resident gets larger, the city government would increase pollution tax thus to control local pollution ($\partial s_i^{LO*} / \partial \alpha > 0$). On the other hand, *ceteris paribus*, an increase in spill-over damage, but not the local pollution damage, will actually prompt the government to reduce pollution tax ($\partial s_i^{LO*} / \partial \beta < 0$). Intuitively, if pollution only harms the neighbour city (and port) without creating local damage, there is no incentive for a city government to charge its local marine sector a pollution tax. Instead, increased pollution to the neighbour will reduce rival port's competitiveness thus indirectly help its own marine sector. In reality, a change in shipping technology usually affects local and spill-over pollution damage simultaneously. If there is an identical change in pollution damage, i.e. an identical change in both α and β, so that $d\alpha = d\beta = dP$, the overall effect on pollution is:

$$ds_i^{LO*} = \left(\frac{\partial s_i^{LO*}}{\partial \alpha} + \frac{\partial s_i^{LO*}}{\partial \beta} \right) dP = \left(a_i - 3b_i \right) dP. \tag{5.21}$$

It can be shown that $\left(a_i - 3b_i \right) > 0$. That is, if local and spill-over pollution per unit of shipping volume increases (decreases) at the same time, local government will increase (decrease) pollution tax.

Further examine the effect of market size as measured by the number of the shipping lines. It can be shown that:

$$\frac{\partial s_i^{LO*}}{\partial n_i} > 0. \tag{5.22}$$

That is, an increase in the number of shipping lines would raise the market output and consequently pollution cost. In order to control an effluent emission, the local government would set a higher tax rate to restrict market outputs to an appropriate level. However, the sign of $\partial s_i^{LO*} / \partial n_j$ cannot be determined because it is dependent on many parameters related to pollution spill-over, inter-port competition, and competition in the liner market.

5.3.2 Pollution Taxation with Regional Coordination

If the two city governments cooperate thus that they behave as if there is a central government coordinating the pollution taxes, the objective is best specified as in equation (5.23), thus that pollution taxes s_1 and s_2 are chosen jointly to maximize the regional social welfare $\Phi = \varphi_1 + \varphi_2$, which is the sum of local social welfare in the two cities.

$$Max_{s_1, s_2} \Phi, \tag{5.23}$$

where $\Phi = \varphi_1 + \varphi_2 = \frac{3t}{2}\left(Q_1^2 + Q_2^2 \right) + t\left(Q_1 Q_2 - 2 \right) + \sum_i \left[\left(P_i - c_i \right) Q_i - PC_i \right]$. Solving which one can obtain the "coordinated pollution tax" as:

$$s_i^{CO*} = (\alpha+\beta) - \frac{(8n_in_j + 9n_i + 18n_j + 18)(2t + V - c - \alpha - \beta)}{12n_i(n_j+1)}. \tag{5.24}$$

Note that this total social welfare maximizing tax is lower than a standard Pigouvian tax (Pigou, 1932), which equals to marginal externality damage or $(\alpha+\beta)$ in the analytical model. Again, this is due to the fact that the competition in the port and liner markets has been explicitly modelled. When there is insufficient competition (e.g., small number of competing lines as measured by n_i, or the two ports are not easily substitutable as measured by a larger transportation cost t), the market output will be below social optimum. Thus, the coordinated ports, or a hypothetical central government, will have an incentive to subsidize shipping lines by charging tax lower than marginal environmental cost. Such a result is consistent with Buchanan (1969), Barnett (1980), and Baumol and Oates (1988), who also considered taxation in markets which are not perfectly competitive[7].

In comparison to the case of pollution tax without coordination, note:

$$\frac{\partial s_i^{CO*}}{\partial \alpha} = \frac{\partial s_i^{CO*}}{\partial \beta} = \frac{20n_in_j + 21n_i + 18n_j + 18}{12n_i(n_j+1)} > 0. \tag{5.25}$$

That is, with coordination, damages caused to either port, as measured by parameters α and β, will be compensated in the pollution tax. This is the main benefit from regional cooperation / coordination. The effects of intra- and inter-port competition on pollution tax are definite as evidenced by the following comparative statics:

$$\frac{\partial s_i^{CO*}}{\partial n_i} = \frac{3}{2n_i^2}(2t + V - c - \alpha - \beta) > 0, \text{ and } \frac{\partial s_i^{CO*}}{\partial n_j} = \frac{1}{12(n_j+1)^2}(2t + V - c - \alpha - \beta) > 0. \tag{5.26}$$

The interpretation is straightforward, as there are more shipping lines competing in the markets and thus output will be larger, the coordinated pollution tax shall always increase to compensate the increased pollution level.

---

[7] Under different theoretical model settings, some scholars found that an imperfect competition does not necessarily imply that the optimal tax should be lower than marginal damages, for example, Yin (2003) and Simpson (Simpson, 1995).

5.4 THE EFFECTS OF POLLUTION TAX

After solving the optimal pollution tax with and without regional coordination, this section investigates the effects of pollution tax on market equilibriums by comparing key results across different settings.

5.4.1 Comparison of Pollution Tax with and without Regional Coordination

When two cities coordinate to maximize total regional welfare, the optimal "coordinated pollution tax" imposed will be higher than the "local pollution tax" charged by independent local governments if $\left(2t+V-c-\alpha-\beta\right)>\left(4t-4\beta\right)$. Otherwise, coordinated pollution tax will be equal to or lower than local pollution tax. To see this, note by equation (5.19) and (5.24), the difference between coordinated tax and local tax is calculated as:

$$s_i^{CO*}-s_i^{LO*}=\zeta(-2t+V-c-\alpha+3\beta)\,, \tag{5.27}$$

where

$$\zeta=\frac{(648+810n_j^2+1536n_i^2n_j+1584n_j^2n_i+2943n_in_j+800n_i^2n_j^2+1350n_i+1458n_j+729n_i^2)}{36n_i(n_j+1)(32n_in_j+35n_i+35n_j+36)}>0\,.$$

Therefore, s_i^{CO*} is greater than s_i^{LO*} if $(V-c)-\alpha+3\beta-2t>0$. Such a condition is more likely to hold as: (a) the two ports are more substitutable to each other (i.e., lower transportation cost t); (b) the shipping service has a high net value $(V-c)$ thus that shipping demand is high; (c) shipping pollution is less harmful to local residents α; but (d) spill-over effect β is larger. Intuitively, as two ports are more substitutable so that there is increased inter-port competition, a local government's incentive to help its local marine industry will be stronger. Similarly, if shipping services bring greater benefits to the economy, local government's incentive to help its own marine sector in the competition with rivalry port will be also stronger. Such considerations (competitive externalities) will not be present in the case of coordinated case. Therefore, the coordinated pollution tax will be higher than the local tax, so that traffic volume and pollution level in the coordinated case will be reduced to regional optimum level.

The effects of local pollution cost α and spill-over pollution cost β are more straightforward: with regional coordination, the spill-over effects will be fully addressed, while independent local government will only take care of local pollution damage. In general, the coordinated pollution tax is more likely to be higher than the local pollution tax as the marine service is of greater economic value, and the two ports are more related to each other in terms of increased inter-port competition and higher spill-over effects.

5.4.2 Market Outputs and Prices

With the local pollution tax, the output of shipping line k at port i is:

$$q_{ik}^{LO*} = \frac{1}{6tn_i}\left[(V-c-\alpha)\kappa_i + 4tf_i + 3\beta g_i\right], \tag{5.28}$$

where $\kappa_i = \frac{(68n_in_j + 69n_i + 75n_j + 72)}{(32n_in_j + 35n_i + 35n_j + 36)} > 0$, $f_i = \frac{(14n_in_j + 18n_i + 15n_j + 18)}{(32n_in_j + 35n_i + 35n_j + 36)} > 0$,

and

$$g_i = \frac{(4n_in_j - n_i + 5n_j)}{(32n_in_j + 35n_i + 35n_j + 36)} > 0 .$$

With the coordinated pollution tax, the shipping line's output is:

$$q_{ik}^{CO*} = \frac{1}{4tn_i}\left(2t + V - c - \alpha - \beta\right). \tag{5.29}$$

The difference of outputs in the two cases is therefore:

$$q_{ik}^{CO*} - q_{ik}^{LO*} = -\frac{(40n_in_j + 33n_i + 45n_j + 36)(-2t + V - c - \alpha + 3\beta)}{12tn_i(32n_in_j + 35n_i + 35n_j + 36)}. \tag{5.30}$$

Again, the relative size of outputs depends on the sign of $(-2t + V - c - \alpha + 3\beta)$. The result is consistent with the findings in section 5.4.1. *Ceteris paribus*, higher pollution tax will lead to lower output, or $s_i^{CO*} > s_i^{LO*}$ implies $q_{ik}^{CO*} < q_{ik}^{LO*}$.

It can be calculated that with coordinated pollution tax, the market price of liner services precisely reflects social cost since $P_i^{CO*} = c + \alpha + \beta$. In addition, the relative size of liner service prices under the two pollution taxes, again, depends on the sign of $(-2t + V - c - \alpha + 3\beta)$ since:

$$P_i^{CO*} - P_i^{LO*} = \frac{2(20n_in_j + 18n_i + 21n_j + 18)(-2t + V - c - \alpha + 3\beta)}{3(32n_in_j + 35n_i + 35n_j + 36)}, \quad (5.31)$$

which simply states that if $s_i^{CO*} > s_i^{LO*}$ then $P_i^{CO*} > P_i^{LO*}$.

5.5 MANAGERIAL AND POLICY IMPLICATIONS

The analysis in this chapter provides several major new insights. In the absence of pollution tax and other control measures, ports and shipping lines are inclined to produce more than the socially optimal level. When the pollution tax (or other tax-equivalent measures) is introduced, demand for shipping and port service declines. The amount of this demand reduction depends on the elasticity of the demand curve as well as the amount of pollution tax introduced. When there is inter-port competition, local government's or port authority's incentive to reduce output and thus pollution level is reduced. This is due to the fact that a unilateral increase of pollution tax by a port will divert shipping lines to the competing port and leads to increased spill-over pollution from the rival port. The port that introduces the pollution tax would suffer from a decrease in competitiveness and an increase in spill-over pollution simultaneously.

It is notable that negative pollution tax (or subsidy) may maximize social welfare under certain market structures. Therefore, a market-based incentive policy (e.g. environmentally differentiated Fairway Dues in Sweden) may be justified, which can have a significant impact on local economy and pollution level. This analysis provides some references on the complexity of setting appropriate levels of economic incentive when firm rivalry and market structures are considered.

Absent of inter-port coordination, pollution spill-over and inter-port competition can lead to distorted pollution taxation. The "coordinated pollution tax" can be either higher or lower than the "local pollution tax", depending on market responses to the pollution fees (i.e., changes in consumption and production). Without regional coordination, there are two conflicting forces determining pollution tax. On the one hand, cities (or ports) have incentive to control local pollution and this requires charging pollution tax. On the other hand, there are also incentives for the cities (or ports) to subsidize its marine sector in the competition with rival port. Whether governments would introduce subsidy or pollution tax is therefore depending on the joint effects of pollution and competition. The local tax alone does not truly reflect marginal social damage.

There are many options for ship pollution and emission control in ports. Most of these options are on a local basis such as speed reduction, cold-iron, and emission charge. These environmental initiatives have effects at a broader scale than a port. It is important to realize that the effect of ship pollution / emission reduction can be maximized when a joint effort is put forward across the region. This study shows that pollution reduction schemes will become more effective when such plans are jointly implemented by local governments. In summary, there is room for social welfare improvement when two local governments work together to decide (coordinated) tax rate, which allows inter-port externalities to be endogenized. That is, despite the potential competition among the ports in a region, it is important for them to coordinate their pollution control efforts, which would enhance the effectiveness of pollution tax, particularly when adverse externality of one port to the others exists. Such the analysis can be extended to problems at a higher level such as international cooperation on pollution control, although international ship emission management involves more complex issues.

5.6 SUMMARY AND CONCLUSION

This chapter examines the managerial and policy implications of pollution tax (or negative incentive) in a region with multiple ports. Unlike previous studies considering one single market and/or one single decision maker, the economic model developed in this study involves two competing ports facing not only direct competition within a port (intra-port competition), but also indirect competition from the other rival port (inter-port competition). Therefore, pollution tax introduced in any one of the ports will affect the outputs of all shipping lines. Another new feature of the model is the consideration of inter-port externalities, in addition to intra-port pollution. Such a conceptual framework demonstrates the inter-relationship of pollution emissions from the two adjacent ports, where regulators at each port can influence, to varying degrees by providing some incentive and disincentive schemes, port performances in terms of output level, profit, pollution emission, and port choice of the shippers.

Although this investigation provides several useful policy recommendations, the theoretical model adopted may be limited by several technical assumptions such as constant marginal costs of port operation and pollution, and homogeneous shipping services. The model does not consider operation issues such as scheduling of ship movements, the air emission-speed relationship, the mix of feeder, and the deep-sea services neither. Although it is unlikely that these issues will change the model conclusions qualitatively, future research relaxing these assumptions will improve the conceptual model. More importantly, while this analysis demonstrated the benefits of cooperation between the adjacent ports, it does not suggest how such cooperation can be achieved. Port governance and ownership forms may play important roles in determining the feasibility of port cooperation. Other factors such as government policy, port management style, and shipping lines' influences on ports, cannot be ignored neither in practice. Empirical studies on these issues would be very useful. Indeed, the modelling work in this study shall be regarded as a complement instead of substitute to empirical investigation. More in-depth studies are needed for the development of future government policy on issues such as pollution control and low carbon shipping.

CHAPTER 6

THE IMPACTS OF PRODUCTION BASE RELOCATION ON PORT CLUSTER COMPETITION – THE CASE OF PEARL RIVER DELTA (PRD) REGION[1]

In addition to the pollution control challenge studied in the previous chapter, another pressing problem to the maritime sector is from the ongoing process of industrial base relocation further away from maritime logistics hubs. This chapter develops an economic model to examine the impact of such process on ports' performance, with a focus on the major ports in the Pearl River Delta region of China. In addition, it explores the effects of hinterland access (positive or negative) externalities arisen from competing ports' sharing a common transportation corridor. The study provides important insights on intra- and inter-port cluster competition, and practical policy recommendations for stakeholders in the Chinese port industry. Although this chapter mainly focuses on the relocation trend in the Pearl River Delta region, the analytical model can be extended to investigate other markets or regions facing similar challenge.

This chapter is organized as follows. Section 6.1 introduces background of the study. Section 6.2 provides information on the overall background of port competition in the PRD region and the ongoing production base relocation process. Section 6.3 describes construction of an economic model used to provide analytical results. Section 6.4 summarizes and concludes the study. The Appendix C lists a number of mathematical derivations.

6.1 INTRODUCTION

China's industrial sector has long developed along the coastal regions of the country's eastern and southern provinces. Many manufacturing firms, both local and multinational corporations (MNCs), have established their production bases and

---

[1] The study in this chapter has been submitted for journal publication in Growth and Change, which is under review, as:

> Homsombat, W., Ng, A.K.Y., Fu, X., The impacts of production base relocation on port cluster competition: the case of Pearl River Delta (PRD) region. *Growth and Change*, under review.

manufacturing hubs in these areas, particularly within the Pearl River Delta (PRD) and the Yangtze River Delta (YRD). The prosperity of the manufacturing sector has also accelerated the development of other related industries, including shipping and port services. The ports of Hong Kong and Shenzhen in the PRD region and the port of Shanghai in the YRD region have clearly benefited from the manufacturing boom in their catchment areas. This is evidenced by the extremely high level of growth in the volume of traffic served by these ports in the past three decades. All three ports ranked among the five busiest container ports in the world in 2011.

The economic development since China launched its reform program in 1979, as well as preferential incentives from local governments, has led the PRD to becoming the most economically dynamic region in mainland China (Enright et al., 2007). The key growth engine has been the production and manufacturing sector. The PRD region has grown into one of the leading manufacturing hubs in the world for products such as electronics, furniture, shoes, fashion and textiles, toys, and telecommunications equipment. Many favorable factors have contributed to this success. The PRD region has excellent transport infrastructure, including ports, airports, highways, and rail systems. The logistics industry is well-developed and local customs services are efficient and business-friendly. The region has also attracted many emigrant workers from the labor-rich provinces of inland China. This has allowed the PRD to maintain its edge in both efficiency and cost competitiveness over other economies in Southeast Asia. In addition, provincial and municipal governments have offered very generous terms to investors, often in the forms of tax incentives and cheap land. All these factors have made the PRD the preferred location for manufacturers, especially those specializing in labor-intensive products. Indeed, ports in southern China, notably Hong Kong and Shenzhen, have benefited greatly from economic growth within the PRD region in the past three decades.

However, the success experienced in the past is introducing new challenges today. Living costs have been rising rapidly in the PRD region, forcing manufacturing firms to constantly increase workers' remuneration. Wages have surged at an annualized rate of 17% (The Boston Consulting Group, 2011). Preferential policies offered by local governments are gradually being withdrawn from labor-intensive production operations, as municipal and provincial governments now aim to set aside more land and subsidies for high-tech and service-oriented industries. The comparative advantages of the PRD for labor-intensive manufacturing are fading quickly. The constant increases in labor and operational costs within the PRD have forced many manufacturing firms to explore alternative locations with a notable focus on inland areas. Although many provinces in western and northern China are economically less developed, they have abundant labor and land resources. The Chinese government is thus implementing a strategic plan to promote economic re-balancing among the provinces in the hope that they all can achieve sustainable growth in the long run. Many inland provinces and cities have regarded attracting relocated firms as an opportunity to catch up with or leapfrog their peers. Local governments and the central government have offered generous incentives, including tax concessions, cheap land, and sometimes even free factory buildings to support investments in these inland provinces, thus further accelerating the relocation process. A survey conducted by the Hong Kong Trade Development Council (HKTDC, 2011a) reveals that many Hong Kong companies operating in the PRD have a positive view of the relocation option. The preferred location choices are areas close to Guangdong such as the provinces of Hunan, Sichuan, Hubei, and the district of Chongqing (HKTDC, 2011a, 2011b, 2011c). A number of high-tech manufacturers have already relocated their labor-intensive assembly and original equipment manufacturer (OEM) production units. For example, Chongqing has become one of the world’s major hubs for laptop computers, assembling about half of all units globally. Many iPhone and iPad OEM production units are also being relocated to the provinces of Sichuan and Henan.

The ongoing relocation process may pose significant challenges to the major ports in the PRD region, which have benefited substantially from the export and import growth driven by the manufacturing boom in the region. The ports of Hong Kong and Shenzhen may face some serious challenges if a large number of firms relocate their operations. Their hinterland access costs will increase, leading to reduced traffic volume. In addition, if production bases are relocated to provinces close to other gateway ports such as Shanghai, then a substantial volume of traffic may be switched to other ports. Because ports on the Yangtze River offer very competitive inland shipping services to a number of major cities and provinces in inland China, manufacturers that relocate to these areas could have lower transportation costs to Shanghai than to the PRD region, even if the geographic distances to the ports are similar. Traffic shifts can be substantial in such cases. Therefore, the relocation of manufacturing operations based in the PRD region will not only influence the performance of the ports of Hong Kong and Shenzhen, but may also reshape the competitive landscape among major port clusters in mainland China (e.g., as between the PRD and the YRD port clusters).

Evaluating the effects of this relocation process comprehensively is not a straightforward exercise. Given that the ports of Hong Kong and Shenzhen share common transportation corridors and transport infrastructure to inland China, the relocation process will have some externality effects on the two ports' hinterland logistics. If there is economy of scale in hinterland access, or a positive externality effect, sharing a common transportation corridor will allow the two ports to lower their hinterland transportation costs. On the other hand, if there is substantial congestion in hinterland transport facilities, or a negative externality effect, then sharing a common transportation corridor will increase the hinterland access costs of both ports. Because Hong Kong and Shenzhen provide substitutable services, an identical change in input costs may have different effects on the two ports.[2] In addition, firms may even take measures to increase their competitors' costs to gain a competitive advantage (Salop and Scheffman, 1983). Therefore, it is difficult to gauge the overall effects of the ongoing production base relocation process in the PRD region without conducting a comprehensive investigation.

The effects of hinterland access on port cluster competition have also been observed in other markets. Notteboom (2009a) pointed out that hinterland access moderated the relationships among major European ports and had profound implications for global supply chains. Although there is no lack of research on the geographical evolution of ports and terminals (see, for example, Ng and Gujar, 2009; Ng and Cetin, 2012; Padilha and Ng, 2012) and port competition (e.g., Notteboom, 2009b; Lam and Yap, 2011), few studies have systematically investigated the implications of a dynamic relocation process such as that occurring in the PRD region. Predictions on the impacts of production base relocation on port cluster competition thus remain untested to date. This chapter aims to address this gap in the literature by investigating the implications of the relocation process on: (a) port performance in terms of port throughput, hinterland access costs, port charges, and

---

[2] Fu et al. (2006) and Oum and Fu (2007) analyzed the effects of airport charge increases on competing airlines which provide differentiated services. In general, they concluded that an identical increase in input prices would have differential impacts on downstream competitive firms.

profitability; (b) port competition within a port cluster (in this context, competition between Hong Kong and Shenzhen in the PRD); and (c) inter-port cluster competition (in this case, competition between the PRD and the YRD port clusters). This study provides fresh insights and important policy recommendations to stakeholders in the Chinese port industry. In addition, the analytical framework employed here can easily be extended to investigate other cases in which competing ports experience major changes in hinterland/input costs.

6.2 PORT COMPETITION AND PRODUCTION BASE RELOCATION

The rapid economic growth of Greater China in recent decades has led to aggressive investments in the port sector. Many ports have been built or expanded. Three port clusters stand out along the coastal areas of mainland China: the Bohai Bay port cluster, which includes the ports of Dalian, Qingdao, and Tianjin; the YRD port cluster, in which Shanghai is the dominant port, followed by Ningbo and Zhoushan; and the PRD port cluster, which has been largely dominated by Hong Kong and Shenzhen, but is complemented by follower ports such as Xiamen and Fuzhou. While these three port clusters compete with each other, competition among the ports within each cluster is even stronger. The following subsections first outline competition between and within the port clusters before providing some background information on the ongoing production base relocation process.

6.2.1 Intra- and Inter- Port Cluster Competition

The port of Hong Kong is strategically located in the PRD. Supported by its high-quality infrastructure and business-friendly regulatory environment, the port has long served as a major gateway for shipping and trade to mainland China and Southeast Asia. It was one of the first Asian ports to become containerized and has long been one of the world's leading ports in terms of shipping volume, productive efficiency, and service quality. In 1979, the Shenzhen Special Economic Zone was established north of Hong Kong's border with the mainland. In the following years, the PRD region as a whole attracted a tremendous amount of overseas investment, mostly in the manufacturing sector. This led to an explosion in demand for shipping and port services in the region. Given the less developed and poorly managed state of

Shenzhen's port, Hong Kong benefited most from this growth in demand. However, from 1979 to 2004, Shenzhen invested over 30 billion yuan to improve its port infrastructure and related facilities. Restrictions on foreign investment in and management of the Chinese port sector were also lifted during this period, with some major terminals being privatized (Cullinane et al., 2004). This allowed the port of Shenzhen to grow rapidly and eventually surpass Hong Kong in terms of traffic volume. A similar development process also took place in the port of Shanghai in the YRD. Today, these three ports are among the five busiest container ports in the world. Their throughput volumes in recent years are summarized in Table 6-1.

Table 6-1 Container throughput and transshipment estimates for Hong Kong, Shenzhen, and Shanghai (2003-2009)

Year/Port ('000 TEU)	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Hong Kong 1/							
Throughput	20,820	22,021	22,424	23,540	23,904	24,494	20,984
Transshipment Estimate	6,267	6,661	6,817	7,062	7,171	7,348	5,141
Transshipment Incidence (%)	30.00	30.30	30.40	30.00	30.00	30.00	24.50
Average growth in port throughput (2003-2009) 2/**:** 0.38%							
Shenzhen							
Throughput	10,615	13,562	15,899	18,171	21,117	21,416	18,105
Transshipment Estimate	1,691	2,215	2,689	3,302	3,759	4,888	3,640
Transshipment Incidence (%)	15.93	16.33%	16.91	18.17	17.80	22.82	20.10
Average growth in port throughput (2003-2009) 2/**:** 10.24%							
Shanghai 1/							
Throughput	11,370	14,557	18,084	21,710	26,150	7,980	25,214
Transshipment Estimate	4,851	6,242	7,793	4,342	5,753	6,156	5,295
Transshipment Incidence (%)	43.00	42.90	43.10	20.00	22.00	22.00	21.00
Average growth in port throughput (2003-2009) 2/**:** 14.98%							

Sources: Drewry Shipping Consultants Ltd, with supplemental data for Shenzhen from the China Ports Yearbook.

Notes: 1/ Transshipment incidence figures were calculated after adjusting for estimated river traffic.

2/ If the crisis year (2009) was dropped from calculations, the average rate of growth in port throughput for Hong Kong, Shenzhen, and Shanghai would increase to 3.32%, 15.38%, and 19.95%, respectively.

It is clear that Shenzhen experienced much faster growth than Hong Kong over the past three decades. The average annual growth in throughput in Hong Kong between 2003 and 2009 was a mere 0.38%, whereas the growth rate for Shenzhen during the same period was 10.24%. The port of Shanghai recorded an even higher average annual growth rate of 14.98% thanks to strong economic growth in the YRD region and competitive river transportation services along the Yangtze River. The rising power of the mainland ports, Shenzhen and Shanghai in particular, is changing the landscape of the port industry along China's coastal regions. Transshipment operations and aggressive investments in capacity at Shenzhen pose significant challenges to Hong Kong, which has traditionally served as both a major gateway to China and a transshipment hub in the region. Although UNESCAP (2005) predicted that the port of Hong Kong would remain a major logistics hub for the region, it is clear that it has been persistently losing its market share to rising mainland ports in the PRD and the YRD regions. The overall picture that emerges from the evidence of recent years shows clear intra- and inter-port cluster competition.

6.2.2 Underlying Incentives for Industrial Relocation from the PRD Region

Continuously rising costs in the PRD region mean the local business environment has become increasingly unfavorable for manufacturing firms. Liao and Chan (2011) compiled a survey conducted by the Chinese Manufacturers' Association of Hong Kong (2008), suggesting the most influential/challenging business environment changes in the PRD region included RMB appreciation, inflation, and the upsurge in raw materials and, in particular, labor costs. As shown in Table 6-2, average wages in the manufacturing sector have increased sharply in all mainland China provinces. The average annual rate of growth in wages in Guangdong during the 2006 to 2010 period was 11.67%, lower than the national average of 14.45%. However, because the wage level has always been higher in Guangdong than in inland provinces, wage differences between Guangdong and inland provinces have barely narrowed. While municipal governments in the PRD region are somewhat concerned about the negative effects of rising labor costs, priority has been increasingly given to improving residents' living standards and upgrading the local economy to one relying more on high value-added manufacturing and service-oriented businesses. Therefore, some local governments are in favor of increasing salaries overall. For example, from 1 February 2012, the minimum wage in the Shenzhen Special Economic Zone increased by an additional 13.6%. Moreover, high fuel prices and hikes in power prices and electricity rates for industrial users have raised operational costs further at manufacturing plants across the country, especially in developed regions with their higher input price levels (HKTDC, 2012). The diminishing comparative advantages of the PRD region have put increasing pressure on manufacturers to relocate their production bases.

Table 6-2 Average wage in the manufacturing sector (Unit: Yuan/Year)

Regions/ Years	**Average wage**					**Wage growth and average (%)**					
	2006	**2007**	**2008**	**2009**	**2010**	**2006**	**2007**	**2008**	**2009**	**2010**	**Ave.**
Coastal regions											
Guangdong	**19785**	**22547**	**24751**	**27578**	**31277**	**9.80**	**13.96**	**9.78**	**11.42**	**13.41**	**11.67**
Fujian	15936	18391	20445	22631	26627	12.00	15.41	11.17	10.69	17.66	13.38
Jiangsu	19117	22510	25187	27765	32209	12.87	17.75	11.89	10.24	16.01	13.75
Shandong	15381	18477	21114	23930	27773	18.14	20.13	14.27	13.34	16.06	16.39
Shanghai	35453	37975	43678	46672	52163	18.83	7.11	15.02	6.85	11.77	11.92
Inner mainland China											
Chongqing	18163	21290	24249	27770	31894	16.93	17.22	13.90	14.52	14.85	15.48
Guangxi	17104	19408	21644	23508	26179	16.94	13.47	11.52	8.61	11.36	12.38
Jiangxi	13780	15423	17643	21508	25579	15.59	11.92	14.39	21.91	18.93	16.55
Ningxia	15970	19461	23015	24431	29560	17.82	21.86	18.26	6.15	20.99	17.02
Shaanxi	15955	17968	21034	23428	26015	18.87	12.62	17.06	11.38	11.04	14.20
Sichuan	16442	18906	22090	24448	28577	15.18	14.99	16.84	10.67	16.89	14.91
Yunnan	19131	20028	23613	23614	28550	11.45	4.69	17.90	0.00	20.90	10.99
National Total	**17966**	**21144**	**24192**	**26810**	**30916**	**14.02**	**17.69**	**14.42**	**10.82**	**15.32**	**14.45**

Source: China Statistical Yearbook 2007-2010, National Bureau of Statistics of China.

Rising costs are clearly a “push factor” for manufacturing companies operating in the PRD region. Furthermore, the Chinese government’s plan to achieve balanced growth across the country has resulted in some preferential incentives being offered to firms considering relocation. Such “pull factors” include incentives such as tax rebates, fast-tracked approval for the establishment of businesses, favorable land supply arrangements, and improved transport and logistics infrastructure from inland provinces to major gateway ports. The Ministry of Commerce has initiated plans designed to encourage investment in the central and western regions. The Ministry selected nine regions of central China as the first batch of areas designated for investment in April 2007. The second target areas were promoted in the following year, most in central and western parts of China as reported in Figure 6-1 and Table 6-3. Table 6-2 shows that wages in most of these designated areas are fairly competitive. Since they were designated as priority regions for relocation, many major manufacturing groups have announced plans to gradually relocate their plants from the PRD region to inland areas. For instance, in 2010, Flextronics expanded its production site at Ganzhou in the province of Jiangxi (PR Newswire, 2010; Global Supply Chain Council, 2010). Foxconn, a well-known OEM supplier for Apple Inc., planned to move its major production campus from Shenzhen to Langfang in Hebei province and to build a new plant in Zhengzhou, Henan (China Daily, 2010). In addition, it agreed to jointly invest in a laptop manufacturing hub in Chongqing with Hewlett-Packard (China Daily, 2009). Due to increasingly restrictive environmental protection policies along the coastal provinces, many producers of chemicals, building materials, textiles, and paper are also evaluating plans to relocate to inland areas (Liao and Chan, 2011; Zhao and Yin, 2011; Knowler, 2012).

Figure 6-1 Target areas for industry relocation by the Ministry of Commerce (as 2008)

Sources: Ministry of Commerce, People's Republic of China, and Li & Fung Research Centre (2008).

Table 6-3 Areas designated for industrial relocation in 2007 and 2008

Region	**Province / Municipality**	**City**	
		First Batch (2007)	**Second Batch (2008)**
Central	Hubei	Wuhan	Yichang, Xiangfan
	Hunan	Chenzhou	Yueyang, Yiyang, Yongzhou
	Henan	Xinxiang, Jiaozuo	Luoyang, Zhengzhou
	Jiangxi	Nanchang Ganzhou	Yian, Shangrao
	Shanxi	Taiyuan	Houma processing zone
	Anhui	Hefei, Wuhu	Anqing
Western	Guangxi		Nanning, Qinzhou
	Sichuan		Chengdu, Mianyang
	Chongqing		
	Shaanxi		Xi’an
	Ningxia		Yinchuan
	Yunnan		Kunming
Others	Hainan		Haikou
	Inner Mongolia		Baotou
	Heilongjiang		Harbin

Sources: Ministry of Commerce, People’s Republic of China, and Li & Fung Research Centre (2008).

The relocation of production bases away from the PRD region is bringing new challenges to the ports of Shenzhen and Hong Kong, which are already experiencing weak demand following the global financial crisis that began in 2008. In the first quarter of 2011, container throughput in Hong Kong and Shenzhen rose 2.4% and 3.6%, respectively, representing a clear slowdown from past years (Shih, 2011). Although the effects of the global financial crisis will eventually recede, the long-term impacts of production base relocation will persist. Therefore, it is important that policy makers in Shenzhen and Hong Kong come up with long-term strategies to maintain their status as regional hub ports and gateways to mainland China. The following section attempts to model the performance implications of relocation for these two ports, thus enabling their stakeholders to formulate feasible plans for long-run growth.

6.3 A MODEL OF PORT COMPETITION IN THE PRESENCE OF HINTERLAND ACCESS EXTERNALITY

This section considers a case whereby many shippers (e.g. manufacturing companies) in the PRD region and nearby provinces in Southern China rely on two port clusters to provide them with international logistics services. Ports in Cluster 1, which include major ports in the PRD region, have been close to these firms, and thus provide them with almost all the shipping services required. Cluster 1 has two competing ports denoted as Port 1 (Hong Kong) and Port 2 (Shenzhen). The other port cluster, the Port Cluster 2 in the YRD region, currently provides few services to these shippers/manufacturers. However, if there is a continued trend of production base relocation, then in the long term, ports in this second cluster may be able to provide (relocated) firms with more competitive services. Port Cluster 2 comprises several ports such as Ningbo and Shanghai. Shanghai is the clear leader among them and dominates the market in terms of market share and pricing capability. To take this consideration into account and ensure analytical tractability, the ports in this cluster are treated as a single (consolidated) “mega-port” denoted as Port 3 (Shanghai). For ease of notation and discussion, the ports involved in the model are referred to as Port 1 Hong Kong, Port 2 Shenzhen, and Port 3 Shanghai. These three ports provide substitutable but differentiated services. Their demand equations are specified as:

$$\begin{cases} \rho_1 = \alpha_1 - \beta_1 q_1 - \gamma_2 q_2 - \gamma_3 q_3 \\ \rho_2 = \alpha_2 - \gamma_2 q_1 - \beta_2 q_2 - \gamma_1 q_3 \\ \rho_3 = \alpha_3 - \gamma_3 q_1 - \gamma_1 q_2 - \beta_3 q_3 \end{cases}, \tag{6.1}$$

which corresponds to a representative consumer maximizing a quadratic utility function of $U(\vec{q}) = \sum_{i=1}^{3} \alpha_i q_i - \frac{1}{2}\left[\sum_{i=1}^{3} \beta_i q_i^2 + 2\gamma_1 q_2 q_3 + 2\gamma_2 q_1 q_2 + 2\gamma_3 q_1 q_3\right] + M$, where M is numeraire goods (money) and $\vec{q}$ denotes a vector of outputs (i.e. port throughputs) at the three ports. Assume that a port’s price is more sensitive to its own output than to those of rival ports. That is, it is further assumed that $\beta_i > \gamma_i$ for all i.

For a (representative/average) shipper, the generalized cost of using port ρ_i is the sum of hinterland access costs h_i and port charges p_i:

$$\rho_i = h_i + p_i . \tag{6.2}$$

The close proximity of Port 1 Hong Kong and Port 2 Shenzhen means they share the same transportation corridor to inland provinces. Per unit logistics costs associated with hinterland access (e.g. the cost of moving a container from the production base to a PRD port) can be specified as:

$$h_i = g_1 d_i (1+\lambda), \qquad i = 1,2, \ d_1 > d_2, \text{ and } \lambda \in (-1,1), \tag{6.3}$$

which is a function of the unit transportation cost of moving a container one kilometer for Port Cluster 1 (in the PRD region), denoted as g_1; distance d_i from the production base to Port i; and a parameter λ which captures the effect of the interdependence among the two ports' hinterland access costs. Overall, there may be two types of countervailing factors. On the one hand, if the hinterland access network had spare capacity, sharing a common transportation corridor would lead to greater utilization of related facilities such as inland terminals/dry ports, warehouses, IT systems, and general administration functions. This would reduce the inland logistics costs of both ports, in which case $\lambda < 0$. On the other hand, if the hinterland access network is short of capacity, then sharing a common transportation corridor is likely to lead to higher logistics costs due to congestion, in which case $\lambda > 0$. If there is no externality at all, then $\lambda = 0$. Suppose congestion costs are not usually as high as transportation costs themselves and so $\lambda \in (-1,1)$. The assumption that $d_1 > d_2$ indicates that for a shipper in mainland China, Hong Kong is more distant than Shenzhen, which simply reflects the geographic locations of the two ports.

Because only one port (Shanghai) is considered in the Port Cluster 2 and thus has no externality effect, hinterland logistics costs for Port 3 are defined as in the following equation:

$$h_3 = g_3 d_3 . \tag{6.4}$$

Taking into account the generalized costs of using each port as defined in (6.2), the demand system (6.1) can be specified as functions of p_i as:

$$\begin{cases} q_1 = \dfrac{(\beta_2\beta_3 - \gamma_1^2)\left(\mathrm{P}_1 - g_1 d_1 \lambda\right) - (\beta_3\gamma_2 - \gamma_1\gamma_3)\left(\mathrm{P}_2 - g_1 d_2 \lambda\right) - (\beta_2\gamma_3 - \gamma_1\gamma_2)\mathrm{P}_3}{2\gamma_1\gamma_2\gamma_3 + \beta_1\beta_2\beta_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)} \\ q_2 = \dfrac{-(\beta_3\gamma_2 - \gamma_1\gamma_3)\left(\mathrm{P}_1 - g_1 d_1 \lambda\right) + (\beta_1\beta_3 - \gamma_3^2)\left(\mathrm{P}_2 - g_1 d_2 \lambda\right) - (\beta_1\gamma_1 - \gamma_2\gamma_3)\mathrm{P}_3}{2\gamma_1\gamma_2\gamma_3 + \beta_1\beta_2\beta_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)} \\ q_3 = \dfrac{-(\beta_2\gamma_3 - \gamma_1\gamma_2)\left(\mathrm{P}_1 - g_1 d_1 \lambda\right) - (\beta_1\gamma_1 - \gamma_2\gamma_3)\left(\mathrm{P}_2 - g_1 d_2 \lambda\right) + (\beta_1\beta_2 - \gamma_2^2)\mathrm{P}_3}{2\gamma_1\gamma_2\gamma_3 + \beta_1\beta_2\beta_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)} \end{cases}, \quad (6.5)$$

where $\mathrm{P}_1 = (\alpha_1 - p_1 - g_1 d_1)$; $\mathrm{P}_2 = (\alpha_2 - p_2 - g_1 d_2)$; and $\mathrm{P}_3 = (\alpha_3 - p_3 - g_3 d_3)$.

Assume the three ports have constant marginal operating costs c_i and follow a pattern of Cournot competition. The profit maximization problem of each port can be specified as:

$$Max_{q_i} \pi_i = (p_i - c_i) q_i, \quad (6.6)$$

where port charges $p_i = \rho_i - h_i$. The Cournot-Nash equilibrium is characterized by the first-order condition $\left(\partial \pi_i / \partial q_i\right) = 0$. Solving the system of equations yields the following equilibrium output for each port:

$$\begin{cases} q_1^* = \dfrac{(4\beta_2\beta_3 - \gamma_1^2)(\mathrm{M}_1 - g_1 d_1 \lambda) - (2\beta_3\gamma_2 - \gamma_1\gamma_3)(\mathrm{M}_2 - g_1 d_2 \lambda) - (2\beta_2\gamma_3 - \gamma_1\gamma_2)\mathrm{M}_3}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} \\ q_2^* = \dfrac{-(2\beta_3\gamma_2 - \gamma_1\gamma_3)(\mathrm{M}_1 - g_1 d_1 \lambda) + (4\beta_1\beta_3 - \gamma_3^2)(\mathrm{M}_2 - g_1 d_2 \lambda) - (2\beta_1\gamma_1 - \gamma_2\gamma_3)\mathrm{M}_3}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} \\ q_3^* = \dfrac{-(2\beta_2\gamma_3 - \gamma_1\gamma_2)(\mathrm{M}_1 - g_1 d_1 \lambda) - (2\beta_1\gamma_1 - \gamma_2\gamma_3)(\mathrm{M}_2 - g_1 d_2 \lambda) + (4\beta_1\beta_2 - \gamma_2^2)\mathrm{M}_3}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} \end{cases}, \quad (6.7)$$

where $\mathrm{M}_1 = (\alpha_1 - c_1 - g_1 d_1)$; $\mathrm{M}_2 = (\alpha_2 - c_2 - g_1 d_2)$; and $\mathrm{M}_3 = (\alpha_3 - c_3 - g_3 d_3)$. Note that the condition for positive output equilibriums requires that:

$$\tilde{\lambda}_3 < \lambda < \min\left\{\tilde{\lambda}_1, \tilde{\lambda}_2\right\}, \quad (6.8)$$

where $\tilde{\lambda}_1 = \dfrac{(4\beta_2\beta_3 - \gamma_1^2)\mathrm{M}_1 - (2\beta_3\gamma_2 - \gamma_1\gamma_3)\mathrm{M}_2 - (2\beta_2\gamma_3 - \gamma_1\gamma_2)\mathrm{M}_3}{g_1\left[d_1(4\beta_2\beta_3 - \gamma_1^2) - d_2(2\beta_3\gamma_2 - \gamma_1\gamma_3)\right]}$;

$\tilde{\lambda}_2 = \dfrac{-(2\beta_3\gamma_2 - \gamma_1\gamma_3)\mathrm{M}_1 + (4\beta_1\beta_3 - \gamma_3^2)\mathrm{M}_2 - (2\beta_1\gamma_1 - \gamma_2\gamma_3)\mathrm{M}_3}{g_1\left[-d_1(2\beta_3\gamma_2 - \gamma_1\gamma_3) + d_2(4\beta_1\beta_3 - \gamma_3^2)\right]}$; and

$\tilde{\lambda}_3 = -\dfrac{-(2\beta_2\gamma_3 - \gamma_1\gamma_2)\mathrm{M}_1 - (2\beta_1\gamma_1 - \gamma_2\gamma_3)\mathrm{M}_2 + (4\beta_1\beta_2 - \gamma_2^2)\mathrm{M}_3}{g_1\left[d_1(2\beta_2\gamma_3 - \gamma_1\gamma_2) + d_2(2\beta_1\gamma_1 - \gamma_2\gamma_3)\right]}$.

The output equilibriums in (6.7) lead to the following port charges:

$$\begin{cases} p_1^* = c_1 + \dfrac{\beta_1\left[(4\beta_2\beta_3 - \gamma_1^2)(\mathrm{M}_1 - g_1 d_1 \lambda) - (2\beta_3\gamma_2 - \gamma_1\gamma_3)(\mathrm{M}_2 - g_1 d_2 \lambda) - (2\beta_2\gamma_3 - \gamma_1\gamma_2)\mathrm{M}_3\right]}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} \\ p_2^* = c_2 + \dfrac{\beta_2\left[-(2\beta_3\gamma_2 - \gamma_1\gamma_3)(\mathrm{M}_1 - g_1 d_1 \lambda) + (4\beta_1\beta_3 - \gamma_3^2)(\mathrm{M}_2 - g_1 d_2 \lambda) - (2\beta_1\gamma_1 - \gamma_2\gamma_3)\mathrm{M}_3\right]}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} \\ p_3^* = c_3 + \dfrac{\beta_3\left[-(2\beta_2\gamma_3 - \gamma_1\gamma_2)(\mathrm{M}_1 - g_1 d_1 \lambda) - (2\beta_1\gamma_1 - \gamma_2\gamma_3)(\mathrm{M}_2 - g_1 d_2 \lambda) + (4\beta_1\beta_2 - \gamma_2^2)\mathrm{M}_3\right]}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} \end{cases}. \qquad (6.9)$$

The corresponding profits can be then calculated as:

$$\begin{cases} \pi_1^* = \beta_1\left(\dfrac{(4\beta_2\beta_3 - \gamma_1^2)(\mathrm{M}_1 - g_1 d_1 \lambda) - (2\beta_3\gamma_2 - \gamma_1\gamma_3)(\mathrm{M}_2 - g_1 d_2 \lambda) - (2\beta_2\gamma_3 - \gamma_1\gamma_2)\mathrm{M}_3}{2\left(4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right)}\right)^2 \\ \pi_2^* = \beta_2\left(\dfrac{-(2\beta_3\gamma_2 - \gamma_1\gamma_3)(\mathrm{M}_1 - g_1 d_1 \lambda) + (4\beta_1\beta_3 - \gamma_3^2)(\mathrm{M}_2 - g_1 d_2 \lambda) - (2\beta_1\gamma_1 - \gamma_2\gamma_3)\mathrm{M}_3}{2\left(4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right)}\right)^2 \\ \pi_3^* = \beta_3\left(\dfrac{-(2\beta_2\gamma_3 - \gamma_1\gamma_2)(\mathrm{M}_1 - g_1 d_1 \lambda) - (2\beta_1\gamma_1 - \gamma_2\gamma_3)(\mathrm{M}_2 - g_1 d_2 \lambda) + (4\beta_1\beta_2 - \gamma_2^2)\mathrm{M}_3}{2\left(4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right)}\right)^2 \end{cases}. \qquad (6.10)$$

The above equilibrium results enable the study to analyze the overall effects of production base relocation, possible externalities affecting hinterland access costs, and unit transportation costs by investigating comparative statics. The detailed derivations are summarized below.

6.3.1 The Effect of Industrial Relocation (d_i)

If many manufacturing firms relocate their production bases away from the PRD region, the distances to all ports will change. As shown in Appendix C, the following analytical results can be obtained with respect to the distance changes:

The effects of a change in distance on the port's own performance:

$$\frac{\partial q_i^*}{\partial d_i} < 0, \ \frac{\partial p_i^*}{\partial d_i} < 0, \text{ and } \frac{\partial \pi_i^*}{\partial d_i} < 0, \qquad \text{where } i = 1,..,3 \qquad (6.11)$$

The effects of a change in distance on rival ports' performance:

$$\frac{\partial q_i^*}{\partial d_j} > 0, \ \frac{\partial p_i^*}{\partial d_j} > 0, \text{ and } \frac{\partial \pi_i^*}{\partial d_j} > 0, \qquad \text{where } i, j = 1,..,3, \ i \neq j \qquad (6.12)$$

The interpretation of these results is straightforward. As shippers (i.e. users of port services) move away from a port, the port's performance will suffer in terms of lower port throughput, reduced port service charge, and declining profitability. This will benefit its rival ports, which experience increasing outputs, a lift in revenue from port service charges, and higher profits. That is, both Shenzhen and Hong Kong will suffer when manufacturing firms relocate away from the PRD region. However, Shanghai may benefit from such pattern as some relocated shippers could use Shanghai as a substitute gateway.

6.3.2 The Effect of Externalities on Hinterland Access Costs (λ)

As explained above, there may be either positive and negative externality effects in hinterland access, as measured by the parameter λ. With the equilibrium outcomes characterized by equations (6.7), (6.9), and (6.10), it can be derived that:

For Hong Kong:

$$\frac{\partial q_1^*}{\partial \lambda} < 0, \ \frac{\partial p_1^*}{\partial \lambda} < 0, \text{ and } \frac{\partial \pi_1^*}{\partial \lambda} < 0 \tag{6.13}$$

For Shenzhen:

$$\frac{\partial q_2^*}{\partial \lambda} \geq 0, \ \frac{\partial p_2^*}{\partial \lambda} \geq 0, \text{ and } \frac{\partial \pi_2^*}{\partial \lambda} \geq 0 \ \text{ when } d_1 - d_2 \geq \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right) d_1; \tag{6.14.1}$$

$$\frac{\partial q_2^*}{\partial \lambda} < 0, \ \frac{\partial p_2^*}{\partial \lambda} < 0, \text{ and } \frac{\partial \pi_2^*}{\partial \lambda} < 0 \ \text{ when } d_1 - d_2 < \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right) d_1 \tag{6.14.2}$$

For Shanghai:

$$\frac{\partial q_3^*}{\partial \lambda} > 0, \ \frac{\partial p_3^*}{\partial \lambda} > 0, \text{ and } \frac{\partial \pi_3^*}{\partial \lambda} > 0 \tag{6.15}$$

The implications for the ports of Hong Kong and Shanghai are clear. For Hong Kong, when there are increasing positive externalities (or decreasing negative externalities when λ is falling), such as stronger economies of density resulting in lowered hinterland access costs or reduced congestion in the shared hinterland transportation corridor, traffic volume and port service charges at Hong Kong will increase, leading to higher profit. This will be bad news for the competing port of

Shanghai, where performance will decrease as it now faces a more competitive rival port.

The implications for Shenzhen (Port 2) are more complex. When hinterland access is improved, two countervailing factors will influence the performance of Shenzhen. On the one hand, improved hinterland access will benefit Shenzhen by reducing hinterland logistics costs and thus the generalized costs of using Shenzhen. On the other hand, because Hong Kong and Shenzhen share common infrastructure, improved hinterland access also implies that Hong Kong will be more competitive. Therefore, the net effect on Shenzhen will depend on the relative size of these two effects. When hinterland access costs for Hong Kong are much larger than those for Shenzhen (in the sense that $d_1 - d_2 \geq \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1$), improved hinterland access will benefit Hong Kong much more than Shenzhen. In such a case, the negative competitive effect on Shenzhen will outweigh the positive effect of cost savings. As a result, Shenzhen will suffer overall from an improvement in hinterland access. Otherwise, if there is not much difference in the costs of hinterland access between Hong Kong and Shenzhen, then both ports will benefit from improved hinterland transport.

The ports of Shenzhen and Hong Kong are very close to each other geographically. This appears to suggest that $d_1 - d_2$ is small, and thus $(\partial q_2^* / \partial \lambda) < 0$ is likely to hold. In reality, however, there may be significant costs associated with delivering goods from inland provinces to Hong Kong, which has separate customs and operating regulations. In addition to costs associated with security checks and customs clearance, mainland Chinese drivers are prohibited from driving container trucks directly to port terminals in Hong Kong. Hong Kong drivers who get paid much more than their mainland counterparts are required to take over driving such trucks at the border. These special arrangements could make the hinterland access costs of Hong Kong much higher than those of Shenzhen. This is not a new finding: a survey conducted by the Better Hong Kong Foundation (2004) showed that Hong Kong had lost competitiveness in comparison with Shenzhen due to higher transport costs for containers crossing the border. Trucking costs could increase substantially as a consequence of higher operating costs (parking, insurance, and maintenance costs), cross-boundary regulation (costs associated with cross-boundary licenses and switching of drivers), and the low frequency of trips (McKinnon, 2011). The new finding in this study is that the cost of crossing the border to Hong Kong will influence Shenzhen's attitude toward cooperation on hinterland access. If cross-border costs are so high that Hong Kong has much higher overall hinterland access costs than Shenzhen (in the sense that $d_1 - d_2 \geq \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1$), then Shenzhen will have no interest in working with Hong Kong to improve hinterland access. It will prefer to keep Hong Kong at a disadvantage due to its inconvenient hinterland access. However, if hinterland access costs to Hong Kong and Shenzhen are similar, then both ports will benefit from cooperating on such access. Therefore, they will have greater incentives to share their facilities and pool capacity (such as by sharing warehouses, dry port terminals, trucking services, and IT systems). Given the hard work carried out by the Hong Kong government and the port of Hong Kong to streamline cross-border cargo flow, it is likely that hinterland access costs for Shenzhen and Hong Kong are now close to each other. That is, the condition $d_1 - d_2 < \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1$ is in reality likely to hold in the current market. Of course, more detailed empirical analysis is needed to confirm this intuition.

6.3.3 The Effects of Ground Transportation Costs (g_i)

Hinterland access costs may change due to many factors such as the availability of new transport facilities (e.g. the availability of good rail transport services and the building of new highways), market structure changes in the logistics sector, or simply fluctuations in fuel prices. Some of these factors will lead to a general increase/decrease in the transportation costs associated with all three ports. In other cases, not all ports will be affected. The unit transportation cost change of Port Cluster 1 (i.e. changes in parameter g_1 for Hong Kong and Shenzhen) is then examined, as well as possible changes associated with transportation costs of the other cluster (i.e. transportation cost for Shanghai g_3). It can be shown that:

Effects on Hong Kong:

$$\frac{\partial q_1^*}{\partial g_1} < 0,\ \frac{\partial p_1^*}{\partial g_1} < 0,\text{ and } \frac{\partial \pi_1^*}{\partial g_1} < 0;\text{ and } \frac{\partial q_1^*}{\partial g_3} > 0,\ \frac{\partial p_1^*}{\partial g_3} > 0,\text{ and } \frac{\partial \pi_1^*}{\partial g_3} > 0 \qquad (6.16)$$

Effects on Shenzhen:

$$\frac{\partial q_2^*}{\partial g_1} \geq 0,\ \frac{\partial p_2^*}{\partial g_1} \geq 0,\text{ and } \frac{\partial \pi_2^*}{\partial g_1} \geq 0 \text{ when } d_1 - d_2 \geq \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1; \qquad (6.17.1)$$

$$\frac{\partial q_2^*}{\partial g_1} < 0,\ \frac{\partial p_2^*}{\partial g_1} < 0,\text{ and } \frac{\partial \pi_2^*}{\partial g_1} < 0 \text{ when } d_1 - d_2 < \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1; \qquad (6.17.2)$$

$$\frac{\partial q_2^*}{\partial g_3} > 0,\ \frac{\partial p_2^*}{\partial g_3} > 0,\text{ and } \frac{\partial \pi_2^*}{\partial g_3} > 0 \qquad (6.17.3)$$

Effects on Shanghai:

$$\frac{\partial q_3^*}{\partial g_1} > 0,\ \frac{\partial p_3^*}{\partial g_1} > 0,\text{ and } \frac{\partial \pi_3^*}{\partial g_1} > 0;\ \frac{\partial q_3^*}{\partial g_3} < 0,\ \frac{\partial p_3^*}{\partial g_3} < 0,\text{ and } \frac{\partial \pi_3^*}{\partial g_3} < 0 \qquad (6.18)$$

As evidenced by $\frac{\partial \pi_1^*}{\partial g_3} > 0$, $\frac{\partial \pi_2^*}{\partial g_3} > 0$, and $\frac{\partial \pi_3^*}{\partial g_1} > 0$, an increase in transportation costs at competing ports will always be good news. However, the effects of a rise in a port's own transportation costs may be complicated. For Hong Kong and Shanghai, rising transportation costs will always reduce their own performance in terms of traffic volumes, port service charges, and operating profits. Again, the situation may be more complicated in Shenzhen. This is due to the fact that because Shenzhen is close to Hong Kong and they share common transportation corridor, a rise in transportation costs will have two implications: on the one hand, it will increase the general costs of using Shenzhen; on the other hand, as suggested by Salop and Scheffman (1983), a firm may benefit from an increase in input prices if it harms its competitors more. Therefore, if transportation costs are significantly lower in Shenzhen than they are in Hong Kong, then a rise in transportation costs could benefit Shenzhen. Again, this shows the importance of cross-boundary costs for the port of Hong Kong. Given the hard work conducted by the Hong Kong government and the port of Hong Kong to streamline cross-border cargo flow referred to earlier, it is likely that Shenzhen and Hong Kong now have similar hinterland access costs. Thus, both Shenzhen and Hong Kong have an incentive to work together to reduce their hinterland access costs.

6.4 SUMMARY AND CONCLUSION

Southern Chinese ports, notably Hong Kong and Shenzhen, have benefited greatly from economic growth within the Pearl River Delta (PRD) region in the past three decades. However, in recent years, constant increases in labor and operational costs within the PRD region have forced many manufacturing firms to relocate further inland. At the same time, the Chinese government is implementing a strategic plan to promote an economic rebalancing among the provinces in the hope that they all can achieve sustainable growth in the long run. Many provinces in western and northern China are economically less developed, but have abundant labor and land resources. This has triggered an ongoing process of relocation for many firms in the PRD region. Given the presence of significant intra- and inter-port cluster competition in the Chinese port industry, this relocation process will not only affect the ports of Shenzhen and Hong Kong, but will also have an impact on ports in other clusters. Although previous studies have analyzed the implications of hinterland access, few have investigated the dynamic effects of production base relocation.

To fill this gap in the literature, this study developed an analytical framework to examine the effects of the ongoing trend of production base relocation. Among the novel features of this model are that it explicitly considers both intra- and inter-port cluster competition, and the possible (positive or negative) externality effects on port hinterland access. These features are important given that Hong Kong and Shenzhen share a transportation corridor to China's inland provinces. Hinterland access may be affected by economies of traffic density (i.e. a positive externality) or congestion effects (i.e. a negative externality). The analytical results suggest that when production bases in the PRD region are moved further inland, an increase in hinterland access costs will reduce the overall performance of Hong Kong in terms of lower throughput, reduced port charge, and a decrease in operating profit. In contrast, the port of Shanghai will benefit from such the relocation trend due to the increased incentives for some traffic to be shifted. In theory, the port of Shenzhen, which shares transportation corridor to inland provinces with Hong Kong, may either suffer or benefit from an increase in hinterland access costs. On the one hand, it will suffer from an increase in the total cost of using the port. On the other hand, an increase in transportation costs may do greater harm Hong Kong and thus help Shenzhen gain a competitive advantage over its neighbor – an intuition similar to the well-known strategy of “raising rivals’ costs”. Therefore, Shenzhen will have an incentive to work with Hong Kong to improve their hinterland access only if Hong Kong has a good network connecting it to mainland China. That is, good cross-border infrastructure will facilitate cooperation between Shenzhen and Hong Kong. Given that the Hong Kong government and the port of Hong Kong have worked hard to improve cross-border cargo flow in recent years, it is likely that in the current market, both Shenzhen and Hong Kong have incentives to work together to address the ongoing production base relocation problem. While a detailed empirical investigation should be carried out to verify this conclusion for the PRD region, the general theoretical implication is clear: a more competitive port is in a better position to cooperate with other stakeholders.

This study provides a number of valuable academic and practical insights. Southern China is a pioneering showpiece for the transformation of regional port governance within a rapidly developing economy where institutional frameworks are highly diversified. This study provides useful insights enabling decision makers to develop pragmatic and sustainable regional governance policies for the future well-being of the PRD region. Given the key role played by ports as the nodal points of supply chains where different stakeholders interact, this study contributes to the development of a fully-integrated regional port system within the PRD in particular and among gateway-hinterland regions in general. It is important to understand the dynamics between ports and regional development, and there is a need to formulate integrated and sustainable port and maritime logistical systems to improve the well-being and development of different geographical regions.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

7.1 CONCLUSIONS

This thesis examines two broad issues in the transport and logistics industry. The first issue is how to evaluate an industrial organization's performance, and how to identify the factors and market dynamics leading to a given performance. The second issue is how to design and evaluate alternative government policies for the transport and logistics industry. These two issues are analyzed for the aviation and maritime industries by using empirical and analytical models. Empirical studies of the aviation industry, presented in Chapters 2, 3, and 4, are used to address the first issue. In Chapters 5 and 6, analytical models are developed for policy analysis in the maritime sector. These two chapters investigate two major challenges of the industry, namely environmental protection management and the impacts of production base relocation.

The key conclusions of the empirical investigations on the aviation industry are as follows.

Chapter 2 measures and compares the productivity and cost competitiveness of nine major North American carriers during the 1990 to 2007 period. The key findings of this analysis are as follows. First, the airlines' productivity levels, measured either by total factor productivity (TFP) or residual total factor productivity (RTFP), significantly improved over the study period, especially after 2003. Second, the airlines' productivity levels were correlated with the overall economic cycle. The Gulf War and the September 11, 2001, terrorist attacks clearly affected airlines' productivity levels in the early 1990s, and in 2001 and 2002, respectively. However, neither level made a significant impact on the overall trend of productivity change. Third, there is no evidence of converging productivity levels among the airlines although they served significantly overlapping markets. Fourth, throughout the study period, labor costs were the most important determinant of airlines' cost competitiveness. This suggests that although restructuring efforts by airlines are necessary and helpful, good control of labor costs is still important. Fifth, airlines with more aggressive fleet expansion levels than the industry average suffered a decrease in productivity, implying that airlines should consider growth strategies more carefully. Sixth, significant efficiency gains in recent years have largely been offset by the sharp increase in fuel prices. This limits the airlines' ability to stimulate traffic growth via substantial price reductions. Finally, preliminary evidence shows that bankruptcy protection during the sample period allowed the filing airlines to improve their RTFPs more than the industry average.

Chapter 3 examines the strategic response of full-service airlines (FSAs) to low-cost carrier (LCC) competition, specifically an airlines-in-airlines strategy in which FSAs established their own low-cost subsidiary (LCS). The study used the operating data of Qantas Group, one of the most successful cases in running this strategy, to empirically investigate the effect such a strategy on airfare and network configuration pattern of the LCS. Using monthly data from January 2009 to November 2011 in the Australian domestic market, the fare regression results reveal that when Qantas and Jetstar operate simultaneously in a route, these two airlines are able to charge higher prices, whereas the rival LCC's price will be reduced. Overall, the average price in the market is increased. The investigation of Jetstar's network configuration shows that there is no significant correlation between an established Qantas route and a new Jetstar's network configuration. However, in a market where Qantas faces competition from other LCCs, there is a significantly higher chance that Jetstar will also serve this route. These results suggest that Jetstar is designed as a fighting brand in response to LCC competition. There is also preliminary evidence that Qantas Group derives some quality benefits from this dual-brand strategy. These results provide fresh insights into the competition effects of the airlines-in-airlines strategy and explain why this strategy is being used by an increasing number of Asian airlines.

Chapter 4 investigates the performances of the major hub airports in Southeast Asia so as to identify key determinants of their competitiveness. The studied airports include Singapore Changi International Airport, Kuala Lumpur International Airport, Bangkok-Suvarnabhumi International Airport, and Hong Kong Chek Lap Kok International Airport. The results suggest the following. First, Hong Kong airport is a leader in terms of network connectivity, traffic growth, hub airline developments, and cargo logistics. Second, Bangkok airport's growth has been constrained by political instability and weak hub airline development; however, the airport has great long-term potential. Third, the development of LCCs is a major driver for traffic growth, but the implications for airport connectivity are unclear. Fourth, despite limited progress on regional liberalization, intra-Asia routes clearly contribute to traffic growth and hub airport connectivity. Finally, governments should safeguard airline competition by promoting market liberalization and airport capacity investments.

The key insights obtained from the analytical models for the maritime sector are as follows.

Chapter 5 analyzes a market-based policy, namely environmental taxation, for pollution control in a region with multiple ports. The investigation reveals that in the absence of inter-port coordination, pollution spill-over and inter-port competition can lead to distorted pollution taxation and emission constraints. As a result, there will be excessive pollution and sub-optimal social welfare. Therefore, despite the potential competition among the ports in a region, it is important for them to coordinate their pollution control efforts. This chapter emphasizes the importance of a regional approach for pollution control and offers key recommendations.

Chapter 6 develops an economic model to assess the impacts of production base relocation on intra- and inter-port cluster competition. The analysis focuses on the major ports in the Pearl River Delta (PRD) region, namely the ports of Hong Kong and Shenzhen, and their competitors such as Shanghai in the Yangtze River Delta (YRD). The findings indicate that the relocation process harms the port of Hong Kong, but benefits the port of Shanghai in terms of higher outputs, service charges, and profits. The implication for Shenzhen is more complex as it shares the same transportation corridor to inland China as Hong Kong, but it also competes with Hong Kong at the same time. Even if Shenzhen benefits from reduced hinterland access costs, it also needs to consider the increased competition from Hong Kong. Such competition is strong as the cross-border cost from Hong Kong to China is higher. The analytical results further suggest that it would be the interests of the PRD ports to work together to reduce hinterland access costs, so that the negative effects of production base relocation would be alleviated. A more competitive port of Hong Kong is in a better position to cooperate with the neighboring port of Shenzhen, and it is important for Hong Kong to improve its cross-border cargo flow.

The findings from Chapter 5 and 6 provide many useful recommendations for policy makers in the maritime sector. The most important point worth mentioning is the cooperation among the adjacent ports in certain areas, even though they are competitors. The analytical results in Chapters 5 and 6 have clearly illustrated the potential benefits of some forms of cooperation.

7.2 RECOMMENDATIONS FOR FUTURE RESEARCH

With regard to the investigations on the aviation industry, the conclusions from Chapter 2 to 4 provide some fresh insights to academia, practitioners, and policy makers in the industry. Still, further research is necessary in some areas. Some directions have already been suggested in each chapter. Perhaps the most important area for future study is related to efficiency and cost competitiveness measurement. The method employed in this thesis does not capture potential quality differentials among airlines. Future studies focusing on efficiency comparison for firms providing quality-differentiated services will be of great value. It is also important to analyze the implications of service differentiation on airline competition and airport performance. In addition, although many researchers believe that running two distinct business models is likely to result in significant efficiency loss, this thesis did not investigate whether there is indeed any efficiency loss, and whether any measure has been taken by an airline group to control such inefficiency. Future studies on these aspects are very valuable to a comprehensive understanding and evaluation of the airlines-in-airlines strategy.

Based on the key findings in Chapter 5 and 6 related to the maritime industry, other possibilities could be considered for future extensions. First, further studies on regional pollution management may need to consider the operational issues of shipping services such as the scheduling of ship movements, the air emission-speed relationship, the mix of feeder, and the deep-sea services. Second, although the analyses in this thesis demonstrate the benefits of cooperation between adjacent ports, it does not suggest how such cooperation can be achieved. There is a need to investigate the institutional factors that affect the feasibility of port cooperation. Finally, additional empirical research is recommended to confirm the findings of the analytical models, and thus achieve a better understanding of the real industry outcomes. These are studies that I intend to pursue following my thesis work.

APPENDIX A: LIST OF NEWLY FORMED LOW-COST CARRIERS IN ASIA

Table A-1 Major low-cost carriers in Asia

Airlines	Country	Associated Carriers	Start of Operations	Aircraft Type	Base Airport
Air Asia	Malaysia	Partnership with Malaysian Airlines	2001 (as LCC)	A320, B737 and B747	KLIA (LCCT)
Thai AirAsia	Thailand	Air Asia	2004	A320 and B737	Bangkok (Suvarnabhumi)
Indonesia AirAsia	Indonesia	Air Asia	2004	A320 and B737	Soekarno-Hatta International
AirAsia X	Malaysia	Air Asia	2007	A330 and A340	Kuala Lumpur International
Jetstar Airways	Australia	Qantas	2003	A320, A321, A330 and B717	Melbourne Airport
Jetstar Asia	Singapore	Qantas	2004	A320	Singapore – Changi
Jetstar Pacific	Vietnam	Qantas	2008	A320, B737	Tan Son Nhat International Airport
Tiger Airways	Singapore	Singapore Airlines	2004	A319 and A320	Singapore – Changi
Tiger Airways Australia	Australia	Tiger Airways	2007	A320	Melbourne Airport
Nok Air	Thailand	Thai Air	2004	ATR42/72 and B737	Bangkok (Don Muaeng)
Jin Air	South Korea	Korean Air	2008	B737	Gimpo International
Air Busan	South Korea	Asiana	2008	A321 and B737	Kimhae International
T'Way Airlines1/	South Korea	None	2005	B737	Cheongju
Eastar Jet	South Korea	None	2009	B737	Gimpo International
Jeju Air	South Korea	None	2006	B737	Jeju International
Air Do	Japan	Code-share /partnership with ANA and Skynet Asia	1998	B737 and B767	Sapporo
Skymark	Japan	None	1998	B737 and B767	Tokyo – Haneda
StarFlyer	Japan	Code-share /partnership with ANA	2006	A320	Kita – Kyushu
Spring Airlines	China	None	2005	A320	Hongqiao, Xinzheng, Meilan
Cebu Pacific	Philippines	None	1996	A320, A319, ATR72	Manila, Cebu, KLIA (LCCT), Singapore (BT)
Lion Air	Indonesia	None	1999	B737, B747, MD80 and MD90	Soekarno Hatta International

Note: 1/ T'Way Airlines was formerly established in 2005 as Hansung Airlines. Due to internal administrative conflicts, it suspended operations in October 2008 and later resumed its flight operations in September 2010 (Morrell, 2010).

APPENDIX B: SOCIAL WELFARE DERIVATION

Social welfare at each port is defined as a summation of net consumer surplus, producer surplus (or shipping lines' profits), port profit, and tax revenue of the local government. Then, the pollution cost will be subtracted from the total value of social welfare so as to represent the environmental concern. From Figure 5-1, specify the consumer surplus as:

$$cs_1 = \int_0^{|z^l|} \left[V - P_1(Q_1,Q_2) - 4tz\right]dz + \int_0^{\tilde{z}} \left[V - P_1(Q_1,Q_2) - 4tz\right]dz \text{, and}$$

$$cs_2 = \int_0^{(1-\tilde{z})} \left[V - P_2(Q_1,Q_2) - 4tz\right]dz + \int_0^{(z^r-1)} \left[V - P_2(Q_1,Q_2) - 4tz\right]dz, \qquad \text{(B.1)}$$

where $\tilde{z} = \frac{1}{2} + \frac{P_2 - P_1}{8t}$, $z^l = -\frac{V - P_1}{4t}$, and $z^r = 1 + \frac{V - P_2}{4t}$. Note that Q_1 and Q_2 do not depend on z , whereas $\tilde{z}$, z^l , and z^r depend on Q_1 and Q_2 . Substitute $P_i(Q_1,Q_2)$ from (5.6) into (B.1), then consumer surplus for each port can be written as:

$$cs_i = \frac{t}{4}\left(7Q_i^2 - Q_j^2 + 2Q_iQ_j\right) + t\left(Q_j - Q_i - 1\right). \qquad \text{(B.2)}$$

Note that total net consumer surplus for these two local cities is:

$$CS = cs_1 + cs_2 = \frac{3t}{2}\left(Q_1^2 + Q_2^2\right) + t\left(Q_1Q_2 - 2\right). \qquad \text{(B.3)}$$

Then, the respective total shipping line profits, port profits, tax revenues, and total pollution costs can be expressed as:

$$\sum\nolimits_{k=1}^{n_i} \pi_{ik} = \sum\nolimits_{k=1}^{n_i} \left(P_i - c - w_i - s_i\right)q_{ik}, \qquad \Pi_i = w_iQ_i,$$

$$\text{GovRev}_i = s_iQ_i, \qquad PC_i = \alpha Q_i + \beta Q_j. \qquad \text{(B.4)}$$

Therefore, the local social welfare and regional welfare are expressed respectively as follows:

$$SW_i \equiv \varphi_i = \frac{t}{4}\left(7Q_i^2 - Q_j^2 + 2Q_iQ_j\right) + t\left(Q_j - Q_i - 1\right) + \left(P_i - c\right)Q_i - PC_i, \qquad \text{(B.5)}$$

$$\Phi = \varphi_1 + \varphi_2 = \frac{3t}{2}\left(Q_1^2 + Q_2^2\right) + t\left(Q_1Q_2 - 2\right) + \sum\nolimits_i \left[\left(P_i - c\right)Q_i - PC_i\right]. \qquad \text{(B.6)}$$

APPENDIX C: ANALYTICAL RESULTS ON MARKET EQUILIBRIUMS

C1. With respect to λ:

For Hong Kong (or Port 1)

$$\frac{\partial q_1^*}{\partial \lambda} = -g_1\Sigma_1 < 0, \ \frac{\partial p_1^*}{\partial \lambda} = -\beta_1 g_1 \Sigma_1 < 0, \text{ and } \frac{\partial \pi_1^*}{\partial \lambda} = -2\beta_1 g_1 q_1^* \Sigma_1 < 0,$$

where $\Sigma_1 = \dfrac{d_1(4\beta_2\beta_3 - \gamma_1^2) - d_2(2\beta_3\gamma_2 - \gamma_1\gamma_3)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$

For Shenzhen (or Port 2)

$$\frac{\partial q_2^*}{\partial \lambda} = -g_1\Sigma_2, \ \frac{\partial p_2^*}{\partial \lambda} = -\beta_2 g_1 \Sigma_2, \text{ and } \frac{\partial \pi_2^*}{\partial \lambda} = -2\beta_2 g_1 q_2^* \Sigma_2,$$

where $\Sigma_2 = \dfrac{-d_1(2\beta_3\gamma_2 - \gamma_1\gamma_3) + d_2(4\beta_1\beta_3 - \gamma_3^2)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]}$, and the above expressions will be:

(1) positive when $d_1 - d_2 \geq \left(1 - \dfrac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1$; and

(2) negative when $d_1 - d_2 < \left(1 - \dfrac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1$

For Shanghai (or Port 3)

$$\frac{\partial q_3^*}{\partial \lambda} = g_1\Sigma_3 > 0, \ \frac{\partial p_3^*}{\partial \lambda} = \beta_3 g_1 \Sigma_3 > 0, \text{ and } \frac{\partial \pi_3^*}{\partial \lambda} = \beta_3 g_1 q_3^* \Sigma_3 > 0,$$

where $\Sigma_3 = \dfrac{d_1(2\beta_2\gamma_3 - \gamma_1\gamma_2) + d_2(2\beta_1\gamma_1 - \gamma_2\gamma_3)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$

C2. With respect to d_i:

For Hong Kong (or Port 1)

$\dfrac{\partial q_1^*}{\partial d_1} = -g_1(1+\lambda)\mathrm{E}_{11} < 0$, $\dfrac{\partial p_1^*}{\partial d_1} = -\beta_1 g_1(1+\lambda)\mathrm{E}_{11} < 0$, and

$\dfrac{\partial \pi_1^*}{\partial d_1} = -2\beta_1 g_1 q_1^*(1+\lambda)\mathrm{E}_{11} < 0$;

$\frac{\partial q_1^*}{\partial d_2} = g_1(1+\lambda)\mathrm{E}_{12} > 0$, $\frac{\partial p_1^*}{\partial d_2} = \beta_1 g_1(1+\lambda)\mathrm{E}_{12} > 0$, and $\frac{\partial \pi_1^*}{\partial d_2} = 2\beta_1 g_1 q_1^*(1+\lambda)\mathrm{E}_{12} > 0$;

$\frac{\partial q_1^*}{\partial d_3} = g_3\mathrm{E}_{13} > 0$, $\frac{\partial p_1^*}{\partial d_3} = \beta_1 g_3\mathrm{E}_{13} > 0$, and $\frac{\partial \pi_1^*}{\partial d_3} = 2\beta_1 g_3 q_1^*\mathrm{E}_{13} > 0$;

where $\mathrm{E}_{11} = \frac{(4\beta_2\beta_3 - \gamma_1^2)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$,

$\mathrm{E}_{12} = \frac{(2\beta_3\gamma_2 - \gamma_1\gamma_3)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$, and

$\mathrm{E}_{13} = \frac{(2\beta_2\gamma_3 - \gamma_1\gamma_2)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$

For Shenzhen (or Port 2)

$\frac{\partial q_2^*}{\partial d_1} = g_1(1+\lambda)\mathrm{E}_{12} > 0$, $\frac{\partial p_2^*}{\partial d_1} = \beta_2 g_1(1+\lambda)\mathrm{E}_{12} > 0$, and $\frac{\partial \pi_2^*}{\partial d_1} = 2\beta_2 g_1 q_2^*(1+\lambda)\mathrm{E}_{12} > 0$;

$\frac{\partial q_2^*}{\partial d_2} = -g_1(1+\lambda)\mathrm{E}_{22} < 0$, $\frac{\partial p_2^*}{\partial d_2} = -\beta_2 g_1(1+\lambda)\mathrm{E}_{22} < 0$, and

$\frac{\partial \pi_2^*}{\partial d_2} = -2\beta_2 g_1 q_2^*(1+\lambda)\mathrm{E}_{22} < 0$;

$\frac{\partial q_2^*}{\partial d_3} = g_3\mathrm{E}_{23} > 0$, $\frac{\partial p_2^*}{\partial d_3} = \beta_2 g_3\mathrm{E}_{23} > 0$, and $\frac{\partial \pi_2^*}{\partial d_3} = 2\beta_2 g_3 q_2^*\mathrm{E}_{23} > 0$;

where $\mathrm{E}_{22} = \frac{(4\beta_1\beta_3 - \gamma_3^2)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$, and

$\mathrm{E}_{23} = \frac{(2\beta_1\gamma_1 - \gamma_2\gamma_3)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$

For Shanghai (or Port 3)

$\frac{\partial q_3^*}{\partial d_1} = g_1(1+\lambda)\mathrm{E}_{13} > 0$, $\frac{\partial p_3^*}{\partial d_1} = \beta_3 g_1(1+\lambda)\mathrm{E}_{13} > 0$, and $\frac{\partial \pi_3^*}{\partial d_1} = 2\beta_3 g_1 q_3^*(1+\lambda)\mathrm{E}_{13} > 0$;

$\frac{\partial q_3^*}{\partial d_2} = g_1(1+\lambda)\mathrm{E}_{23} > 0$, $\frac{\partial p_3^*}{\partial d_2} = \beta_3 g_1(1+\lambda)\mathrm{E}_{23} > 0$, and $\frac{\partial \pi_3^*}{\partial d_2} = 2\beta_3 g_1 q_3^*(1+\lambda)\mathrm{E}_{23} > 0$;

$\frac{\partial q_3^*}{\partial d_3} = -g_3\mathrm{E}_{33} < 0$, $\frac{\partial p_3^*}{\partial d_3} = -\beta_3 g_3\mathrm{E}_{33} < 0$, and $\frac{\partial \pi_3^*}{\partial d_3} = -2\beta_3 g_3 q_3^*\mathrm{E}_{33} < 0$;

where $\mathrm{E}_{33} = \frac{(4\beta_1\beta_2 - \gamma_2^2)}{2\left[4\beta_1\beta_2\beta_3 + \gamma_1\gamma_2\gamma_3 - (\beta_1\gamma_1^2 + \beta_3\gamma_2^2 + \beta_2\gamma_3^2)\right]} > 0$

C3. With respect to g_i:

For Hong Kong (or Port 1)

$$\frac{\partial q_1^*}{\partial g_1} = -(1+\lambda)\Sigma_1 < 0\,,\ \frac{\partial p_1^*}{\partial g_1} = -\beta_1(1+\lambda)\Sigma_1 < 0\,,\text{ and}$$

$$\frac{\partial \pi_1^*}{\partial g_1} = -2\beta_1 q_1^*(1+\lambda)\Sigma_1 < 0\,;$$

$$\frac{\partial q_1^*}{\partial g_3} = d_3\mathrm{E}_{13} > 0\,,\ \frac{\partial p_1^*}{\partial g_3} = \beta_1 d_3\mathrm{E}_{13} > 0\,,\text{ and }\frac{\partial \pi_1^*}{\partial g_3} = 2\beta_1 d_3 q_1^*\mathrm{E}_{13} > 0$$

For Shenzhen (or Port 2)

$$\frac{\partial q_2^*}{\partial g_1} = -(1+\lambda)\Sigma_2\,,\ \frac{\partial p_2^*}{\partial g_1} = -\beta_2(1+\lambda)\Sigma_2\,,\text{ and }\frac{\partial \pi_2^*}{\partial g_1} = -2\beta_2 q_2^*(1+\lambda)\Sigma_2\,,$$

which will be (1) positive when $d_1 - d_2 \geq \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1$; and

(2) negative when $d_1 - d_2 < \left(1 - \frac{2\beta_3\gamma_2 - \gamma_1\gamma_3}{4\beta_1\beta_3 - \gamma_3^2}\right)d_1$

$$\frac{\partial q_2^*}{\partial g_3} = d_3\mathrm{E}_{23} > 0\,;\ \frac{\partial p_2^*}{\partial g_3} = \beta_2 d_3\mathrm{E}_{23} > 0\,;\text{ and }\frac{\partial \pi_2^*}{\partial g_3} = 2\beta_2 d_3 q_2^*\mathrm{E}_{23} > 0$$

For Shanghai (or Port 3)

$$\frac{\partial q_3^*}{\partial g_1} = (1+\lambda)\Sigma_3 > 0\,,\ \frac{\partial p_3^*}{\partial g_1} = \beta_3(1+\lambda)\Sigma_3 > 0\,,\text{ and }\frac{\partial \pi_3^*}{\partial g_1} = 2\beta_3 q_3^*(1+\lambda)\Sigma_3 > 0\,;$$

$$\frac{\partial q_3^*}{\partial g_3} = -d_3\mathrm{E}_{33} < 0,\ \frac{\partial p_3^*}{\partial g_3} = -\beta_3 d_3\mathrm{E}_{33} < 0,\text{ and }\frac{\partial \pi_3^*}{\partial g_3} = -2\beta_3 d_3 q_3^*\mathrm{E}_{33} < 0$$

REFERENCES

Air Transport Research Society (ATRS), 2010. *Airport Benchmarking Report 2010*, ATRS, Vancouver.

Airports Council International (ACI), 2011. Year to Date Passenger Traffic. May 13, 2011.

Atkinson, S.E., Halvorsen, R., 1984. Parametric efficiency tests, economies of scale, and input demand in U.S. electric power. *International Economic Review*, 25 (3), 662-647.

Bailey, E.E., Carnegie-Mellon, U., 1987. *Public Regulation: New Perspectives on Institutions and Policies.* MIT Press series on the regulation of economic activity, MIT Press, Cambridge, Massachusetts.

Bailey, E.E., Graham, D.R., Kaplan, D.P., 1985. *Deregulating the Airlines*. The MIT Press, Cambridge, Massachusetts.

Baltagi, B.H., Griffin, J.M., 1995. Airline deregulation: the cost pieces of the puzzle. *International Economic Review*, 36 (1), 245-258.

Barbot, C., 2009. Airport and airline competition: incentives for vertical collusion. *Transportation Research Part B*, 43 (10), 952-965.

Barnett, A.H., 1980. The Pigouvian tax rule under monopoly. *American Economic Review*, 70 (5), 1037-1041.

Barrett, S., 2004. How do the demands for airport services differ between full-service carriers and low-cost carriers? *Journal of Air Transport Management*, 10 (1), 33-39.

Basso, L.J., Zhang, A., 2007. Congestible facility rivalry in vertical structures. *Journal of Urban Economics*, 61 (2), 218-237.

Baumol, W.J., Oates, W.E., 1988. *The Theory of Environment Policy*. 2nd Eds. Cambridge University Press, Cambridge.

Bean, C.R., 1990. Endogenous growth and the procyclical behaviour of productivity. *European Economic Review*, 34 (2-3), 355-363.

Bellido-Arregui, M., 2003. *Environmental Taxes and Global Warming*. Master Thesis, Graduate Department of Law, University of Toronto.

Berry, S., 1992. Estimation of a model of entry in the airline industry. *Econometrica*, 60 (4), 889-917.

Boguslaski, C., Ito, H., Lee, D., 2004. Entry patterns in the Southwest Airlines route system. *Review of Industrial Organization*, 25 (3), 317-350.

Bowen, J., 2000. Airline hubs in Southeast Asia: national economic development and nodal accessibility. *Journal of Transport Geography*, 8 (1), 25-41.

Buchanan, J.M., 1969. External diseconomies, corrective taxes, and market structure. *American Economic Review*, 59 (1), 174-177.

Button, K., Lall, S., 1999. The economics of being an airport hub city. *Research in Transportation Economics*, 5, 75-105.

Button, K., Lall, S., Stough, R., Trice, M., 1999. High-technology employment and hub airports. *Journal of Air Transport Management*, 5 (1), 53-59.

Calthrop, E., Proost. S., 2003. Environmental Pricing in Transport, in: Hensher, D.A., Button, K.J. (Eds.), *Handbook of Transport and the Environment*. Elsevier, Amsterdam, pp. 529-545.

Caves, D.W., Christensen, L.R., Diewert, W.E., 1982. Multilateral comparisons of output, input, and productivity using superlative index numbers. *The Economic Journal*, 92 (365), 73-86.

Caves, D.W., Christensen, L.R., Swanson, J.A., 1981. Productivity growth, scale economies, and capacity utilization in U.S. railroads, 1955-74. *American Economic Review*, 71 (5), 994-1002.

Caves, D.W., Christensen, L.R., Trethway, M.W., 1984. Economies of destiny versus economies of scale: why trunk and local service airline costs differ. *RAND Journal of Economics*, 15 (4), 471-489.

Centre for Asia Pacific Aviation, 2002. *Low cost airlines in the Asia Pacific region: an exceptional intra-regional traffic growth opportunity*. Centre for Asia Pacific Aviation, Sydney, New South Wales.

Centre for Asia Pacific Aviation, 2011. World airport rankings 2010: Hong Kong eclipses Memphis as the world's busiest cargo hub. March 16 <www.centreforaviation.com/analysis/world-airport-rankings-2010-hong-kong-eclipses-memphis-as-the-worlds-busiest-cargo-hub-47887>.

Chin, A.T.H., Tay, J.H., 2001. Developments in air transport: implications on investment decisions, profitability and survival of Asian airlines. *Journal of Air Transport Management*, 7 (5), 319-330.

China Daily, 2009. HP, Foxconn to build laptop manufacturing hub in Chongqing. August 8 <www.chinadaily.com.cn/business/2009-08/05/content_8528616.htm>.

China Daily, 2010. Rising labor costs trigger industrial relocation. July 6 <www.chinadaily.com.cn/bizchina/2010-07/06/content_10069557.htm>.

Chinese Manufacturers' Association of Hong Kong, 2008. Survey the business environment in the PRD. Hong Kong.

Christensen, L.R., Jorgensen, D.W., 1969. The measurement of U.S. real capital input, 1929–1967. *Review of Income and Wealth*, 15 (4), No. 293–320.

Creedy, S., 2008. Qantas's new chief Alan Joyce supports Jetstar. Australian Business.

Cullinane, K., Fei, W.T., Cullinane, S., 2004. Container terminal development in mainland China and its impact on the competitiveness of the port of Hong Kong. *Transport Reviews*, 24 (1), 33-56.

De Wit, J., Veldhuis, J., Burghouwt, G., Matsumoto, H., 2009. Competitive position of primary airports in the Asia-Pacific rim. *Pacific Economic Review*, 14 (5), 639-650.

Dixit, A., Chintagunta, P.K., 2007. Learning and exit behavior of new entrant discount airlines from city-pair markets. *Journal of Marketing*, 71 (2), 150-68.

Doganis, R., 2006. *The Airline Business*. 2nd Eds. Routledge, New York.

Dresner, M., Lin, J.S.C., Windle, R., 1996. The impact of low-cost carriers on airport and route competition. *Journal of Transport Economics and Policy*, 30 (3), 309-328.

Ducruet, C., Lee, S., Ng, A.K.Y., 2011. *Port Competition and Network Polarization at the East Asian Maritime Corridor*. French National Centre for Scientific Research (CNRS).

Easdown, G., Wilms, P., 2002. Ansett the collapse. Lothian Books, Melbourne.

Enright, M.J., Scott, E.E., Enright, Scott & Associates, 2007. *The Greater Pearl River Delta*. 5th Eds. Invest Hong Kong of the HKSAR Government, Hong Kong SAR.

Ehrlich, I., Gallais-Hammono, G., Liu, Z., Lutter, R., 1994. Productivity growth and firm ownership: an analytical and empirical investigation. *Journal of Political Economy*, 102 (5), 1006-1038.

Ferrari, C., Benacchio, M., 2000. Market structure in container terminal operators and port services. *Proceedings of the International Association of Maritime Economists Annual Meeting*, Naples, Italy, September 13-15.

Fickling, D., Wang, J., 2012. Qantas, China Eastern plan cheap flights for Asia Middle. Bloomberg, March 26 <www.bloomberg.com/news/2012-03-25/qantas-plans-hong-kong-budget-airline-with-china-eastern.html>.

Forsyth, P., 1998. *Airline Deregulation in Australia: A Medium Term Assessment*. Air Transport Research Group, Conference, Dublin, July.

Forsyth, P., 2003. Low-cost carriers in Australia: experiences and impacts. *Journal of Air Transport Management*, 9 (5), 277-284.

Francis, G., Fidato, A., Humphreys, I., 2003. Airport-airline interaction: the impact of low cost carriers on two European airports, *Journal of Air Transport Management*, 9 (4), 267-273.

Francis, G., Humphreys, I., Ison, S., Aicken, M., 2006. Where next for low cost airlines? A spatial and temporal comparative study. *Journal of Transport Geography*, 14 (2), 83-94.

Fu, X., Dresner, M., Oum, T.H., 2011a. Effects of transport service differentiation in the US domestic airline market. *Transportation Research Part E*, 47 (3), 297-305.

Fu, X., Homsombat, W., Oum, T.H., 2011b. Airport-airline vertical relationships, their effects and regulatory policy implications. *Journal of Air Transport Management*, 17 (6), 347-353.

Fu, X., Lijesen, M., Oum, T.H., 2006. An analysis of airport pricing and regulation in the presence of competition between full service airlines and low cost carriers. *Journal of Transport Economics and Policy*, 40 (3), 425–447

Fu, X., Oum. T.H., Zhang, A., 2010. Air transport liberalization and its impacts on airline competition and air passenger traffic. *Transportation Journal*, 49 (4), 24-41.

Fu, X., Zhang, A., 2010. Effects of airport concession revenue sharing on competition and social welfare. *Journal of Transport Economics and Policy*, 44 (2), 119–138

Gillen, D., Gados, A., 2008. Airlines within airlines: Assessing the vulnerabilities of mixing business models. *Research in Transportation Economics*, 24 (1), 25-35.

Gillen, D.W., Morrison, W.G., Steward, C., 2003. *Air Travel Demand Elasticities: Concepts, Issues and Measurement*. Department of Finance, Canada, Ottawa.

Gillen, D.W., Oum, T.H., Tretheway, M.W., 1985. *Airline Cost and Performance: Implications for Public and Industry Policies*, University of British Columbia, Centre for Transportation Studies, Vancouver, B.C., Canada.

Gillen, D.W., Oum, T.H., Tretheway, M.W., 1990. Airline cost structure and policy implications. *Journal of Transport Economics and Policy*, 24 (2), 9-34.

Global Supply Chain Council, 2010. Flextronics to open new plant in Ganzhou, Jiangxi province. June 3 <www.supplychains.com/en/art/3714/>.

Golaszewski, R., Sanders, M., 1992. Financial stress in the airline industry. *Journal of the Transportation Research Forum*, 32 (2), 313-320.

Good, D.H., Rhodes, E.L., 1991. Productive efficiency, technological change and the competitiveness of U.S. airlines in the Pacific rim. *Journal of the Transportation Research Forum*, 31 (2), 347-358.

Goolsbee, A., Syverson, C., 2008. How do incumbents respond to the threat of entry? Evidence from the major airlines. *Quarterly Journal of Economics*, 123 (4), 1611-1633.

Graf, L., 2005. Incompatibilities of the low-cost and network carrier business models within the same airline grouping. *Journal of Air Transport Management*, 11 (5), 313-327.

Graham, B., Vowles, T.M., 2006. Carriers within carriers: a strategic response to low-cost airline competition. *Transport Reviews*, 26 (1), 105-126.

Hall, R.E., 1991. *Recessions as Re-organizations*. NBER Macroeconomics Annual, NBER, Cambridge MA.

Homsombat, W., Fu, X., Sumalee, A., 2010. Policy implications of airline performance indicators: analysis of major North American airlines. *Transportation Research Record*, 2177, 41-48.

Homsombat, W., Lei, Z., Fu, X., 2011. Development status and prospects for aviation hubs – a comparative study of the major airports in South-east Asia. *The Singapore Economic Review*, 56 (4), 573-591.

Hooper, P., 2005. The environment for Southeast Asia’s new and evolving airlines. *Journal of Air Transport Management*, 11 (5), 335–347.

IAPH, 2007. *Tool Box for Port Clean Air Program*. International Association of Ports and Harbors.

Inamura, H., Saraswati, B., 2008. *Assessing the Efficiency of Southeast Asia Airline Companies: An Application of Data Envelopment Analysis*. Manuscript, Graduate School of Information Sciences, Tohoku University.

International Air Transport Association (IATA), 2005. *Airport Charges Comparisons and Submission to Hong Kong SAR.* Legislative Council, Economic Services Panel, April 29.

International Air Transport Association (IATA), 2008. *Airport and Air Navigation Charges Manual*. Geneva, Switzerland.

Ito, H., Lee, D., 2003. *Incumbent Responses to Lower Cost Entry: Evidence from the US Airline Industry*. Working Papers 2003-22, Brown University, Department of Economics.

Jordan, W.A., 1982. *Performance of Regulated Canadian Airlines in Domestic and Transborder Operations,* Consumer and Corporate Affairs Report, Canada.

Jordan, W.A., 1998. Excessive aircraft orders: a predictor of airline losses. *Proceedings of the 40th Annual Meeting of the Transportation Research Forum*, 586-599.

Kanafani, A., Ghobrial, A.A., 1985. Airline hubbing – some implications for airport economics. *Transportation Research Part A*, 19 (1), 15-27.

Kaylay, A., Singhal, R., Tashjian, E., 2007. Is chapter 11 costly? *Journal of Financial Economics,* 84 (3), 772-796.

Kim, I., 2007. Environmental cooperation of Northeast Asia: transboundary air pollution. *International Relations of the Asia-Pacific*, 7 (3), 439-462.

Knibb, D., 2005. New Qustralians. *Airline Business*, 21 (1), 56-58.

Knowler, G., 2012. Shenzhen reaching out as cargo heads inland. Maritime Professional, January 26 <www.maritimeprofessional.com/Blogs/Far-East-Maritime/January-2012/Shenzhen-reaching-out-as-cargo-heads-inland.aspx>.

Lam, J.S.L, Yap, W.Y., 2006. A measurement and comparison of cost competitiveness of container in Southeast Asia. *Transportation*, 33 (6), 641-654.

Lam, J.S.L., Yap, W.Y., 2011. Container port competition and complementarity in supply chain systems: evidence from the Pearl River Delta. *Maritime Economics and Logistics*, 13 (2), 102–120.

Li & Fung Research Centre, 2008. *China Industry Relocation and Upgrading Trends: Implications for Sourcing Business*. China Distribution & Trading, Issue 56.

Liao, H.F., Chan, R.C.K., 2011. Industrial relocation of Hong Kong manufacturing firms: towards an expanding industrial space beyond the Pearl River Delta. *GeoJournal*, 76 (6), 623-639.

Liu, C.M., 2009. Entry behavior and financial distress: an empirical analysis of the US domestic airline industry. *Journal of Transport Economics and Policy*, 43 (2), 237-256.

Lohmann, G., Albers, S., Koch, B., Pavlovich, K., 2009. From hub to tourist destination – an explorative study of Singapore and Dubai's aviation-based transformation. *Journal of Air Transport Management*, 15 (5), 205-211.

Lucas, R.E., 1988. On the mechanics of economic development. *Journal of Monetary Economics*, 22 (1), 3-42.

Luo, M., Liu, L., Gao, F., 2010. Bertrand competition with capacity expansion: case study for container port competition between Hong Kong and Shenzhen, China. *Transportation Research Record*, 2166, 74-81.

Maeda, R., 2009. Japan industry unites against carbon tax. Reuters, December 7 <http://uk.reuters.com/article/2009/12/07/climate-japan-idUKTOE5B609U20091207>.

McKinnon, A., 2011. *Hong Kong and Shenzhen Ports: Challenges, Opportunities and Global Competitiveness*. Working Paper Series, Hong Kong Centre for Maritime and Transportation Law, City University of Hong Kong.

Morrell, D., 2010. LCC Hansung Airlines to re-launch as T'Way Airlines. September 11 <www.airplane-pictures.net/news.php?p=797>.

Morrell, P., 2005. Airlines within airlines: an analysis of US network airline responses to low cost carriers. *Journal of Air Transport Management*, 11 (5), 303-312.

Morrison, S.A., 1997. *Airline Deregulation and Fares at Dominated Hubs and Slot-Controlled Airports*. Testimony to the Committee on the Judiciary, United States House of Representatives, Washington, D.C., November 5.

Morrison, S.A., 2001. Actual, adjacent and potential competition estimating the full effect of Southwest Airlines. *Journal of Transport Economics and Policy*, 35 (2), 239-256.

Ng, A.K.Y., Cetin, I.B., 2012. Locational characteristics of dry ports in developing economies: some lessons from Northern India. *Regional Studies*, 46 (6), 757-773.

Ng, K.Y.A., Gujar, G.C., 2009. The spatial characteristics of inland transport hubs: evidences from Southern India. *Journal of Transport Geography*, 17 (5), 346-356.

Nomura, S., 2011. *Keys to the Success of LCC Business in Japan*. Japan Tourism Marketing Co. (JTM), Monthly JTM Report, October.

Notteboom, T.E., 2009a. The Relationship between Seaports and the Intermodal Hinterland in Light of Global Supply Chains: European Challenges. OECD, International Transport Forum, Round Table 143.

Notteboom, T.E., 2009b. Complementarity and substitutability among adjacent gateway ports. *Environment and Planning A*, 41 (3), 743-762.

Nyathi, M., Hooper, P., Hensher, D., 1993. Compass Airlines 1 December 1990 to 20 December 1991. What went wrong? *Transport Reviews*, 13 (2), 119-149 and 13 (3), 185-206.

OECD, 1999. *Environmental Taxes and Green Tax Reform*. OECD Round Table on Sustainable Development, Organisation for Economic Co-operation and Development, Oslo, Norway, August 30-31.

Ohashi, H., Kim, T-S., Oum, T.H., Yu, C., 2005. Choice of air cargo transshipment airport: an application to air cargo traffic to/from Northeast Asia. *Journal of Air Transport Management*, 11 (3), 149-159.

Oum, T.H., Fu, X., 2007. Air transport security user charge pricing: an investigation of flat per-passenger charge vs. Ad Valorem user charge schemes. *Transportation Research Part E*, 43 (3), 283-293.

Oum, T.H., Fu, X., Yu, C., 2005. New evidences on airline efficiency and yields: a comparative analysis of major North American air carriers and its implications. *Transport Policy*, 12 (2), 153-164.

Oum, T.H., Park, J-H, 2004, Multinational firms’ location preference for regional distribution centers: focus on the Northeast Asian region. *Transportation Research Part E*, 40 (2), 101-121.

Oum, T.H., Tretheway, M.W., 1990. Airline hub and spoke systems. *Journal of Transportation Research Forum*, 30, 380-93.

Oum, T.H., Yu, C., 1995. A productivity comparison of the world's major airlines. *Journal of Air Transport Management*, 2 (3-4), 181-195.

Oum, T.H., Yu, C., 1998a. Cost competitiveness of major airlines: an international comparison. *Transportation Research Part A*, 32 (6), 407-422.

Oum, T.H., Yu, C., 1998b. *Winning Airlines: Productivity and Cost Competitiveness of the World's Major Airlines*. Kluwer Academic Publishers, Norwell, Massachusetts.

Oum, T.H., Zhang, Y., 1991. Utilization of quasi-fixed inputs and estimation of cost functions. *Journal of Transport Economics and Policy*, 25 (2), 121–134.

Padilha, F., Ng, A.K.Y., 2012. The spatial evolution of dry ports in developing economies: the Brazilian experiences. *Maritime Economics & Logistics*, 14 (1), 99-121.

Park, Y., 2003. An analysis for the competitive strength of Asian major airports. *Journal of Air Transport Management*, 9 (6), 353-360.

Pilling, M., 2004. Brand extensions. *Airline Business*, 20 (3), 46-48.

Pigou, A.C., 1932. *The Economics of Welfare*. 4th Eds. McMillan, London.

PR Newswire, 2010. Flextronics opens power facility in Ganzhou, Jiangxi China. August 24 <www.prnewswire.com/news-releases/flextronics-opens-power-facility-in-ganzhou-jiangxi-china-101441399.html>.

Salop S., Scheffman D., 1983. Raising rivals' costs. *American Economic Review*, 73 (2), 267-271.

Shih, T.H., 2011. HK, Shenzhen losing export role as factories move inland. South China Moring Post, April 19 <topics.scmp.com/news/china-business-watch/article/HK-Shenzhen-losing-export-role-as-factories-move-inland>.

Sinclair, R.A., 1995. An empirical model of entry and exit in airline markets. *Review of Industrial Organization*, 10 (5), 541-557.

Simpson, R.D., 1995. Optimal pollution taxation in a Cournot duopoly. *Environmental and Resource Economics*, 6 (4), 359-369.

Strassmann, D.L., 1990. Potential competition in the deregulated airlines. *The Review of Economics and Statistics*, 72 (4), 696-702.

Szep, J., 2010. Thai Airways details public offering plans. Reauters (Bangkok), August 17 <www.reuters.com/article/2010/08/17/thaiair-idUSSGE67G0AK20100817>.

Talley, W.K., 2003. Environmental Impacts of Shipping, in: Hensher, D.A., Button, K.J. (Eds.), *Handbook of Transport and the Environment*. Elsevier, Amsterdam, pp. 279-291.

Tan, AK-J., 2010. The ASEAN multilateral agreement on air services: en route to open skies. *Journal of Air Transport Management*, 16 (6), 289-294.

The Better Hong Kong Foundation, 2004. *Restoring Hong Kong's Competitiveness as A Sea-Trade Logistics Hub*. Reports & Publications, July 29.

The Boston Consulting Group (BCG), 2011. Made in the USA, again: manufacturing is expected to return to America as China's rising labor costs erase most savings from offshoring. Press releases, May 5 <www.bcg.com/media/PressReleaseDetails.aspx?id=tcm:12-75973>.

The Economic Planning Unit of Malaysia, 2010. *Tenth Malaysian Plan 2011-2015*. The Economic Planning Unit, Prime Minister's Department, Putrajaya.

The Hong Kong Trade Development Council (HKTDC), 2011a. Investment environment of southern Hunan as a destination for industrial relocation. Economic Forum - Global Economic Analysis & Reports, May 18.

The Hong Kong Trade Development Council (HKTDC), 2011b. Multinational Electronics Firms "Go West" in China. Economic Forum - Global Economic Analysis & Reports, May 25.

The Hong Kong Trade Development Council (HKTDC), 2011c. Central China the New Location for Electronics Production. Economic Forum - Global Economic Analysis & Reports, May 25.

The Hong Kong Trade Development Council (HKTDC), 2012. An update on Production Costs on the Mainland. Economic Forum - Global Economic Analysis & Reports, January 12.

Tretheway, M., Kincaid, I., 2010. Competition between airports: occurrence and strategy, in: Forsyth, P., Gillen, D., Muller, J., Niemeier, H. (Eds.), *Airport Competition: The European Experience*, Ashgate, Aldershot, pp. 119-136.

United Nations ESCAP, 2005. *Free Trade Zone and Port Hinterland Development*. UNESCAP, Transport Division.

United Nations ESCAP, 2008. *Summary of the Conference on Transboundary Air Pollution in North-east Asia*. North-East Asian Subregional Programme for Environmental Cooperation (NEASPEC), Tokyo, Japan, December 17-19.

United States Environmental Protection Agency, 2009. *Proposal to Designate an Emission Control Area for Nitrogen Oxides, Sulfur Oxides and Particulate Matter, Technical Support Document, Chapter 2 Emission Inventory*. Assessment and Standards Division, Office of Transport and Air Quality, US Environmental Protection Agency.

U.S. Department of Commerce, 2010. *Doing Business in China: 2010 Country Commercial Guide for US Companies*. U.S. and Foreign Commercial Services and U.S. Department of State.

Yan, J., Fu, X., Oum, T., 2008. *Exploring Network Effects of Point-to-Point Networks: An Investigation of the Spatial Entry Patterns of Southwest Airlines*. Working Papers 2008-21, School of Economic Sciences, Washington State University.

Windle, R.J., 1991. The world's airlines: a cost and productivity comparison. *Journal of Transport Economics and Polic*y, 25 (1), 31-49.

Windle, R.J., Dresner, M.E., 1992. Partial productivity measures and total factor productivity in the air transport industry: limitations and uses. *Transportation Research Part A*, 26 (6), 435-445.

Windle, R.J., Dresner, M.E., 1995. The short and long run effects of entry on US domestic air routes. *Transportation Journal*, 35 (2), 14-25.

Windle, R.J., Dresner, M.E., 1999. Competitive responses to low cost carrier entry. *Transportation Research Part E*, 35 (1), 59-75.

Yin, X., 2003, Corrective taxes under oligopoly with inter-firm externalities. *Environmental and Resource Economics*, 26 (2), 269-277.

Yuan, X-M., Low, J.M.W., Tang, L.C., 2010. Roles of the airport and logistics services on the economic outcomes of an air cargo supply chain. *International Journal of Production Economics*, 127 (2), 215-225.

Zhang, A., 2003. Analysis of an international air-cargo hub: the case of Hong Kong. *Journal of Air transport Management*, 9 (2), 123-138.

Zhang, A., Fu, X. and Yang, H., 2010, Revenue sharing with multiple airlines and airports. *Transportation Research Part B*, 44 (8-9), 944-959.

Zhang, A., Hanaoka, S., Inamura, H., Ishikura, T., 2008. Low-cost carriers in Asia: deregulation, regional liberalization and secondary airports. *Research in Transport Economics*, 24 (1), 36-50.

Zhang, A., Zhang, Y., 2002. Issues on liberalization of air cargo services in international aviation. *Journal of Air transport Management*, 8 (5), 275–287.

Zhao, X., Yin, H., 2011. Industrial relocation and energy consumption: evidence from China. *Energy Policy*, 39 (5), 2944-2956.