ESSAYS IN TRANSPORT ECONOMICS AND POLICY

- POLICY EVALUATIONS IN THE AVIATION AND MARITIME SECTORS

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Essays in Transport Economics and Policy
- policy evaluations in the aviation and maritime sectors

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CERTIFICATE OF ORIGINALITY

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ABSTRACT

Major policies have been implemented and proposed in the aviation and maritime sectors in recent years, with various aims such as to improve financial performance of firms, to reduce pollution and to promote regional development and social welfare. However, many of these policies have not been sufficiently studied. For some of the policies adopted, their full effects, and mechanisms leading to such effects remained unclear. For some of the policies being proposed, there is also a need to quantify and benchmark the effects of alternative policy options, *ex ante*. This thesis examines three important issues in the transport industry in three essays of policy evaluation and economic analysis.

Essay one empirically examines Chinese airlines' competitiveness and benchmarks with other leading airlines in the world. It is found that Chinese airlines' efficiencies have improved during the last decade, but their productivities still lag behind that of industry leaders. Chinese airlines' profitability is attributable to high yields and low input prices in the domestic market. The results implied that Chinese government's policy reforms are steps in the right direction, but the deregulation efforts have been incomplete and inadequate. The Chinese government should embrace the global trend of deregulation and liberalization more enthusiastically, and allow more competition in both the airline markets and inputs supply market. In addition, airline input market in China shall be further liberalized so as to lower Chinese airline's unit cost and to enhance its existing cost advantage against foreign carriers

Essay two theoretically analyzes and benchmarks two different Emission Trading Scheme (ETS) restricting greenhouse gas (GHG) emission from the international shipping industry, namely an open ETS and a maritime only ETS (METS). The analysis quantifies the differential impacts of ETS on container shipping and dry bulk shipping sectors. It is found that an ETS, whether open or maritime only, will decrease ship speed, carrier outputs and fuel consumption for both the container and bulk sectors. The increased ship operation cost will deteriorate this output reduction under ETS. To overcome this negative impact, carriers have more incentive to improve fuel efficiency through technical and operational measures. In addition, the degree of competition in a sector will have spill-over effects to the other sector under the METS. This study

provides a framework to identify the moderating effects of market structure and firm competition on emission reduction schemes, and emphasizes the importance of understanding the differential impacts of ETS schemes brought to individual sectors within an industry.

Essay three uses the South China region as a case to examine factors and conditions affecting regional port governance. A game theory model is developed and calibrated for Shenzhen and Hong Kong ports in Pearl River Delta (PRD). In particular, it is found that the likelihood to form a port alliance is dependent on many factors, such as service differentiation among ports, relative cost efficiency and market potential of neighboring ports. Therefore, both the Hong Kong government and the China central government should carefully design long-run ports development strategy taking into account of these factors that affect port governance.

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CHAPTER 1
INTRODUCTION

The transport sector contributes significantly to the well-being of the society (employment, tax revenue, investment and economic output), and also provides indispensable inputs to other sectors such as tourism, logistics and trade. Efficient and well developed transport systems are of critical importance to the modern society. In recent years, the constant social and economic developments around the world have called for continued improvements in the transport industry in terms of higher efficiency, increased reliability and better environment protection. The transport industry has been upgrading itself through continuous industrial reforms and corporate strategy developments in a very dynamic environment. Major policy options have been implemented or proposed in the transport sector, with various aims such as to promote social welfare, to improve financial performance and to reduce pollution. However, many of these recent policy changes have not been sufficiently studied. For some of the policies adopted, their full effects, and mechanisms leading to such effects, remained unclear. For some of the policies being proposed, there is also a need to quantify and benchmark the effects of alternative policy options *ex ante*. This thesis aims to investigate some of these important policy changes, and benchmark alternative options so that the optimal policies and best industry practices can be identified.

Policy evaluation is not an easy task. Industrial organizations optimize their strategies given the regulations imposed on them, the strategies adopted by competitors, and market conditions such as consumer demands, upstream/downstream market structures. It is important for policy makers to accurately measure the performances of individual firms, and to understand (predict) the strategies (to be) adopted by industrial organizations. Ideally, all policy analysis should be based on real industry data. However, this is often impossible in practice due to various constraints in time, budget and data availability. Therefore, empirical investigation and analytical models should be selectively used in policy evaluations. In this thesis I develop modeling approaches for various market structures with varying degree of data availability. These studies are summarized and reported in three essays in this thesis. In the first essay, I measure and benchmark airline competitiveness based entirely on real industry data. Government policies, such as deregulation and liberalization, are treated as exogenous events influencing firms' performances. In the second essay analytical models are used to evaluate alternative regulations on greenhouse gas (GHG) emission in the maritime transport sector. The analysis considers one regulator only *i.e.* International Maritime Organization (IMO), which evaluates alternative emission trading schemes (ETS) taken into account of shipping firms' strategies. Using analytical solutions and numerical simulations, the third investigation studies strategic choice of cooperation and competition among neighboring marine ports. These ports are under different governments / regimes (i.e. Hong Kong vs. Shenzhen), but their operations and strategies jointly influence regional developments. In summary, in this thesis I have tried to develop policy analysis frameworks which can be applied to a range of market structures thus that prominent policy changes in the transport industry can be evaluated.

Some important insights have been obtained in these studies. Essay one investigates leading Chinese airlines' productivity, yield, cost competitiveness and input prices, and benchmarks them against major airlines around the world. The output and input data were compiled for the Chinese Big Three airlines (Air China, China Southern and China Eastern) and major airlines in North America, Asia-Pacific and Europe. Total factor and partial productivities were calculated for sample airlines to measure their operational efficiency. In addition, airlines' average yield and unit cost index were constructed and compared. The key results of this essay are as follows: (1) Chinese airlines' efficiencies have improved during the last decade, but their productivities still lag behind that of industry leaders. (2) Chinese airlines' profitability is attributable to high yields and low input prices in the domestic market. (3) The unit cost advantage enjoyed by Chinese airlines has been diminishing over time. These investigation results lead to following policy implications: the Chinese government's policy reforms are steps in the right direction, but the deregulation efforts have been incomplete and inadequate. The Chinese government should embrace the global trend of deregulation and liberalization more enthusiastically, and allow more competition in airline market. In addition, airline input market in China shall be further liberalized so as to lower Chinese airline's unit cost and to enhance its existing cost advantage against foreign carriers.

Essay two proposes an economic model to theoretically analyze and benchmark two different ETS mechanisms restricting GHG from the international shipping industry, namely an open ETS and a maritime only ETS (METS). The analysis sheds light on differential impacts of ETS on container shipping and dry bulk shipping sectors. It is found that an ETS, whether open or maritime only, will decrease ship speed, carrier outputs and fuel consumption for both the container and bulk sectors, even in the presence of “wind-fall” profit to carriers. The increased ship operation cost will deteriorate this output reduction under ETS. To overcome this adverse impact, carriers have stronger incentive to improve fuel efficiency through voluntary adoption of better technical and operational measures. In addition, the degree of competition in a sector will have spill-over effects to the other sector under the METS. Specifically, when the sector that sells (buys) permits is more collusive (competitive), the equilibrium permit price will rise. This study provides a framework to identify the moderating effects of market structure and firm competition on emission reduction schemes, and emphasizes the importance of understanding the differential impacts of ETS schemes brought to individual sectors within an industry.

Essay three uses the South China region as a case to examine factors and conditions affecting regional port governance. A game theory model is developed and calibrated for Shenzhen and Hong Kong ports in Pearl River Delta (PRD). It investigates the port governance options, notably alliance formation for ports serving partially overlapping hinterlands. In particular, it is found that the likelihood to form a port alliance is dependent on many factors, such as service differentiation among ports, relative cost efficiency and market potential of neighbouring ports. Therefore, both the Hong Kong government and the China central government should carefully design long-run ports development strategy taking into account of these factors that affect port governance.

Overall, these aforementioned investigations suggest that the effects of government regulation and policy can be complicated and two-sided. Where sufficient competition can be retained or market-based mechanism can be used, as the cases studied in essay one and three, policy makers should be prudent introducing direct regulations on individual firms / industrial organizations. However, in the presence of externalities, such as the case studied in essay two, government intervention and coordination may still be needed. These studies testify the great challenges in policy formulation and evaluation, and the need to apply appropriate analysis frameworks to distinctive problems.

CHAPTER 2

BECHMARKING THE PERFORMANCE OF CHINESE AIRLINES

-AN INVESTIGATION OF PRODUCTIVITY, YIELD, AND COST COMPETITIVENESS

2.1 INTRODUCTION AND BACKGROUND

In the past few decades, the Chinese aviation industry has experienced tremendous growth, driven by the country's fast-expanding economy. In terms of market size, the number of air passengers grew at an annualized rate of 14.9% between 1990 and 2010. Since 2005 China has been the world's second-largest aviation market, second only to the United States. Chinese carriers are now among the most profitable airlines in the world. In 2010 the total earnings reached RMB35.1 billion (USD5.18 billion), accounting for about 60% of the industry's global profit. Chinese airlines' profits this year were twice those of airlines in the United States and four times those of European airlines. Although Chinese airlines suffered substantial operation loss in 2008 due to the global financial crisis as most other major airlines in the world (see Table 2-1), in the years followed they had been among the most profitable airlines. Ironically, China Eastern Airlines received a government capital injection of 10 billion RMB (US$1.45bn) in 2009, and another injection of more than 3 billion RMB (US$0.44bn) in 2012 to trim debt. China Southern and Air China, received capital injections of 2 billion RMB (US$0.29bn) and 1 billion RMB (US$0.15bn) respectively in 2012. Figure 2-1 illustrates the rapid growth of Chinese airlines in terms of RPK and RFTK in the 2001 to 2010 period. When benchmarked with the world largest aviation market in US, China experienced faster growth in air traffic volume although its market size was still much smaller than that of the US. Even with the SARS epidemic in 2003 and the global financial crisis in 2008, Chinese airlines achieved traffic growth in every single year. Traffic growth was mainly led by domestic market, whereas the international sector had not been fully explored.

Table 2-1. Pre-tax Profit and Revenue Passenger Kilometers (RPK) for “Big Three”

	China Eastern		China Southern		Air China	
Year	Profit	RPK	Profit	RPK	Profit	RPK
2004	650	27,581	233	37,196	3,560	46,645
2005	-528	36,381	-1,853	61,923	3,374	52,405
2006	-3,338	50,272	357	69,582	3,929	63,362
2007	378	57,183	2,879	81,727	5,606	70,026
2008	-15,256	53,785	-4,724	83,184	-10,978	68,747
2009	249	60,942	432	93,002	5,066	75,474
2010	5,418	93,153	8,093	111,328	14,834	105,695
2011	4,841	100,895	6,930	122,344	9,355	123,489
2012	3,012	109,112	4,738	135,534	6,576	129,773

Source: Company’s annual report
Remark: the pre-tax profit is in million RMB, and the RPK is in million.

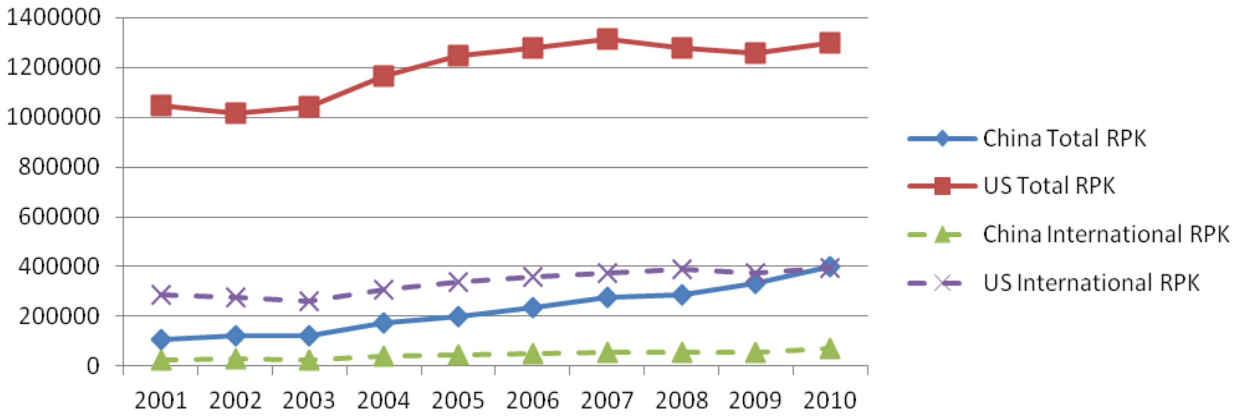

Figure 2-1-a

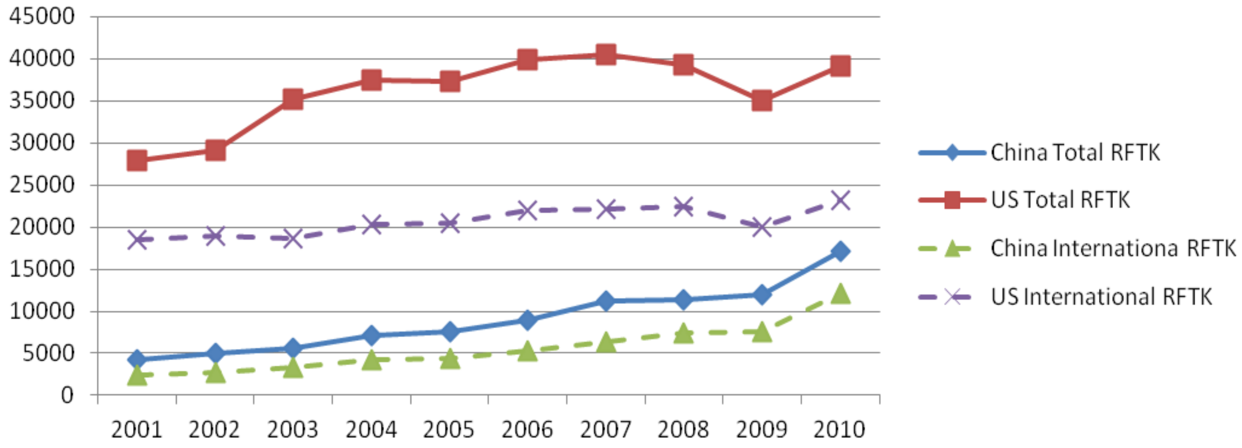

Figure 2-1-b

Figure 2-1. Revenue passenger kilometer (RPK) and Revenue freight tonne kilometer (RFTK) for China and US.

Source: Statistical data on civil aviation of China and the U.S. Department of Transport

Other than the booming Chinese economy, the driving forces for Chinese airlines' strong growth in scale and profitability remain unclear. There have been major changes in the Chinese aviation market during the past decade. Recent studies (see for example Zhang and Chen 2003; Liu et al. 2009; Zhang and Round 2009, 2011; Lei and O'Connell 2011; Homsombat et al. 2011; Lau et al. 2011; Zhang et al., 2013) have pointed to the major deregulation since the late 1990s; many new airlines have been allowed into the domestic market, including both (provincially) state-owned firms and privately owned carriers. In 2005 foreign ownership of airlines was allowed up to a cap of 49%. Route regulations have been removed for most destinations, except for a few mega-airports such as Beijing, Shanghai, and Guangzhou. In most cases airlines are allowed to set their own prices, by offering price discounts off the nominal standard fares set by the Civil Aviation Administration of China (CAAC). Distribution channels are also now competitive. In addition to an increasing number of ticket agents, airlines now increasingly rely on sales through their websites and online travel portals such as Ctrip, elong, and Taobao. Many airports have been commercialized and (partially) privatized. Regulations in the international markets are also being relaxed gradually. All these deregulation efforts and industry developments may help to explain the overall competitiveness and productivity of Chinese airlines.

At the same time, there is clear evidence that the Chinese aviation industry has not achieved global competitiveness. As observed by Fu et al. (2012), Chinese airlines' revenue and profits are mostly derived from domestic markets. Despite their leadership in scale and profit, Chinese carriers still lack the confidence to freely compete with their international peers. Many regulatory measures remain in both domestic and international markets. Zhang et al. (2009) observed that there are still substantial regulations in areas such as aircraft purchase and fleet buildup, pilot recruitment, fuel purchase, airport charges, and route entry and pricing for low-cost carriers. Chinese low cost carriers are thus not aggressive competitors as those in Europe or North America (Fu et al. 2011). Despite the continuous expansion of the overall market, the top three airline groups (the so-called "Big Three", which include Air China, China South, and China Eastern) account for more than 70% of the domestic market. These airlines are all majority state-owned, and the implementation of anti-trust/competition laws is neither frequent nor strict. Clearly, there is insufficient competition in the aviation market, which is probably a major contributing factor to Chinese airlines' record profits in recent years. Figure 2-2 benchmarks market concentration conditions in the domestic markets of China and the US. Both markets have experienced significant growth in the sample period as shown in Figure 2-1. However, the HHI index in mainland China was clearly higher than the case of US, suggesting a highly concentrated domestic market in China. Figure A1 in Appendix demonstrated the frequency distribution of the route level HHI for Chinese domestic routes. The means are above 4,000, much higher than 1,800 the threshold defined by DOJ to initiate the concern of insufficient competition. This high market concentration in China is also evidenced by the number of carriers in each market. Note in mainland China, large airlines often control many subsidiary airlines to serve medium hubs. Therefore, the effective competitors are fewer than the numbers reported. The effects of various regulation/deregulation policies are also evident: CAAC guided nine of the largest Chinese state-owned airlines to merge into three airlines groups (Big Three) in year 2003. This led to a substantial increase in market concentration. However, in recent years there appeared to be a trend of deregulation: private investments in airlines are allowed, and route entry regulation has been removed in most routes. This explains the decline of market concentration. Market concentration in the US domestic market has been quite stable, except that the number of airlines has declined due to airline restructuring efforts which led to merger and acquisition, and bankruptcy of a few carriers.

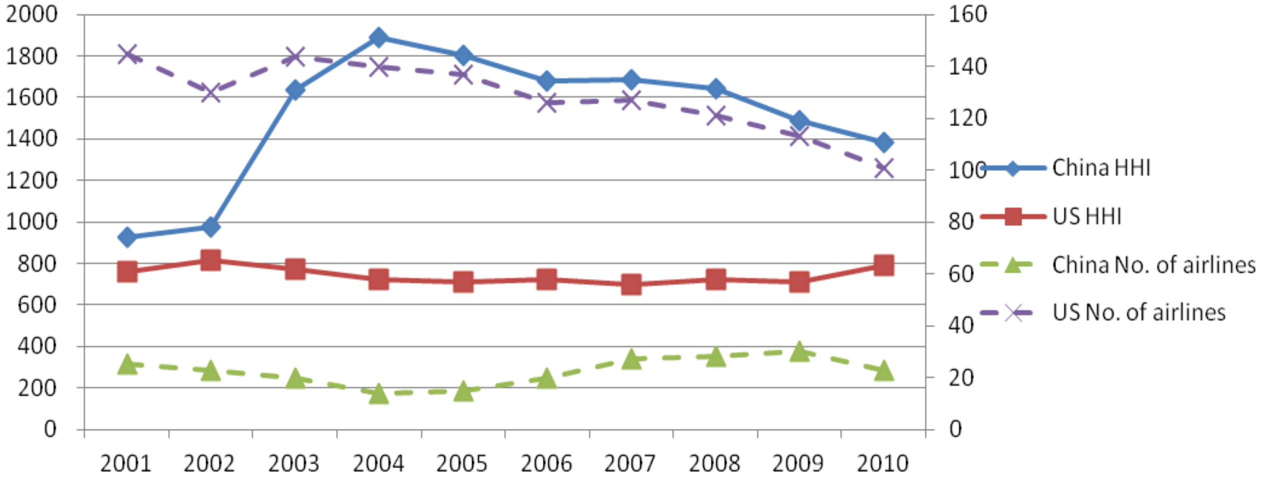

Figure 2-2. HHI index and Number of airlines for China

Source: Compiled from OAG database.
*Numbers of airlines are calculated by counting the number of airline codes used in the schedule database. HHI index is calculated using national market shares by number of scheduled seats.

In summary, there have been some major deregulation efforts in the Chinese aviation market in recent years. However, significant regulations remain and the market is still not as competitive as in mature markets in North America and Europe. Market shares are heavily concentrated to a few state-owned mega-carriers which have considerable market power in domestic market but could barely compete in international markets despite record profits in recent years (Fu et al. 2012, Zhang et al., 2013). The growth of low-cost carriers has been limited, and various regulations remain in the international market. Other than the country’s booming economy, it is unclear what factors have driven the Chinese airlines’ strong growth in scale and profitability. As a result, it is difficult to evaluate the Chinese carriers’ competitiveness against major international airlines, or to precisely evaluate the effects of the aviation policies adopted by the Chinese government.

This essay quantifies the recent developments in the Chinese aviation market by investigating the performances of leading Chinese carriers during the 2001 to 2010 period. Both Total Factor Productivity (TFP) and Partial Factor Productivity measurements are calculated for the Big Three Chinese airlines, which are then benchmarked to some of the leading airlines in Asia Pacific, North America and Europe. Comparisons of average yield, unit cost and input price are also made. These investigations allow us to assess the overall performances of Chinese airlines, and map the evolutionary path of such performance measures over the sample period. These quantitative data are used to evaluate the effects of the various aviation policies adopted by the Chinese government, and to identify areas in which Chinese airlines could improve towards the industry's best practices.

The rest of this chapter is organized as follows. Section 2.2 presents the data sources, descriptive statistics and methodology used in the computation of productivity indicators. Section 2.3 computes and benchmarks airlines' TFP and various Partial Factor Productivity levels. Section 2.4 compares Chinese airlines' yields, unit costs and input prices to leading carriers in the world. The last section summarizes and concludes the study.

2.2. DATA DESCRIPTION AND METHODOLY

Three largest Chinese airlines, namely China Eastern, China Southern and Air China, are selected in this study. These three carriers jointly account for the majority of the international air services in China, and thus our investigation will also provide important insights into the competitiveness of Chinese airlines in the global market. We use the word 'airlines' to refer to airline groups, as each company experienced major consolidation in 2002[1]. Our sample contains eleven more major network carriers,

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[1] In 2002, China Eastern airlines merged with China Northwest and Yunnan airlines; China Southern merged with China Northern and Xinjiang airlines; and Air China merged with China Southwest and CNAC airlines. The merger integrations for China Eastern and China Southern were completed in 2005,

including three Asia Pacific carriers (Singapore Airlines, Cathay Pacific Airways, and Thai Airways), five North American carriers (American Airlines, Delta, Continental, United, and Air Canada), and three European airlines (Lufthansa, Air France, and KLM). These airlines are large and jointly account for a significant share of the global market. This sample includes some of the most successful and well-established airlines in the world, and is thus representative of the current airline industry in terms of geographic location, network coverage, and global airline alliances. They serve as ideal benchmarks for Chinese airlines. Due to data availability limitation, some other world leading network carriers were not included in the sample, such as Korean Air, Japan Airlines, British Airways etc.

Some of these sample airlines experienced major merger and acquisitions during our study period, including the 2005 Air France and KLM merger, the 2008 Delta and Northwest merger, and the 2010 merger between United and Continental airlines. In the calculations of TFP and other measures, the airlines' post-merger performances are based on the aggregated data of the newly formed airlines after the mergers. For example, the TFP results for Air France and KLM after 2005 are based on the Air France-KLM airline group, although we still report identical results for two airlines (i.e. Air France and KLM).

We use a TFP computation method similar to that adopted by Windle and Drenser (1992), Oum and Yu (1995), Oum, Fu, and Yu (2005), and Homsombat, Fu and Agachai (2010). Five inputs and three outputs are included in the calculation. The three output variables are passenger services, freight services, and incidental services. The passenger and freight services include both scheduled and non-scheduled airline operations measured in Revenue-Tonne-Kilometers (RTK). Incidental services contain a wide range of non-airline outputs such as catering, ground handling, aircraft maintenance for other airlines, consulting, and hotel business. The input variables are labor, fuel, materials, flight equipment, and ground property and equipment (GPE). Labor input is measured by the yearly number of full-time employees. Fuel input is measured by gallons of fuel consumed. For flight equipment, different types of aircrafts

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whereas integration was competed in 2003 for Air China. In 2010, China Eastern acquired Shanghai airlines and Air China acquired Shenzhen airlines.

are compounded into a fleet quantity index using the translog multilateral index procedure proposed by Caves et al. (1982) and Oum et al. (2005). Leasing prices of different types of aircrafts are used as weights in constructing the fleet quantity index. The GPE price index is obtained using the method proposed by Christensen and Jorgenson (1969). GPE cost and fleet equipment cost are categorized together as a single capital input, as GPE cost is much smaller than fleet equipment cost. The material cost is a catch-all cost, covering all the net operating expenses, excluding fuel and labor.

The abovementioned output and input variables are aggregated into a multilateral output and a multilateral input index, respectively, using the translog multilateral index procedure. Total factor productivity is defined as the ratio of the output index to the input index. Let i and j denote two different airlines or time periods, then a comparison of gross TFP levels between two airlines or time periods is calculated as:

$$(2.1) \qquad \frac{TFP_i}{TFP_j} = \frac{Y_i/Y_j}{X_i/X_j}.$$

Taking the logarithm of Equation (1) yields

$$(2.2) \qquad \ln TFP_i - \ln TFP_j = \left(\ln Y_i - \ln Y_j\right) - \left(\ln X_i - \ln X_j\right),$$

where

$$(2.3) \qquad Y_i = \prod_k \left(\frac{Y_{ki}}{\tilde{Y}_k}\right)^{\frac{(R_{ki}+\bar{R}_k)}{2}}, \; Y_j = \prod_k \left(\frac{Y_{kj}}{\tilde{Y}_k}\right)^{\frac{(R_{kj}+\bar{R}_k)}{2}},$$

$$(2.4) \qquad X_i = \prod_p \left(\frac{X_{pi}}{\tilde{X}_p}\right)^{\frac{(W_{pi}+\bar{W}_p)}{2}}, \; X_j = \prod_p \left(\frac{X_{pj}}{\tilde{X}_p}\right)^{\frac{(W_{pj}+\bar{W}_p)}{2}},$$

and

Y_{ki} is the output k for observation i;

R_{ki} is the revenue share of output k for observation i;

$\bar{R}_k$ is the arithmetic mean of revenue shares of output k over all observations;

$\tilde{Y}_k$ is the geometric mean of output k over all observations;

X_{pi} is the input p for observation i ;

W_{pi} is the input cost shares of input p for observation i;

$\tilde{X}_p$ is the geometric mean of input p over all observations.

The information contained in the airlines' annual reports is used as the main source to compile a panel data for the 2001 to 2010 period[2]. Other reliable data sources are consulted to validate data quality and consistency. These references include ICAO databases, financial and operational data provided by the Bureau of Transportation Statistics in United States, and Statistical Data on Civil Aviation of China issued by the CAAC. Aircraft leasing prices are obtained from Avmark.[3] Some descriptive statistics of the sample airlines are reported in Figures 2-3, 2-4, and 2-5, which report sample airlines' total operating revenue, share of cargo and incidental operation. Total operating revenue is one of the routine measures used in the airline industry for airline size and financial strength. Shares of cargo and incidental revenue measure airlines' product mix, and are important control variables in productivity analysis since passenger, cargo and incidental operation involve quite different input mix. In general, the selected airlines in North America and Europe had larger scales than the Chinese airlines in our sample, although the Big Three experienced major traffic volume growth during the sample period. This is partly due to mergers between mega-carrier groups during the past decade, which substantially increased the average size of the world's leading airlines. In 2005, American airlines had a total revenue of USD20.7 billion, which was almost double the size of the sum of the Big Three. Revenue comparison however is subject to the influences of exchange rate fluctuations. The appreciation of Euro during the sample period significantly increased European airlines' revenue measured in US dollar.

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[2] Different airlines adopt different fiscal year calendars. Most of our sample airlines adopt a fiscal year ending at Dec 31; however, it is Sep 30 for Thai Airways, and March 31 for Singapore Airlines, Air France and KLM.

[3] The most recent aircraft leasing price we have is up tp April 2009. To calculate the aircraft price index for 2010, we use the leasing price in April 2009 to represent that of 2010.

Meanwhile, since 2005 to 2010 the Chinese RMB appreciated by 21% against US dollar, contributed to part of the revenue growth of Chinese carriers. Singapore Airlines and Cathay Pacific have extensive long-haul inter-continental traffic. Without a large domestic market, however, their company size is moderate compared to the mega-carriers in North America and Europe.

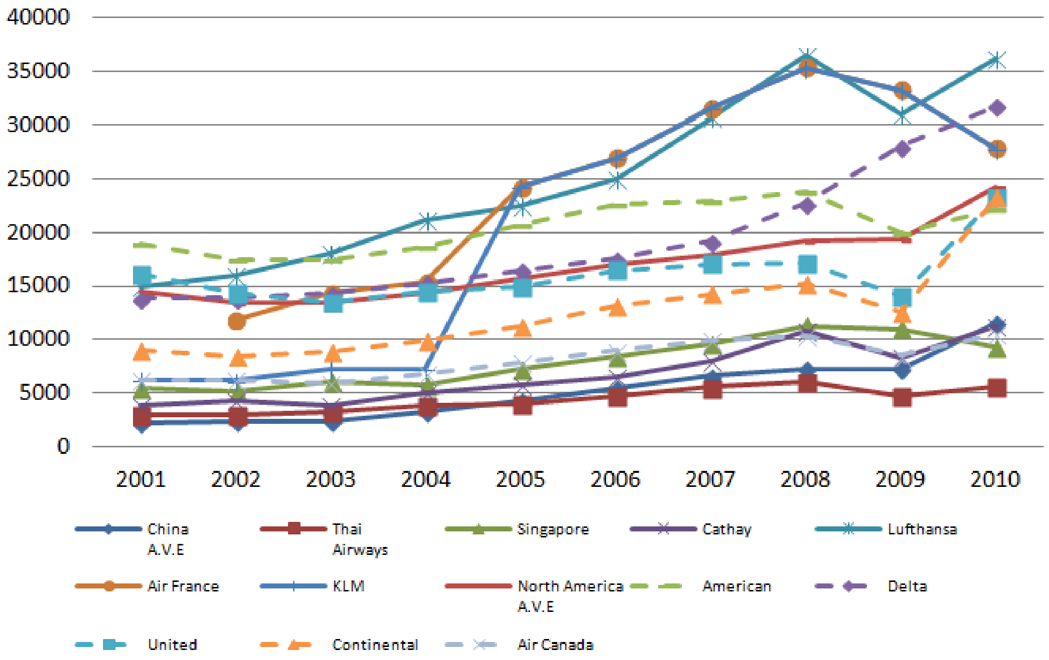

Figure 2-3. Total operating revenue for sample airlines (in millions of US dollars)

Source: Airlines' annual reports

As reported in 2-4 and 2-5, with regards to airlines' output mix, North American airlines rely mostly on passenger services, which typically account for 90% of their annual total revenues. Cargo and incidental revenues are a mere 10%. This is partly due to the presence of strong integrated carriers such as UPS and FedEx. The two Asia Pacific carriers in our sample, Singapore Airlines and Cathay Pacific, derive considerably larger proportions of their revenue from cargo operations than the other airlines in the sample. These two airlines have dedicated air cargo subsidiaries, SIA Cargo and Cathay Pacific Cargo, respectively. Cargo revenue share was 24% for Singapore Airlines and 29% for Cathay Pacific in 2005. Boeing's calculations, as presented in Figure 2-6, suggest that several other Asian airlines also have very large cargo operations. For example, the cargo segment made up 41% and 34% of EVA Air and Korean Air's total traffic revenue, respectively, in 2010. Many Asian airlines have benefited from the booming trade and manufacturing operations in the region. By comparison, the Big Three derive a mere 10% of their revenues from cargo operations. Clearly, they have not been able to fully exploit the market potential of the air freight business in China. The weakness of Chinese airlines in air freight operation is also clear manifested by their lack of freighters (see Table A1) and small market share of Chinese international air freight market (see Figure A2) In addition, Chinese airlines derived less incidental revenue than other leading carriers. Incidental revenue only accounted for around 5% of the total operating revenue for Big Three, while the same ratios were about 10% for North American airlines. Among all sample airlines, Lufthansa derived a higher proportion of revenue from incidental service, as the Lufthansa group owns many subsidiaries offering a variety of services such as aircraft maintenance, catering service, tour agency and IT services. Singapore airlines saw an increase of incidental services, including revenue from its subsidiaries such as the Singapore Airport Terminal Service Group (SATS), and SIA Engineering Group (SIAEC).

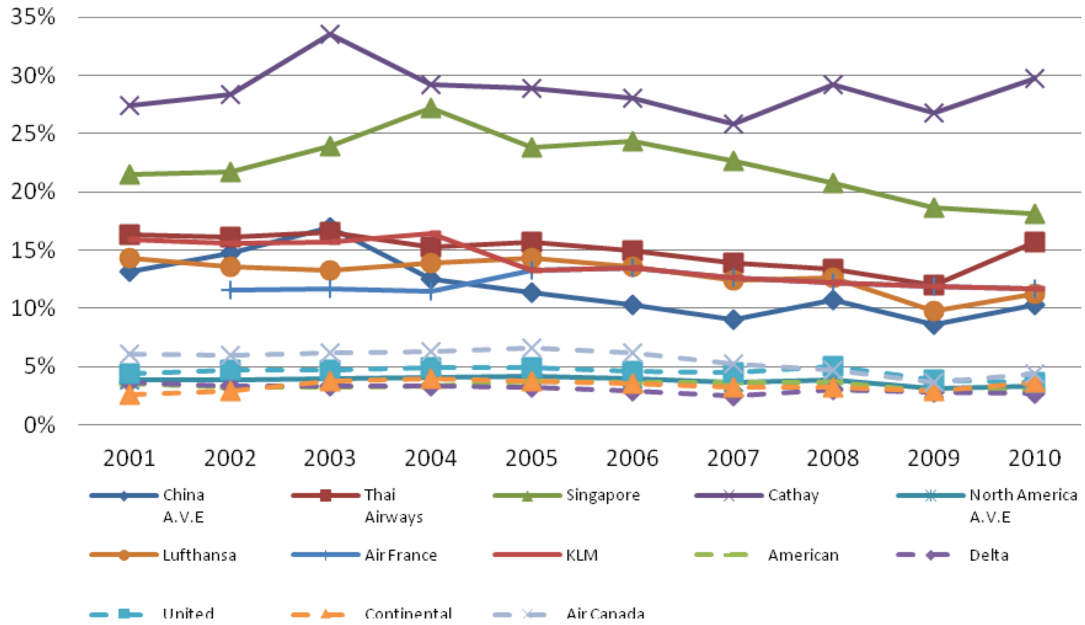

Figure 2-4. The share of cargo revenue for sample airlines

Source: Airlines' annual reports

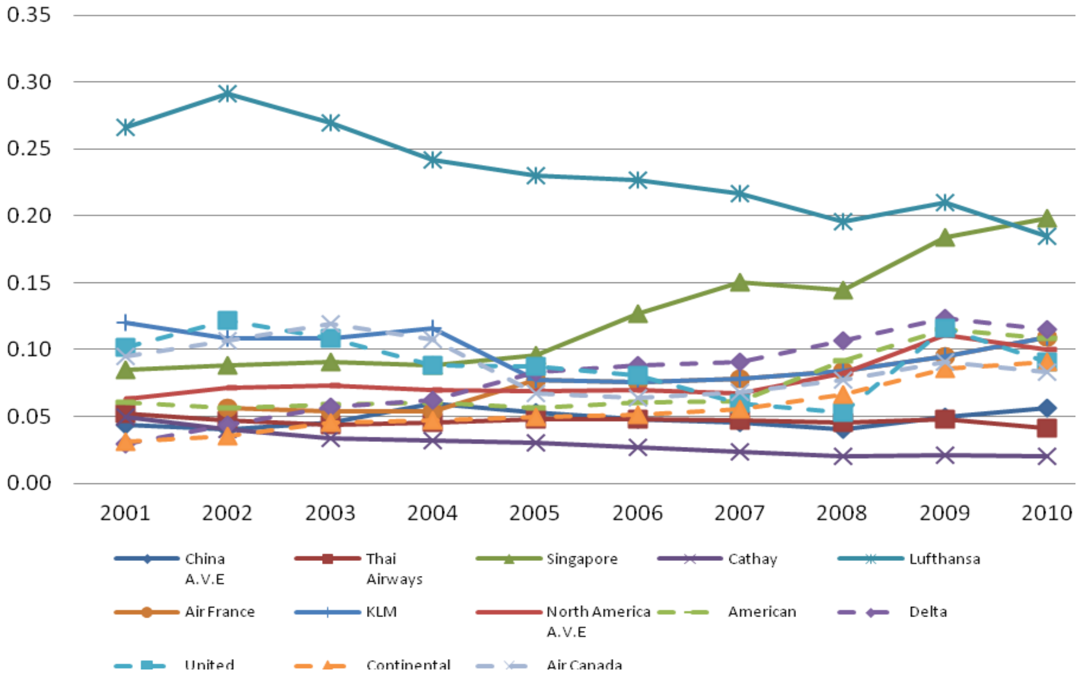

Figure 2-5. The share of incidental revenue for sample airlines

Source: Airlines' annual reports

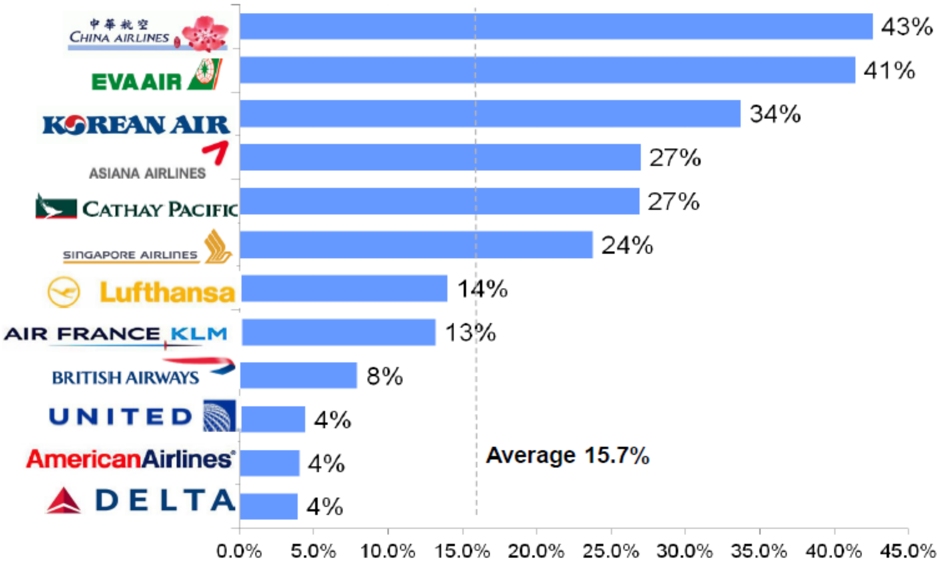

Figure 2-6. Percent of cargo revenue in airlines' total traffic revenue

Source: Jim Edgar, regional director of cargo marking, Boeing 2010.

2.3 TOTAL AND PARTIAL FACTOR PRODUCTIVITY

In this section, we calculate and benchmark airlines' TFPs and partial productivity. TFP measures the overall efficiency level of an airline, whereas partial productivity measures the extent to which particular inputs have been utilized.

2.3.1 TFP results and interpretations

The calculated TFP results are presented in Table 2-2. The TFP index of American Airlines in 2005 is normalized to one, and the other TFP values are normalized accordingly. To benchmark airlines' performance by region, the average TFP values for mainland China and North America are computed, and presented in Figure 2-7. Note that these gross TFP values have not been corrected for airlines' network configurations such as average stage length, market scale and route density (see Table 2-3). As shown in Table 2-3(a), the productivity leadership of Singapore airlines and Cathay Pacific are at least partly due to their much longer average stage length from extensive inter-continental services. In addition, US market has higher route density (ASK per route) and larger networks in terms of number of routes and airports, thus partly contributing to higher gross TFP levels of US carriers than those of the Big Three in China.

Table 2-2. Gross Total Factor Productivity (TFP) Index (Normalized at American Airlines 2005=1)

Year	China Eastern	China Southern	Air China	Chinese A.V.G	Thai Airways	Singapore	Cathay	American	Delta	United	Continental	Air Canada	North American A.V.G	Lufthansa	Air France	KLM
2001	0.49	0.51	0.50	0.50	0.68	1.12	1.04	0.72	0.77	0.79	0.88	0.76	0.78	0.64		0.85
2002	0.50	0.54	0.53	0.52	0.73	1.01	1.17	0.74	0.81	0.92	0.86	0.79	0.82	0.67	0.71	0.83
2003	0.49	0.50	0.54	0.51	0.66	1.01	1.11	0.85	0.89	0.99	0.98	0.80	0.91	0.65	0.75	0.82
2004	0.60	0.56	0.63	0.60	0.70	1.01	1.10	0.94	0.86	1.07	0.96	0.95	0.95	0.70	0.77	0.94
2005	0.56	0.57	0.68	0.61	0.70	1.10	1.10	1.00	1.01	1.11	0.99	0.91	1.01	0.72	0.89	0.89
2006	0.59	0.61	0.75	0.65	0.74	1.29	1.05	1.04	1.06	1.15	1.03	0.92	1.05	0.71	0.88	0.88
2007	0.63	0.66	0.76	0.69	0.78	1.32	1.03	1.05	1.01	1.14	1.06	0.94	1.05	0.74	0.90	0.90
2008	0.60	0.67	0.64	0.64	0.68	1.32	1.02	0.98	0.75	0.98	1.05	0.95	0.93	0.74	0.92	0.92
2009	0.62	0.68	0.75	0.69	0.74	1.33	1.10	1.02	1.03	1.12	1.09	0.91	1.04	0.71	0.95	0.95
2010	0.71	0.72	0.77	0.74	0.86	1.30	1.11	1.06	1.09	1.09	1.09	1.00	1.07	0.74	0.95	0.95

Note: 1. United Airlines and Continental Airlines merged in 2010. Thus the TFP for the two airlines in 2010 is for the new merged airline.

2. Air France and KLM merged in 2005. Thus the TFP for the two airlines from 2005 to 2010 are for the new merged airline.

3. The weight used to calculate the Chinese and North American average TFP is the airlines' revenue share.

(Unless otherwise stated, the above three notes apply to other calculated statistics).

Table 2-3. Network configurations for selected airlines and major aviation markets

(a) Mean of average stage length for sample airlines from year 2001 to 2010

Airlines	**China Eastern**	**China Southern**	**Air China**	**Thai Airways**	**Singapore**	**Cathay**	**American**
Average Stage Length	1146	1111	1429	2328	3918	3357	1762
Airlines	**Delta**	**United**	**Continental**	**Air Canada**	**Lufthansa**	**Air France**	**KLM**
Average Stage Length	1466	2171	1616	1372	1527	1412	1986

Source: Compiled with airline schedule data from OAG database

(b). Number of routes /airports and average ASK (million) per route for Chinese and US domestic aviation markets

	Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
No. of Routes	**China**	1,518	1,450	1,522	1,263	1,435	1,541	1,802	1,840	2,015	2,195
	US	6,321	6,003	6,199	6,262	6,493	6,426	6,711	6,773	6,169	6,188
No. of Airports	**China**	116	114	114	110	123	130	143	145	154	156
	US	559	534	552	541	555	550	546	526	511	508
ASK per route	**China**	72	85	110	126	130	139	137	145	160	170
	US	193	189	183	191	186	183	181	170	173	175

Source: Compiled using data from OAG database. An airport is counted if the number of scheduled seats in that year was greater than 10,000. A route is counted if the number of scheduled flight that year was greater than 52, or on average one flight per week.

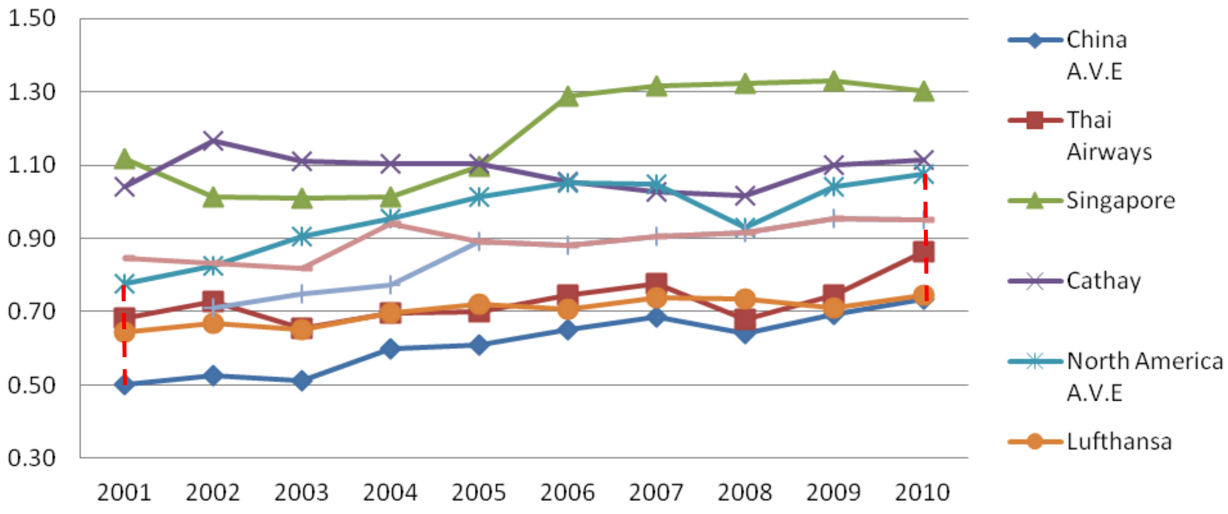

Figure 2-7. Gross TFP (Normalized at American Airlines 2005=1)

Overall, Chinese airlines' productivity improved steadily from 2001 to 2010, with an average TFP increase of 48% during this period (from 0.50 to 0.74). However, the productivity gap between Chinese and North American airlines did not shrink in terms of absolute value. In 2001 the difference in average TFP between Chinese and North American airlines was 0.28. This gap actually increased to 0.33 in 2010. Overall, although Chinese airlines have improved their corporate management and productivity levels over the years, they have not been able to adopt in a timely manner the best industry practices in airline operations and management pioneered by their international peers. One key cause could be the majority state ownership, which does not provide sufficient incentive or freedom to airline managers to improve corporate management. In addition, the domestic market is not as competitive as the mature markets in Europe and North America. As a result, Chinese carriers face less pressure to reduce costs and increase efficiency.

As expected, external shocks such as the 9/11 incident, the SARS epidemic in 2003, and the financial crisis in 2008 had negative effects on airline productivity. For example, the average TFP for North American airlines decreased from 1.05 in 2007 to 0.93 in 2008. Despite China's healthy GDP growth, Chinese airlines also experienced TFP decline from an average of 0.69 in 2007 to 0.64 in 2008. The severe financial tsunami reduced traffic demand sharply. However, airlines' inputs, such as fleet and labor force, cannot be adjusted instantaneously, leading to poor TFP performances in the short-term in 2008. There has been a quick rebound in airlines' TFP since 2009. Demand recovered faster than expected with coordinated stimulation efforts globally, and airlines' aggressive cost-cutting strategies combined with the low fuel price in 2009 helped to get airlines back on their feet. Overall, it can be seen that external shocks did not change the long-term TFP growth pattern. The aviation industry has proved to be resilient to short-term shocks.

2.3.2. Partial Factor Productivity

In addition to TFP, we also compute several Partial Factor Productivity measures to identify possible sources of productivity growth. In this section, labor, fuel, and capital productivity are calculated using a method similar to those adopted in Gillen et al. (1985). The calculation details are explained in the following sub-sections.

2.3.3.1. Labor Productivity

Labor productivity is usually measured by output per employee. Employee to aircraft ratio is a popular index in the airline industry, obtained by dividing the total number of employees by the number of aircrafts. A higher ratio may suggest labor redundancy, but it may also be ascribed to higher service level. The calculated employee to aircraft ratios are summarized in Table 2-4. However, without controlling for other factors, this measure provides rather mixed conclusion: Chinese airlines did have much higher employee to aircraft ratio than U.S. carriers. However, Chinese airlines appeared to be comparable to most other airlines. In fact, European airlines in our sample had even higher ratios. Clearly, without controlling for the composition of labor force[4] (e.g. number of employees for operation, marketing and management etc.) and fleet mix (i.e. a Boeing 747 clearly requires more support than a Boeing 737), employee to aircraft ratio is not a very precise measure for labor productivity.

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[4] Organizations such as ICAO provide some statistics for labor force in each category (e.g. cabin crew, pilots etc.), however, not all sample airlines are included in these databases. We have compiled our data from airline annual reports, which don't contain detailed labor force breakdown. Therefore we are not able to conduct in-depth analysis on this issue.

Output can be measured by either Revenue-Tonne-Kilometers[5] (RTK) or total revenue. Both the RTK per employee and revenue per employee values are reported as in Figures 2-8 and 2-9. Overall, Chinese airlines' labor productivity gradually improved over the study period. The average RTK per employee for Chinese carriers rose from 177 thousand to 233 thousand, a 32% increase. Revenue per employee almost doubled, increasing from USD113,000 in 2001 to USD200,000 in 2010. However, one should be cautious in interpreting this increase in revenue per employee as a pure productivity gain. Multiple factors, such as the substantial appreciation of the Chinese RMB during this period, may have contributed to revenue increases. As well, the airlines' revenue may not be an objective measure of airlines' output level as airlines are operating in different markets and based in different countries. Thus the revenue per employee adjusted by countries' Purchasing Power Parity (PPP) is also computed and reported in Table A2 of Appendix. In addition, as several major mergers occurred during the sample period, it is likely that the consolidated airline groups acquired higher pricing power. Thus, one should refer to RTK per employee as the objective measurement of labor productivity in this study.

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[5] RTK includes both airline's passenger RTK and freight RTK.

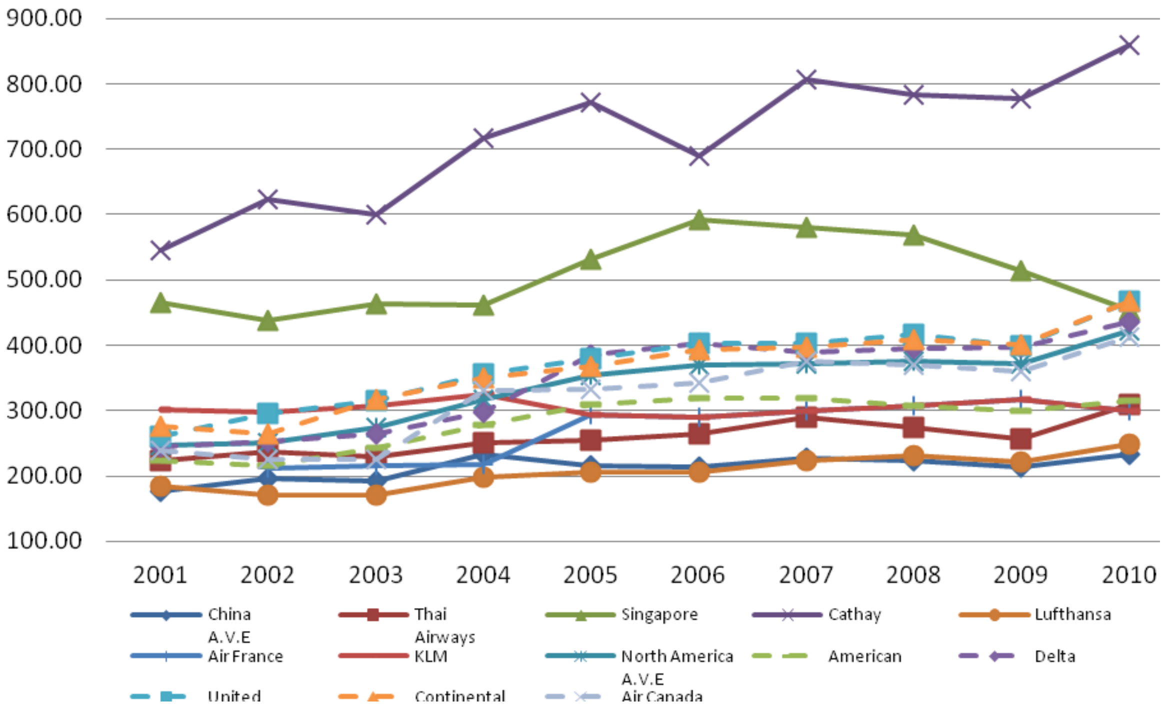

Figure 2-8. RTK (1000) per employee

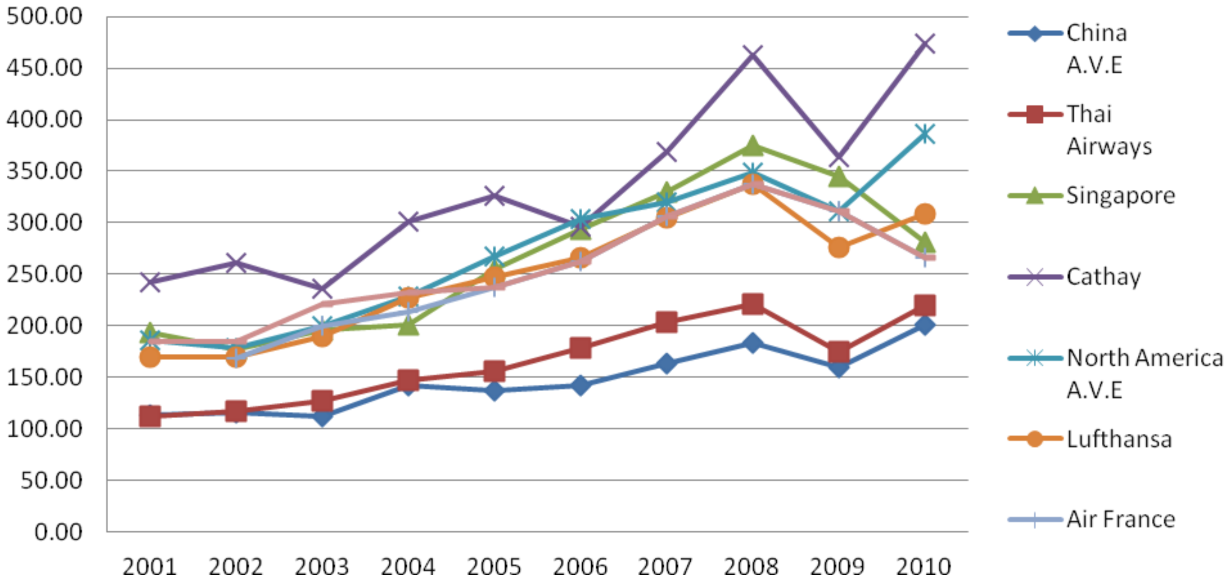

Figure 2-9. Revenue (1,000 USD) per employee

Table 2-4. Employee to Aircraft Ratio

Year	**China Eastern**	**China Southern**	**Air China**	**China A.V.G**	**Thai Airways**	**Singapore**	**Cathay**	**American**	**Delta**	**United**	**Continental**	**Air Canada**	**North America A.V.G**	**Lufthansa**	**Air France**	**KLM**
2001	192.9	147.5	224.4	191.9	320.5	304.7	206.4	90.7	93.7	154.7	82.2	93.7	111.5	255.0		244.7
2002	168.8	139.6	227.4	185.5	315.0	286.6	200.8	99.2	90.4	127.0	79.2	98.9	101.6	273.6	181.6	237.6
2003	169.4	133.1	208.4	175.2	315.2	263.9	181.0	92.6	84.8	118.4	65.1	103.3	94.1	248.2	187.7	252.2
2004	202.1	119.1	194.2	173.7	311.9	266.5	177.3	90.9	81.8	122.7	64.4	90.9	91.6	246.0	192.6	175.3
2005	162.8	131.9	175.8	156.2	297.4	248.4	172.0	88.3	85.8	123.9	63.6	87.9	91.2	210.2	179.7	179.7
2006	187.3	152.9	159.6	165.5	304.5	242.0	185.3	86.3	85.5	119.6	64.4	82.8	88.8	217.5	178.1	178.1
2007	181.5	137.8	162.7	159.1	303.2	240.7	137.3	89.9	95.2	119.6	67.5	75.4	81.5	196.5	174.1	174.1
2008	184.0	141.7	135.4	151.3	305.5	229.7	144.6	94.3	91.9	116.7	64.0	77.9	78.6	202.5	168.3	168.3
2009	178.7	139.3	153.8	155.0	296.7	243.0	140.6	88.7	82.5	68.2	66.0	74.0	76.7	155.6	166.8	166.8
2010	160.8	160.3	139.0	152.9	287.6	244.3	141.5	85.6	97.8	74.3	74.3	72.7	81.2	164.9	167.6	167.6

However, when benchmarked to other leading airlines, Chinese carriers still have plenty of room for improvement. Their RTK/revenue per employee levels are among the lowest in the sample. In theory, as the labor input price in China is much lower than in developed economies, it is economically optimal for Chinese airlines to use more labor to substitute for (relatively) more expensive capital inputs, which may explain their poor labor productivity. Several airline managers interviewed by us rejected such a hypothesis, blaming for substantial inefficiency in the aviation industry in general. They suggested that with decent profitability in recent years, Chinese carriers had made a lot of investments on automation and capital investments. However, it takes time for the industry to streamline its business process and improve operational efficiency. For example, although computer databases for cargo bills and shipments have been developed by airlines, airports, freight forwarders and customs, these systems don't talk to each other, and thus, a lot of repeated data entry jobs are done manually. Such a process is labor extensive and prone to errors. Despite the rapid increase in salary levels in China, the gap in labor productivity between airlines in China and other regions actually grew. Airlines in most markets, especially those in the United States, have undergone painful restructuring processes as a response to a series of negative shocks. Chinese airlines, in contrast, have benefited from the strong growth in the domestic market. As a result, they face less pressure in cost cutting in a growth market. Low labor productivity has certainly been a major contributing factor for Chinese airlines' low TFP scores.

Chinese airlines' low labor productivity will worsen the shortage in human resource supply. The compensation level in the aviation industry has outpaced the overall salary growth in China. Still, the labor supply in the Chinese aviation industry has barely kept up with the rapid market expansion, partly due to the specialized knowledge and skills required by the aviation industry. The Chinese Academy of Personnel Science estimates that in the next 20 years, China will face a shortage of 240,000 personnel in the aviation industry[6]. Many medium sized airlines and private airlines already face great challenges in recruiting sufficient pilots. Spring airlines and Juneyao airlines had to hire expat pilots. Chinese

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[6] See the link from the Xinhua news agency website: http://big5.xinhuanet.com/gate/big5/news.xinhuanet.com/fortune/2007-06/17/content_6252277.htm

airlines need to improve their labor productivity to cope with fast market growth and rising labor costs.

2.3.3.2. Fuel productivity

In addition to labor productivity, we also calculated fuel productivity (see Figure 2-10). Fuel productivity is measured as RTK per gallon of fuel consumed. The values for Chinese airlines' fuel efficiency are fairly stable, at around 9.0 RTK per gallon of fuel consumption. Chinese airlines' fuel performances are better than those of North American airlines, whereas Singapore Airlines and KLM have the highest fuel efficiency, partly due to their young fleets and network configuration. Overall, the average fuel efficiency of Chinese airlines is comparable to those of other airlines, confirming our conjecture that their labor productivity is the major reason for the poor TFP values.

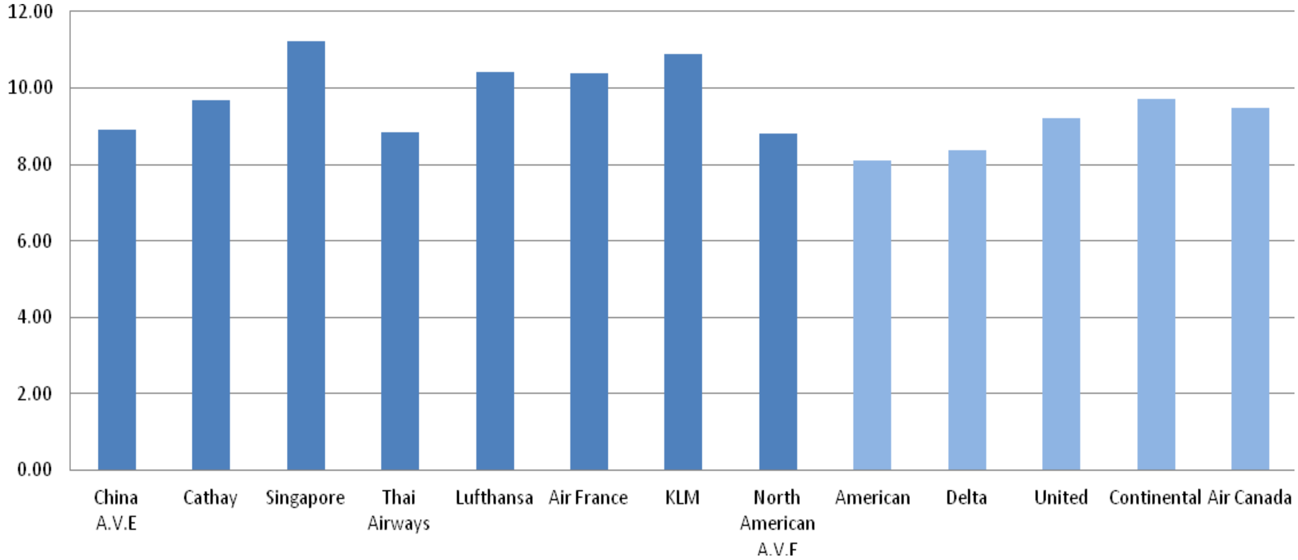

Figure 2-10. RTK per gallon fuel consumption (average for 2001 to 2010)

Our investigation of the Total and Partial Factor productivities of the sample airlines suggests that although Chinese carriers have achieved steady productivity growth during the last decade, they still lag behind their counterparts in developed markets. Chinese airlines must quickly learn the industry's best practices and improve their efficiency levels to achieve competitiveness in international markets.

2.4. YIELD, UNIT COST, AND INPUT PRICE BENCHMARKING

Productivity is an essential measure for evaluating an airline's performance. However, productivity alone cannot explain a firm's overall performance. Despite their low productivity, Chinese airlines were able to achieve higher profits than the more efficient airlines in other markets during the study period. To identify the source of such high profitability, this section benchmark airlines' average yield, unit cost, and input price levels.

2.4.1. Average yield and unit cost

An airline's yield is an important determining factor of its overall financial performance. Average yield is calculated by dividing total passenger revenue by total revenue passenger kilometers (RPK). Our calculation results at company level suggest that Chinese airlines' average yields were fairly stable during the 2001 to 2005 period, when the Chinese RMB was pegged to the US dollar. Average yields had increased since 2005 and reached 8.97 US cents per RPK in 2008, a value close to that of North American carriers (9.11 US cents). In 2009 and 2010, Chinese airlines' average yields exceeded their North American counterparts by 0.18 and 0.85 US cents, respectively. Even after adjusting the impact of average stage length on the yields, the Chinese airlines yields in year 2009 and 2010 are quite comparable to US (see Figure A3 in Appendix). This illustrates the substantial pricing power of the Big Three in our sample. This is partly due to market consolidations, particularly the consolidation of nine major airlines into the Big Three between 2002 and 2004. Average yields for Chinese airlines increased by 32%, from 7.09 US cents in 2005 to 9.33 US cents in 2010. It appears that there has been insufficient competition in the Chinese domestic market, and thus airlines' record profits could have been achieved at the expense of consumers and the overall economy.

As all of the airlines in our sample derived substantial revenue from international routes, the average yield at the company level may be misleading. Therefore, we compute route-specific yields in the Chinese domestic market, as reported in Table 2-5(a). Table 2-4(b) reports US carriers' average yield at the company level, including both domestic and international services. As US network carriers are likely to have lower yields in long haul international flights, it is probably more reasonable to compare the Big Three's average yield with those of US regional carriers. Still, Chinese airline's yields are higher than or at least comparable to the US regional carriers. This clearly indicates that the Big Three have acquired substantial pricing power over the years.

Table 2-5. Yield comparison between Chinese and US airlines

(a) Average yield for different categorized Chinese domestic routes (USD/Kilometer)

Route Category	**2008-Q4**	**2009-Q1**	**2009-Q2**	**2009-Q3**	**2009-Q4**	**2010-Q1**	**2010-Q2**
Top 1- Top 50	0.096	0.101	0.101	0.118	0.111	0.109	0.122
Top 51- Top 150	0.098	0.105	0.104	0.117	0.110	0.110	0.117
others	0.117	0.119	0.119	0.130	0.124	0.124	0.130
All	0.114	0.117	0.116	0.128	0.122	0.122	0.128

Note: The yield is calculated by dividing ticket price by flying distance. The fare data is from PaxIS. Flying distance is from OAG. The data are for the "Big Three" airlines only.

(b) Average yield for US Carriers (USD/kilometer)

Airline Group	**2008-Q4**	**2009-Q1**	**2009-Q2**	**2009-Q3**	**2009-Q4**
Regional	0.121	0.117	0.103	0.098	0.104
Low-Cost	0.084	0.075	0.071	0.071	0.078
Network	0.083	0.075	0.068	0.070	0.075
21-Carrier Total	0.085	0.077	0.071	0.071	0.078

Source : US DOT.

Apart from pricing ability, an airline's unit cost also determines its profitability. Following Oum and Yu (1995), we construct a unit cost index by dividing total cost by the multilateral output index, which is then normalized by setting the value of American Airlines in 2005 to one. As shown in Figure 2-11, Chinese airlines' unit costs remain lower than those of the airlines in North America and Europe. Although Chinese airlines are less productive, they enjoy lower input prices compared to carriers in developed countries. However, this cost advantage has been gradually diminishing over the years. In 2001, Chinese airlines on average had a 28.1% lower unit cost than North American carriers. By 2010 this number had decreased to a mere 6.25%.

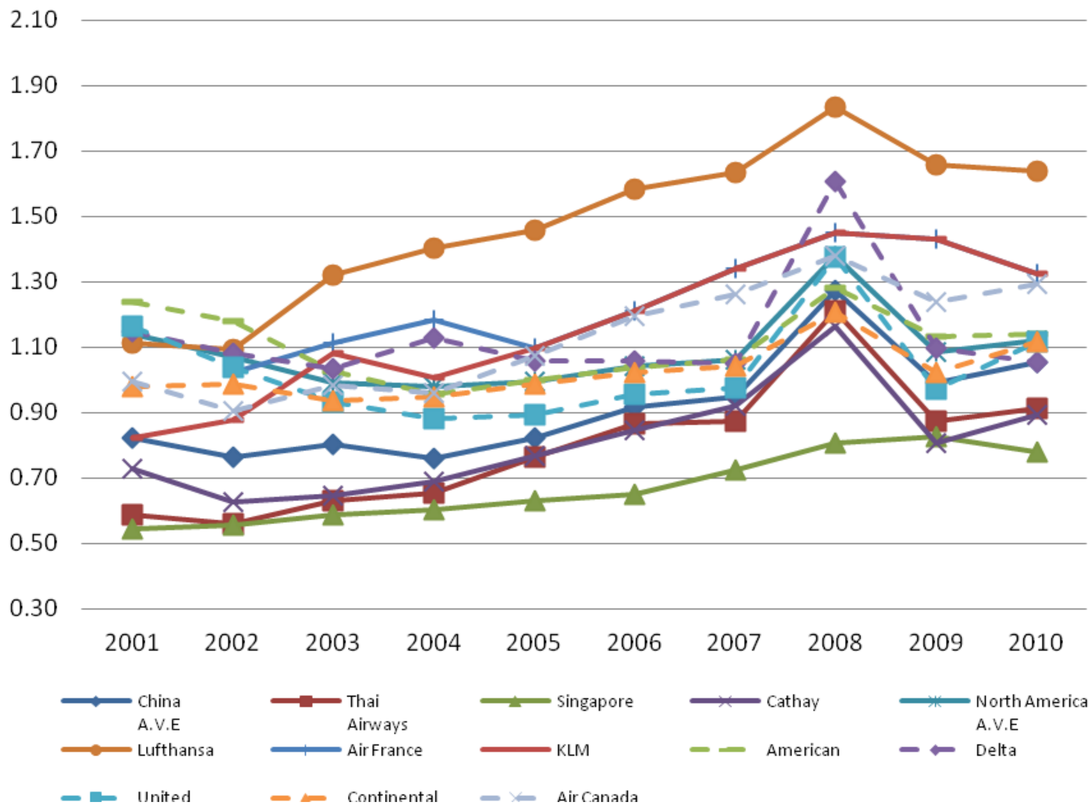

Figure 2-11. Unit Cost Index (Normalized at American Airlines 2005=1)

There are two reasons for the shrinking unit cost difference between Chinese and North American airlines. First, the rapid appreciation of the Chinese Renminbi (RMB) since 2005 has inflated the Chinese airlines' costs as reported in US dollars. Second, North

American airlines had very tight cost control during this period due to aggressive restructuring efforts. The average unit cost index for North American airlines decreased from 1.14 in 2001 to 1 in 2005, then rebounded moderately to 1.12 in 2010. Several North American airlines experienced severe financial difficulties during this period. United Airlines and Delta applied for bankruptcy protection in 2002 and 2005, respectively. North American airlines exerted great efforts in cost saving during this period to survive.

2.4.2. Input prices

The differences in unit costs among airlines can be explained by airlines' productivity levels and disparity in input prices. Clearly, it is much easier for carriers with lower input prices to achieve lower unit costs. Thus, it is important to examine the airlines' input prices. As labor and fuel jointly account for over 60% of an airline's total operating expenses, their prices are compared and presented in Table 2-6 and Figure 2-12, respectively. To calculate labor price we divided the total labor cost by the total number of full-time employees. The fuel price is the average cost per a gallon.

Figure 2-12. Fuel Price (USD per American gallon)

Table 2-6-1 . Labor price (1,000 USD per year)

Year	**China Eastern**	**China Southern**	**Air China**	**Chinese A.V.G**	**Thai Airways**	**Singapore**	**Cathay**	**American**	**Delta**	**United**	**Continental**	**Air Canada**	**North American A.V.G**	**Lufthansa**	**Air France**	**KLM**
2001	6.92	9.97	7.77	8.28	19.65	41.23	60.76	76.57	80.29	84.29	70.42	52.07	76.09	45.58		44.39
2002	7.97	11.85	9.38	9.85	20.33	33.67	62.41	76.57	82.09	97.63	67.40	49.08	78.70	46.59	50.18	49.43
2003	10.65	11.32	10.69	10.88	21.05	41.73	64.05	75.35	89.83	85.35	81.10	56.49	80.01	54.91	60.85	65.15
2004	10.83	16.10	12.12	12.96	25.51	40.48	68.11	72.95	91.66	82.07	73.69	72.81	79.46	64.44	70.68	75.29
2005	9.83	14.14	13.59	12.78	27.72	51.30	66.15	76.41	94.97	70.65	67.01	63.85	76.64	66.46	73.02	73.02
2006	11.56	13.29	16.54	13.90	30.62	54.68	57.98	78.67	85.09	77.58	69.97	67.83	77.19	67.44	77.86	77.86
2007	14.05	16.64	19.13	16.74	34.65	62.14	71.32	79.18	76.10	77.47	73.80	74.79	76.68	74.67	88.84	88.84
2008	14.82	19.58	25.67	20.39	33.79	68.20	68.13	79.13	80.14	86.22	73.08	67.78	78.39	77.11	98.23	98.23
2009	16.41	18.76	24.26	20.08	28.29	54.98	71.05	86.27	84.31	80.28	79.14	62.38	81.07	74.16	95.06	95.06
2010	23.13	19.40	27.93	23.60	40.88	47.67	75.44	87.50	84.72	89.32	89.32	76.76	86.45	75.34	93.44	93.44

Table 2-6-2 . Labor price (1,000 USD per year) adjusted by PPP

Year	China Eastern	China Southern	AirChina	China A.V.E	Thai Airways	Singapore	Cathay	American	Delta	United	Continental	Air Canada	North America A.V.E	Lufthansa	Air France	KLM
2001	20.92	30.15	23.49	25.06	78.62	77.60	66.39	76.57	80.29	84.29	70.42	66.21	77.45	58.58		57.05
2002	24.34	36.18	28.65	30.06	79.18	64.86	71.68	76.57	82.09	97.63	67.40	62.65	80.11	57.12	61.53	60.60
2003	32.33	34.37	32.46	33.02	79.71	81.02	79.71	75.35	89.83	85.35	81.10	64.55	80.82	55.73	61.76	66.12
2004	31.59	46.96	35.34	37.81	93.29	75.04	90.34	72.95	91.66	82.07	73.69	76.98	79.90	59.63	65.41	69.68
2005	28.18	40.54	38.97	36.65	100.15	94.68	90.58	76.41	94.97	70.65	67.01	63.75	76.63	62.28	68.44	68.44
2006	32.03	36.84	45.83	38.52	102.05	97.32	82.16	78.67	85.09	77.58	69.97	63.69	76.71	64.74	74.73	74.73
2007	35.45	41.97	48.25	42.23	104.40	101.34	101.02	79.18	76.10	77.47	73.80	66.34	75.68	66.31	78.90	78.90
2008	32.28	42.67	55.94	44.44	96.37	107.69	96.98	79.13	80.14	86.22	73.08	58.59	77.32	65.27	83.14	83.14
2009	35.63	40.74	52.69	43.60	82.09	87.60	101.83	86.27	84.31	80.28	79.14	59.55	80.78	66.95	85.81	85.81
2010	47.23	39.62	57.02	48.20	107.03	71.91	109.38	87.50	84.72	89.32	89.32	64.73	85.32	70.66	87.64	87.64

It is obvious that Chinese airlines enjoy much lower labor input prices than other airlines. Although the average salary in Chinese airlines substantially increased from USD8,280 in 2001 to USD23,600 in 2010, the final salary level is still only about one third of the levels of North American and European airlines. As shown in Figure 2-13, on average, labor only accounted for 10% of Chinese airlines' total operating costs. In contrast, this ratio was above 25% for North American and European airlines, and was 20% for the selected Asian carriers. Although Chinese airlines do enjoy substantial advantages due to the low labor input price in China, in the long-run such an advantage is likely to be eroded. To compete successfully in the global market, Chinese carriers need to retain the best managerial/professional personnel with competitive remuneration packages, especially when they expand their service network overseas. In addition, the relatively tight supply of trained aviation professionals will also drive up industry salary levels.

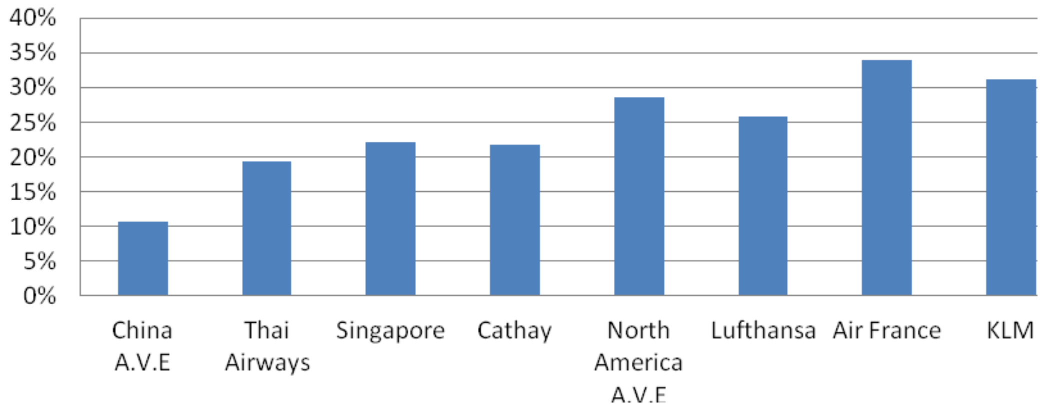

Figure 2-13. The share of labor cost (average for 2001 to 2010)

Although Chinese airlines enjoy lower labor and material input prices, their fuel input prices were higher than North American carriers in most years during the sample period. Aviation fuel supply in China is controlled by the China National Aviation Fuel Ltd., a state-owned monopoly. As fuel prices have remained high in recent years, the detrimental effects of such a monopoly are likely to be more significant, reducing Chinese carriers' competitiveness in international markets. Figure 2-11 shows the tremendous increase in fuel prices in recent years; they have almost doubled from around USD1 per gallon in 2001 to more than USD2 in 2010. The poor financial performance of most airlines in 2008 was due to record fuel prices. The age of cheap fuel is probably gone forever. As fuel accounts for a high proportion of Chinese airlines' total costs, it is important for the Chinese government to help its airlines cope with high fuel prices. Allowing one company to monopolize a nation's aviation fuel supply is unlikely to be the right answer.

2.5. SUMMARY AND CONCLUSION

In the past decade, the Chinese airline industry experienced extraordinary growth in scale and profitability. However, no quantitative study has investigated Chinese airlines' performance in terms of productivity and cost competitiveness. As a result, apart from the country's strong economic growth, the forces driving this phenomenal development remain unclear. This study quantifies the recent developments in the Chinese aviation market by investigating the performances of leading Chinese carriers during the 2001 to 2010 period, and benchmarks the results with representative airlines from Asia, North America and Europe. Our analysis suggests that Chinese airlines steadily improved their operational efficiency during the sample period. However, they still lag behind leading airlines in developed markets. Chinese airlines' Total and Partial Factor productivities are lower than those of their international peers, especially those from North America. There has been no productivity convergence between carriers in China and North America, making it difficult for Chinese airlines to enhance their competitiveness in the international markets.

Our findings also identify several factors that account for Chinese airlines' remarkable profitability, in spite of their low productivity. First, Chinese airlines enjoy much lower input prices compared to those of their international peers. Even after the substantial salary increases during the sample period, Chinese airlines' average labor remuneration is merely one third of what major US airlines are paying. This allows Chinese carriers to achieve lower unit costs than their foreign counterparts. Meanwhile, Chinese airlines were able to charge similar or even higher prices than US carriers due to the high market concentration and absence of strict implementation of anti-trust laws in the Chinese domestic market. The rapid appreciation of the RMB also contributed to Chinese airlines' high profit margin in the last decade. Although fleet purchases are usually financed in US dollars, the majority of the airlines' revenues are from domestic markets. However, in the long-term, currency appreciation will also lead to input price increase. Chinese airlines will eventually have to rely on efficiency and productivity gains.

Overall, although Chinese airlines have indeed improved their corporate management and productivity levels over the years, they have not adopted the best industry practices pioneered by their international peers in a timely manner. The Chinese government's policy reforms are steps in the right direction, but the deregulation efforts have been incomplete and inadequate. The Chinese government should embrace the global trend of deregulation and liberalization more enthusiastically, and allow more competition in both the airline markets and inputs supply market.

CHAPTER 3

INVESTIGATING THE IMPACTS OF INTRODUCTING EMISSION TRADING SCHEME TO SHIPPING INDUSTRY

3.1 INTRODUCTION AND BACKGROUND

International shipping is the most energy efficient means of transportation in terms of CO_2 emission per ton-mile cargo shipped. However, due to the enormous cargo volume, it still contributes a significant part of the global emission. According to International Maritime Organization (IMO), international shipping emitted 870 million tons of CO_2 in year 2007, or about 2.7% of global CO_2 emissions from fuel consumption. Considering the sustained growth of international shipping driven by world economic development, CO_2 emissions from this sector is expected to triple by 2050. In contrast, the Cancun Agreement reached during the 2010 meeting of the United Nations Framework Convention on Climate Change (UNFCCC) proposed that temperature increase compared to pre-industrial revolution cannot exceed 2°C, which requires global green house gas (GHG) emission to be reduced by 50% below the 1990 level by 2050 (European Commission (EU) 2013a). Therefore, the shipping industry has an important role to play in the global CO_2 emission control.

CO_2 emissions from International aviation and shipping are not covered by the Kyoto Protocol. Instead, they are handled through the International Civil Aviation Organization (ICAO) and IMO respectively. The Marine Environment Protection Committee (MEPC) of IMO has been evaluating various policy options to reduce GHG emissions from ships. Many technical and operational measures have been formulated by MEPC, such as the Energy Efficiency Design Index (EEDI), the Ship Energy Efficiency Management Plan (SEEMP), and the Energy Efficiency Operational Indicator (EEOI). To motivate the shipping industry to adopt the most efficient operational practices, IMO has also been considering possible market-based measures (MBMs) in international shipping. European Commission (2013a) noted that despite the adoption of ship efficiency standards, EU-related emissions from shipping are expected to increase by 51% during 2010-2050, and thus, both the IMO and the European Commission recognize that MBMs are needed in addition to technical and operational measures. European Commission (2013a) suggested a gradual approach consisting three subsequent steps: (1) implementing a system of monitoring, reporting and verification of emissions; (2) definition of reduction targets for the international shipping; (3) application of a MBM.

Among the MBMs being considered, one of the most promising alternatives is the Emission Trading Scheme (ETS) (Kageson, 2007; Miola et al, 2011). In the US, the trading programme of SO_2 has been very successful (Klaassen 1996). Since the initial launch in 2005, the EU ETS has become by far the largest ETS in the world, including about 12,000 installations, representing 45% of EU emissions of CO_2 (Grubb 2006, Wrake et al. 2012). However, there has been rather limited progress in reducing CO_2 emissions from the international shipping sector[7] (European Commission 2013b). Whereas numerous political and institutional factors might be blamed for such a slow progress, some important issues remain to be studied and evaluated concerning the ETS itself. An ETS involving the shipping industry can be either "open" or "closed". In an open system, shipping companies can trade emission permits with other industries (e.g., electricity generation, manufacturing, agriculture), while in a closed ETS shipping companies can only trade among themselves. In theory, an open / broader ETS is preferred since it allows emission permits to be efficiently allocated among different sectors. In the study commissioned by the Federal Environment Agency of Germany, Kageson (2007) argued that international shipping is growing fast and associated CO_2 emissions are estimated with a high degree of uncertainty. Therefore, it is difficult to identify an appropriate emission cap. In a closed system the cap has to be more generous, since an excessively tight cap can hardly be changed at a later stage. In contrast, an open system has the advantage of allowing trade with other industries. The large scale of an open-system also makes the system to be more transparent. However, a closed ETS restricted to a particular industry / sector also has its own advantages. Studies such as Schmidt et al. (2004), Bosi and Ellis (2005) argued that sectroal mechanism may be more feasible than a broad mechanism from a policy, institutional and economic perspective. It is

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[7] As stated in European Commission (2013b), "The Council and the Parliament recalled an earlier commitment to take action in the Climate and Energy Package adopted on 23 April 2009: 'in the event that no international agreement which includes international maritime emissions in its reduction targets through the International Maritime Organisation has been approved by Member States or no such agreement through the UNFCCC has been approved by the Community by 31 December 2011, the Commission should make a proposal to include international maritime emissions in the Community reduction commitment, with the aim of the proposed act entering into force by 2013.' .... This deadline has passed without sufficient international action."

relatively easy to target a given sector instead of the entire economy. Building technical capacity and data collecting are more manageable at a sectoral level. In addition, in certain industries, a few multinationals hold a prominent market share. These firms may easily diffuse the best practices. In summary, both broad and sector-specific mechanisms are being considered by regulators and government agencies, and no definite decision has been made.[8]

Clearly, the implications to the shipping industry are different under these two types of ETSs. Yet, few studies are available in public domain investigating these important issues. In addition, the shipping industry is not composed of homogeneous carriers. Different types of cargo are carried in specialized ships which have different operational costs and energy efficiency. The market structure and firm conduct are also different across shipping sectors. For example, compared with container ships, on average, it is generally perceived that dry bulk ships are older, less expensive and less energy efficient. Bulk cargos tend to have lower value per ton, and thus ship speed is generally lower compared to container ships. In terms of market structure, the container shipping market tends to be less competitive due to high market concentration, and the existence of liner conferences and alliances (Cullinane and Khanna 2000; Song and Panayides 2002). Therefore, the ETSs under consideration would have differential impacts on the various shipping sectors, and thus, differential effects to international trade as international shipping is one indispensible component in global supply chain (Song and Panayides 2008, Cristea et al. 2013).

Apparently, any proposed mechanism need to be endorsed or supported by major stake-holders. Without a good assessment and a clear understanding of the associated consequences, it will be difficult for the sectors within the international shipping industry to reach a consensus toward the proposed emission reduction schemes. The international shipping industry, together with other major stake-holders, would prefer postponing decision-making in the presence of unknown risks and market changes. Bosi and Ellis (2005) called for careful investigations, as *ex ante* studies are needed for the formation of a mechanism, whereas *ex post* studies are needed to monitor and evaluate progress. However, previous emission control studies on international shipping have mostly focused on operations and technologies (see for example Eyring et al. 2005, DNV 2010), emission

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[8] For detailed and updated information related to mechanism design and choice, see for example UNFCCC's reports at http://unfccc.int/bodies/awg-lca/items/4488.php and OECD/IRA's reports at http://www.oecd.org/env/cc/scaling-upmarketmechanisms.htm

volume and cost simulation (see for example Wang et al. 2007, Buhaug, et al. 2009, Eide, et al. 2009, 2011, Liao et al. 2010), or emission permit allocation mechanisms (see for example Kling and Zhao, 2000; Haites, 2009; Hepbrun et al, 2006). Although a few studies did provide comprehensive evaluations of alternative emission control policies (see for example Delft et al. 2006, Kageson 2007, Eide et al. 2011), they have rarely analyzed the economic implications to the international shipping industry other than estimating the cost increase caused by ETS. Differential impacts to various sectors within the international shipping industry have not been touched upon either. Since the inception of EU ETS in 2005, a number of economic studies have been carried out, investigating a wide range of issues such as cost pass-through ratio and effects on end product's prices (Kim et al, 2009, Chen et al. 2008, Sijm et al. 2006), effects on firms' profitability and stock prices (Smale et al. 2006, Oberndorfer, 2009, Demailly and Quirion 2006, Veith et al. 2009, Mo et al. 2012), alternative emission permit allocation methods (Bode, 2006) and geographic and country differences (Knight 2011, Viguier et al. 2006). Although these studies provide rich insights on EU ETS, they have mostly focused on one single sector (i.e. the power generation industry) without investigating the implications of an open vs. a closed scheme. The implications of differences across sectors within an industry are not considered either. Therefore, these studies don't provide direct guidance with respect to ETSs' effects on the international shipping industry.

In this chapter, we investigate and benchmark two different ETS mechanisms for the international shipping industry, namely an open ETS vis-a-vis a closed Maritime only scheme (METS). The analytical solutions allow us to evaluate the effectiveness of ETSs in achieving emission reduction objectives. It is found that an ETS, whether open or closed, will decrease ship speed, carrier output and fuel consumption in both container and bulk shipping sectors even in the presence of "wind-fall" profit to shipping lines. The level of reduction has a negative relationship with emission permit price. Under the open ETS, emission reduction target of the shipping industry is not definite / pre-determined, because shipping companies can always trade emission permits with other industries. The increased ship operation cost will deteriorate the output reduction under ETS. To overcome this negative impact, ships have stronger incentive to improve fuel efficiency through technical and operational measures. Under METS, the emission reduction objective is predetermined and will definitely be reached. The permit price will have the same impact on the shipping quantity, speed and fuel consumption as in the case of open ETS. However, market structure will have more significant impacts than an open ETS. The degree of competition / collusiveness of one sector will only affect itself in an open ETS, but will affect the other sector in the case of METS. Such an externality is due to the fact that competitiveness in each sector will affect market equilibrium in that sector, and thus, the price of emission permit prevailing in both sectors.

This chapter is organized as follows. Section 3.2 sets up the basic model and solves the market equilibrium without any ETS, which is used as a benchmark case. Section 3.3 solves the equilibrium under an open ETS. Section 3.4 considers an METS for the container and bulk shipping sectors. Section 3.5 provides concluding remarks and proposes future research.

3.2. ECONOMIC MODEL AND BENCHMARK CASE

This study models the impacts of ETS to two representative sectors in the international shipping industry—dry bulk[9] and container shipping, because for former has the largest market share in terms of tonnage of cargo shipped, whereas the latter has the fastest growth rate (UNCTAD, 2011). Since each sector in the international shipping industry has fairly distinctive operating characteristics, our modeling results should hold for the case of multiple sectors in general. Focusing on two sectors however will make the model mathematically tractable, thus that clear intuition can be obtained in addition to closed-form solutions.

We consider the case where there are N_1 (N_2) carriers providing homogenous container (bulk) shipping services in a particular shipping market (global or regional). Before ETS is introduced, the annual demands for container shipping and bulking shipping are independent from each other (not substitutable), which can be modeled with the following demand functions

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[9] Dry bulk group includes the five major bulks (iron ore, coal, grain, bauxite/alumina and phosphate rock) and other dry bulk.

(3.1.1) $$P_1 = a_1 - b_1 \sum_{i=1}^{N_1} q_{1,i} \qquad i = 1, \dots N_1 \text{ and } N_1 \geq 1$$

(3.1.2) $$P_2 = a_2 - b_2 \sum_{i=1}^{N_2} q_{2,i} \qquad i = 1, \dots N_2 \text{ and } N_2 \geq 1$$

where $q_{r,i}$ is carrier *i's* outputs ($r = 1$ for container carrier; $r = 2$ for bulk carrier), while P_r is the market shipping price. Define $t_{r,i}$ as the shipping time for carrier i. If the average distance per voyage is D_r , the average speed is $S_{r,i}$ for carrier i, then we need time $t_{r,i} = D_r / S_{r,i}$ to finish one voyage

Before an ETS is introduced, a carrier's cost for one ship is the sum of fuel cost $f_{r,i}$ and $\gamma_{r,i}$. The term γ_r is a catch all cost standing for all ship operational cost except the fuel cost. It should include ship capital, labor, maintenance, port dues and general administration cost, contracting cost which are directly related to particular ship operation. γ_r is assumed to be exogenous to the model. In convenience, hereafter γ_r is called as ship operation cost.

Following Psaraftis (2008, 2009), fuel cost can be expressed as a cubic function of ship speed as specified in equation (3.2), where λ_r is a coefficient representing a ship's energy efficiency which depends on ship operation. And η is fuel price.

(3.2) $$f_{r,i} = \eta \lambda_r S_{r,i}^3$$

The lower the value of λ_r is, the higher the energy efficiency is for the ship, because less fuel consumption is required for given $S_{r,i}$.

It is assumed that a carrier maximizes its profit by choosing the optimal quantity and ship speed, thus that the objective function of the carrier can be written as:

(3.3) $$Max_{q_{r,i}, S_{r,i}} \pi_{r,i} = P_r q_{r,i} - (f_{r,i} + \gamma_r) \frac{q_{r,i} D_r}{U_r S_{r,i}\, \rho}$$

Where U_r is the average capacity of a ship and ρ is to measure ship's "days at sea". It is the proportional time that a ship sails on the sea during. $P_r q_{r,i}$ is the total revenue.

$f_{r,i}+\ \gamma_r$ is the total operating cost per ship, equaling fuel cost plus a catch-all ship operation cost. The speed is measured in knot (nautical miles / hour), thus $f_{r,i}$ is a ship's hourly fuel consumption. To be consistent, units for other variables are normalized to hourly basis. Then $\frac{q_{r,i}}{U_r S_{r,i}\,\rho/D_r}$[10] is the total number of ships utilized by carrier i to accomodate hourly demand [11]. The corresponding first order conditions (FOCs) for (3.3) are:

$$\text{(3.4.1)}\quad \frac{\partial \pi_{r,i}}{\partial q_{r,i}} = a_r - 2b_r q_{r,i} - b_r \sum_{j\neq i}^{N_r} q_{r,j} - b_r q_{r,i} \sum_{j\neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}} - \frac{D_r}{U_r S_{r,i}\,\rho}\left[\eta \lambda_r S_{r,i}^3 + \gamma_r\right] = 0$$

$$\text{(3.4.2)}\quad \frac{\partial \pi_{r,i}}{\partial S_{r,i}} = -\ \frac{q_{r,i}}{U_r\ \rho/D_r}\left[2\ \eta \lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2}\right] = 0$$

Referring to Brander and Zhang (1990, 1993), Fu et al (2006), Basso and Zhang (2008), we introduce conduct parameters $\nu_{ri,j}$ in FOC (3.4.1), so that our model is applicable to a spectrum of competition games.

$$\nu_{ri,j} = \sum_{j\neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}},\quad -1 \le \nu_{ri,j} \le N_r - 1$$

Conduct parameter $\nu_{ri,j}$, where $i \neq j$, measures how aggressively one firm competes with other firms in the same market[12]. Within the range of $-1 \le \nu_{ri,j} \le N_r - 1$,

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[10] $\frac{D_r}{\rho S_{r,i}}$ is the hours that one ship to finish one voyage. In one hour, one ship can finish $1/(\frac{D_r}{\rho S_{r,i}})$ voyages. $q_{r,i}$ is hourly demand, and $\frac{q_{r,i}}{U_r}$ is total number of voyages for carrier i in one hour. Therefore total number of ships needed based on hourly demand is $\frac{q_{r,i}}{U_r}$ divided by $1/(\frac{D_r}{\rho S_{r,i}})$, which is $\frac{q_{r,i} D_r}{U_r S_{r,i}\,\rho}$.

[11] In practical shipping operation, the number of ships utilized is incremental. When one ship is fully loaded, any additional cargo may require one more ship to be deployed. To make our objective functions differentiable, we assume that load factor of ship is 100% and the number of ship is continuous. Clearly, the conclusion of the economic model will not alter when relaxing the above assumptions (i.e. when the number of ships is discrete or load factor is lower than what we modeled).

[12] Using Conduct Parameter Method (CPM) or "Conjecture Variation" to measure market competition intensity is widely adopted in economic studies, such as Bresnahan (1981), Roberts (1984) and Graddy (1995). For a review, see Corts (1999). Brander and Zhang (1990, 1993), Fu et al (2006), Basso and Zhang (2008) applied CPM to the transport industry.

the more negative the $\nu_{ri,j}$ is, the more fierce the competition is between two firms.. Specifically, $\nu_{ri,j} = 0$ corresponds to the Cournot competition; $\nu_{ri,j} = -1$ corresponds to Bertrend competition; $\nu_{ri,j} = N_r - 1$ corresponds to Perfect collusion among firms to maximize joint profit. The second order condition (SOC) for (3.3) is checked and proven to hold (see Appendix A).

Considering non-trivial cases only, we restrict to non-negative optimal traffic quantity thus that the FOC (3.4.2) can be transformed as (3.4.3)

$$2\eta\lambda_r S_{r,i}^3 - \gamma_r = 0 \tag{3.4.3}$$

Imposing symmetry so that $q_{r,1} = q_{r,2} = \cdots = q_{r,N_r} = q_r$; $S_{r,1} = S_{r,2} = \cdots = S_{r,N_r} = S_r$; $\nu_{ri,j} = \nu_{ri,g} = \nu_{r,i,}$, $i \neq j \neq g$, and further $\nu_{r,1} = \nu_{r,2} = \cdots \nu_{r,N_r} = \nu_r$, the equilibrium speed and quantity for a carrier can be solved as

$$\tilde{S}_r = \sqrt[3]{\frac{\gamma_r}{2\eta\lambda_r}} > 0 \tag{3.5.1}$$

$$\tilde{q}_r = \frac{2a_rU_r\rho - 3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2}}{2U_r\rho b_r[(N_r+1)+\nu_r]} \tag{3.5.2}$$

By (3.5.1), the optimal speed is a function of the fixed cost and energy efficiency of ships, as well as fuel price. It is clear that ship speed is lower if a ship has lower fixed cost, lower efficiency (higher λ_r), or higher fuel price.

The fuel consumption volume at equilibrium can be obtained as

$$\tilde{F}_r = \lambda_r\tilde{S}_r^3\frac{\tilde{q}_r}{U_r\rho\tilde{S}_r/D_r} = \frac{\sqrt[3]{2\lambda_r{\gamma_r}^2}D_r(2a_rU_r\rho - 3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2})}{4\sqrt[3]{\eta^2}U_r^2\rho^2 b_r[(N_r+1)+\nu_r]} \tag{3.5.3}$$

The non-negativity of shipping quantity $\tilde{q}_r$ and fuel consumption $\tilde{F}_r$ implies that

$$2a_rU_r\rho > 3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2} \tag{3.6}$$

In addition, following comparative statics results can be obtained (see Appendix B for derivation details)

(3.7) $\frac{\partial\tilde{q}_r}{\partial\eta} < 0,\ \frac{\partial\tilde{q}_r}{\partial\lambda_r} < 0,\ \frac{\partial\tilde{q}_r}{\partial D_r} < 0,\ \frac{\partial\tilde{q}_r}{\partial\nu_r} < 0,\ \frac{\partial\tilde{q}_r}{\partial U_r} > 0,\ \frac{\partial\tilde{q}_r}{\partial\gamma_r} < 0;\ \frac{\partial\tilde{S}_r}{\partial\eta} < 0,\ \frac{\partial\tilde{S}_r}{\partial\lambda_r} < 0,\ \frac{\partial\tilde{S}_r}{\partial\gamma_r} > 0\ ;\ \frac{\partial\tilde{F}_r}{\partial\eta} < 0,\ \frac{\partial\tilde{F}_r}{\partial\nu_r} < 0.$

The interpretations of above comparative statics are straightforward: when fuel price increases or the fuel efficiency is lower, carriers will reduce ship speed to save fuel, leading to lower total fuel consumption and traffic volumes. When ship operation cost increases, carriers increase ship speed to reduce the number of ships needed and save on ship operation cost . When carriers are more collusive, they will reduce capacity deployed so as to raise market price, which allows them to achieve higher profits.

3.3. AN OPEN ETS

Under an open ETS, carriers can trade emission permits with other industries. As the international shipping only accounts for 2.7% of the global CO_2 emission, including it in an open scheme such as the EU ETS should have minimum effects on the price of emission permit. Therefore, the price of emission permit is modeled as exogenous. In such a case, ETS is equivalent to a uniform charge on emission, which can be a positive tax/charge (if carriers buy emission permit) or negative subsidy (if carriers sell emission permit). Since there is a definite relationship between fuel consumption and gas emission, ETS is equivalent to a tax/subsidy on fuel consumption. Reflecting the common practices as observed in existing ETSs, it is assumed that each carrier is pre-allocated a quota of free emission which is θ $(0 < \theta < 100\%)$ percentage of her fuel consumption absent of ETS. A shipping firm's profit maximization problem is defined as follows. Where $\chi > 0$ is the exogenously determined emission charge per ton of fuel.

(3.8) $$Max_{q_{r,i},S_{r,i}}\,\pi_{r,i} = P_r q_{r,i} - (f_{r,i} + \gamma_r)\frac{q_{r,i}D_r}{U_r S_{r,i}\,\rho} - \chi[\lambda_r S_{r,i}^3 \frac{q_{r,i}D_r}{U_r S_{r,i}\,\rho} - \theta\tilde{F}_r]$$

Since the container and bulk shipping sectors trade emission permits under the open ETS separately, the solutions for these two sectors are thus independent. The outcomes of trade are determined by exogenous emission permit price χ and the target of emission reduction percentage $(1 - \theta)$. The corresponding FOCs for maximization problem (3.8) are:

(3.9.1) $$\frac{\partial \pi_{r,i}}{\partial q_{r,i}} = a_r - 2b_r q_{r,i} - b_r \sum_{j\neq i}^{N_r} q_{r,j} - b_r q_{r,i} \sum_{j\neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}} - \frac{D_r}{U_r S_{r,i}\,\rho}[(\eta + \chi)\lambda_r S_{r,i}^3 + \gamma_r] = 0$$

(3.9.2) $$\frac{\partial \pi_{r,i}}{\partial S_{r,i}} = -\frac{q_{r,i}}{U_r\,\rho/D_r}\left[2\,(\eta + \chi)\lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2}\right] = 0$$

Imposing symmetry so that $q_{r,1} = q_{r,2} = \cdots = q_{r,N_r} = q_r$, and $S_{r,1} = S_{r,2} = \cdots = S_{r,N_r} = S_r$; $\nu_{ri,j} = \nu_{ri,g} = \nu_{r,i,} = \nu_r, i \neq j \neq g$, the equilibrium quantity and speed for container shipping group can be solved as

(3.10.1) $$\bar{q}_r = \frac{2a_r U_r \rho - 3D_r \sqrt[3]{2(\eta+\chi)\lambda_r {\gamma_r}^2}}{2U_r \rho b_r[(N_r+1)+\nu_r]}$$

(3.10.2) $$\bar{S}_r = \sqrt[3]{\frac{\gamma_r}{2(\eta+\chi)\lambda_r}} > 0$$

and fuel consumption is

(3.10.3) $$\bar{F}_r = \frac{\sqrt[3]{2\lambda_r {\gamma_r}^2}\,D_r(2a_r U_r \rho - 3D_r \sqrt[3]{2(\eta+\chi)\lambda_r {\gamma_r}^2})}{4\sqrt[3]{(\eta+\chi)^2}\,U_r^2 \rho^2 b_r[(N_r+1)+\nu_r]}$$

The non-negativity of $\bar{q}_r$ and $\bar{F}_r$ implies that

$$(3.11). \qquad 2a_r U_r \rho > 3D_r \sqrt[3]{2(\eta+\chi)\lambda_r {\gamma_r}^2}$$

Compared to solutions in (3.5), it is observed under the open ETS, the equilibrium solutions in (3.10) are equivalent to adding the emission permit price χ to fuel price η. From (3.7), we know $\frac{\partial \tilde{q}_r}{\partial \eta} < 0, \frac{\partial \tilde{S}_r}{\partial \eta} < 0$ and $\frac{\partial \tilde{F}_r}{\partial \eta} < 0$. Therefore, it is clear that under the open ETS, for any θ <1, the fuel consumption, traffic quantity and ship speed of the carriers will decrease for any positive price of the emission permit. The degree of reduction depends on the exogenously determined emission permit price χ. Specifically, for a larger χ, there will be greater reductions in fuel consumption, traffic quantity and speed.

Note the target emission reduction percentage $(1-\theta)$ does not affect the equilibrium fuel consumption volume, traffic quantity and speed (as θ does not enter the FOCs for optimization problem (3.8)). However, θ determines the trading behavior of the shipping industry with other sectors under the open ETS. Define θ_r' as the ratio of fuel usage in the open ETS to that in the case of no ETS, i.e.,

$$(3.12) \qquad \theta_r' = \frac{\bar{F}_r}{\tilde{F}_r} = \sqrt[3]{(\frac{\eta}{\eta+\chi})^2} \frac{(2a_r U_r \rho - 3D_r \sqrt[3]{2(\eta+\chi)\lambda_r {\gamma_r}^2})}{(2a_r U_r \rho - 3D_r \sqrt[3]{2\eta\lambda_r {\gamma_r}^2})} < 1$$

When $\theta > \theta_r'$, carrier sells its emission permit to other sectors under the open ETS. When $\theta < \theta_r'$ carriers buy permit. θ_r' is a decreasing function of χ. That is, when the price of emission permit increases, carriers have a stronger incentive to reduce fuel usage and sell emission permits. Also, it is interesting to note that θ_r' is not dependent on market competition condition, as measured by the number of shipping firms or carriers' conduct parameters. This indicates that the market structure has no effects on the degree of emission abatement of the international shipping industry under the open ETS.

Due to the fact that most of the containerships are newer than dry bulk ships, it is generally believed that container ships are more expensive to operate (larger γ) and fuel efficient (smaller λ) than dry bulk ships. If such a condition holds, it is possible to analyze the differential impacts of open ETS on the two shipping sectors. Define the proportional reduction in output and speed as in (3.13.1) and (3.13.2) respectively:

(3.13.1) $$R_r = \frac{\tilde{q}_r - \bar{q}_r}{\tilde{q}_r}$$

Take partial derivatives of R_r and θ_r' w.r.t. γ_r and λ_r, it can be shown that:

$$\frac{\partial R_r}{\partial \gamma_r} > 0 \text{ and } \frac{\partial R_r}{\partial \lambda_r} > 0; \ \frac{\partial \theta_r'}{\partial \gamma_r} < 0 \text{ and } \frac{\partial \theta_r'}{\partial \lambda_r} < 0.$$

These comparative statics indicate that increased ship operational cost (larger γ_r) can deteriorate carriers' output reduction and force them to use less fuel when open ETS is implemented. Thus, it is also clear that shipping firms now have stronger incentive to improve fuel efficiency (smaller λ_r) in order to avoid too much negative impacts on output and fuel consumption brought by ETS. Although IMO has implemented several technical and operation standards forcing ships to upgrade fuel efficiency, our analysis shows that market based measure can be effective to stimulate voluntary adoption of these measures by shipping firms.

To quantity open ETS differential impacts on different shipping sector, the difference in R_r is calculated as follows

$$R_1 - R_2 = \frac{6\sqrt[3]{2}\rho\left(\sqrt[3]{\eta+\chi} - \sqrt[3]{\eta}\right) K}{\left(2a_1U_1\rho - 3D_1\sqrt[3]{2\eta\lambda_1{\gamma_1}^2}\right)\left(2a_2U_2\rho - 3D_2\sqrt[3]{2\eta\lambda_2{\gamma_2}^2}\right)}$$

It is clear that sign of $R_1 - R_2$ and $\frac{d(R_1 - R_2)}{d\chi}$ is determined by term $K = a_2U_2D_1\sqrt[3]{\lambda_1{\gamma_1}^2} - a_1U_1D_2\sqrt[3]{\lambda_2{\gamma_2}^2}$. When $K < 0$, $R_1 < R_2$, container sector has less proportional output reduction then dry bulk and *vise versa*. This difference in proportional output reduction is getting larger with χ increase. In contrary, sign of $\theta_1' - \theta_2'$ depends on $-K$. When $K < 0$, $\theta_1' > \theta_2'$, indicating dry bulk ship will use less (sell more) emission permit under the open ETS and *vise versa*.

However, sign of K is ambiguous when referring to its analytical form. Interactions of various parameters jointly determine sign of K. For example, although it is intuitively true that $a_1 > a_2$ as container shipping service has higher "reservation price", $\lambda_2 > \lambda_1$ as dry bulk ship is less fuel efficient, we cannot claim $K < 0$ because $U_2 > U_1$ as dry bulk ship is larger and $\gamma_1 > \gamma_2$ as containership is more expensive. In order to shed light on differential impact of open ETS on carrier's output reduction, an empirical investigation based on real industry data is called for.

For speed reduction benchmarking purpose, define

$$T_r = \frac{\tilde{S}_r - \bar{S}_r}{\tilde{S}_r} \tag{3.13.2}$$

Substituting (3.5.2) and (3.10.1) into (3.13.2) leads to $T_r = 1 - \sqrt[3]{\frac{\eta}{(\eta+\chi)}}$. It is interesting to observe that T_r is only dependent on fuel price η and permit price χ, implying that container ship and dry bulk ship will have the same proportional speed reduction. But as containerships have higher absolute speed, they will have larger speed reduction in magnitude.

The implementation of an open ETS affects the profit of shipping lines. Substitute the values of $\bar{q}_r, \bar{S}_r, \bar{F}_r$ back into the profit function, and totally differentiate that with respect to the permit price χ, we get:

$$\frac{d\bar{\pi}_{r,i}}{d\chi} = \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial q_{r,i}}\frac{\partial q_{r,i}}{\partial\chi} + \sum_{j\neq i}^{N_r}\frac{\partial\bar{\pi}_{r,i}}{\partial q_{r,j}}\frac{\partial q_{r,j}}{\partial\chi}}_{\geq 0} + \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial S_{r,i}}\frac{\partial S_{r,i}}{\partial\chi}}_{=0} + \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial\chi}}_{\geq or < 0} \tag{3.14}$$

$$= (\nu_r - N_r + 1) b_r \bar{q}_r \frac{\partial\bar{q}_r}{\partial\chi} - [\lambda_r \bar{S}_r{}^3 \frac{\bar{q}_r}{U_r \bar{S}_r \rho / D_r} - \theta\tilde{F}_r]$$

Since $\nu_r \leq N_r - 1$ and $\frac{\partial\bar{q}_r}{\partial\chi} < 0$, the first expression $(\nu_r - N_r + 1) b_r \bar{q}_r \frac{\partial\bar{q}_r}{\partial\chi}$ is non-negative. This can be regarded as a "Freight Market" effect. An increase in χ reduces each carrier's output level $\bar{q}_r(\chi)$, leading to higher freight rate. This is similar to collusion among carriers aiming at reducing their outputs jointly, and will increases their profits. The second term, $-[\lambda_r \bar{S}_r{}^3 \frac{\bar{q}_r}{U_r \bar{S}_r\, \rho / D_r} - \theta\tilde{F}_r]$, can be regarded as a "Emission Market" effect, which is negative when a shipping company buys permits and positive when a shipping company sells emission permits. The overall effect on a carrier's profit is determined by the relative size of Freight Market Effect vs. Emission Market Effect. If the market demand for shipping service is elastic, or the price of the emission permit is low, the sign for $\frac{d\bar{\pi}_{r,i}}{d\chi}$ will be positive.

From (3.14), it is also clear that the change of carrier profit with respect to emission permit price is dependent on the proportion of emission permit freely allocated, carriers' competition behavior and the degree of competition as measured by the number of competing shipping firms (i.e., parameters $\theta,\ \nu_r$ and N_r respectively). It can be further concluded that: in the case of perfect collusion among carriers (i.e., $\nu_r = N_r - 1$), shipping firms' profits will decrease with χ and be lower than the benchmark case (without ETS) for any given θ. In the case of Bertrand competition among carriers (i.e., $\nu_r = -1$), shipping firms' profits will always be higher than the benchmark case. In the case of Cournot competition (i.e., $\nu_r = 0$), the change of carrier profit will depend on the proportion of emission allowance freely allocated. If only a small proportion of emission allowance is allocated, in the sense that $\theta < \frac{2}{N_r+1}$ in our model, the shipping firms' profit will decrease. However, if a large proportion of emission permits are allocated, in the sense that $\theta \geq \frac{2}{N_r+1}$ in our model, shipping firm's profit will increase.

3.4. A MARITIME ONLY ETS (METS)

In the case of METS, the price of emission permit is no longer exogenously determined. Instead, it is the result of emission permit trade between the container and bulk sectors. In order to investigate the effects of permit trading, we start the analysis without trade first. Since the proportion of free permits allocated is less than 100% (i.e., $\theta<1$), the optimal solution is obtained when all the free permits are used. Therefore, the problem for each sector is a maximization problem with binding constraint:

(3.15) $$Max_{q_{r,i},S_{r,i}}\ \pi_{r,i} = P_r q_{r,i} - (f_{r,i} + \gamma_r)\frac{q_{r,i}D_r}{U_r S_{r,i}\,\rho}$$

$$s.t. \quad \lambda_r S_{r,i}^3 \frac{q_{r,i}D_r}{U_r S_{r,i}\,\rho} = \theta \tilde{F}_r$$

By introducing the Lagrangian multiplier $\phi_{r,i} > 0$, we can specify the corresponding Lagrangian function as follows.

(3.16) $$L_{\phi_{r,i}} = P_r q_{r,i} - (f_{r,i} + \gamma_r)\frac{q_{r,i}D_r}{U_r S_{r,i}\,\rho} - \phi_{r,i}[\,\lambda_r S_{r,i}^3 \frac{q_{r,i}D_r}{U_r S_{r,i}\,\rho} - \theta \tilde{F}_r]$$

The corresponding FOCs for the Lagrangian function (3.16) with respect to $q_{r,i}, S_{r,i}$, and $\phi_{r,i}$ can be derived as follows

(3.17.1)

$$\frac{\partial L_{\phi_{r,i}}}{\partial q_{r,i}} = a_r - 2b_r q_{r,i} - b_r \sum_{j\neq i}^{N_r} q_{r,j} - b_r q_{r,i} \sum_{j\neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}} - \frac{D_r}{U_r S_{r,i}\,\rho}[(\eta + \phi_{r,i})\lambda_r S_{r,i}^3 + \gamma_r] = 0$$

(3.17.2) $$\frac{\partial L_{\phi_{r,i}}}{\partial S_{r,i}} = -\frac{q_{r,i}D_r}{U_r\,\rho}\left[2\,(\eta + \phi_{r,i})\lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2}\right] = 0$$

(3.17.3) $$\frac{\partial L_{\phi_{r,i}}}{\partial \phi_{r,i}} = \lambda_r S_{r,i}^3 \frac{q_{r,i}D_r}{U_r S_{r,i}\rho} - \theta \tilde{F}_r = 0$$

Imposing symmetry on equations (3.17) we have following important equation:

(3.18) $$\theta \tilde{F}_r = \frac{\sqrt[3]{2\lambda_r {\gamma_r}^2}\,D_r(2a_r U_r \rho - 3D_r \sqrt[3]{2(\eta+\widehat{\phi}_r)\lambda_r {\gamma_r}^2)}}{4\sqrt[3]{(\eta+\widehat{\phi}_r)^2 U_r^2 \rho^2}\,b_r[(N_r+1)+\nu_r]}$$

The parameter $\hat{\phi}_r$ is the shadow price of emission permit, or the contribution to the profit of a shipping firm by relaxing the emission constraint by one unit, i.e. $\frac{d\hat{\pi}_r}{d(\theta\tilde{F}_r)} = \hat{\phi}_r$. Clearly, when $\hat{\phi}_1$ and $\hat{\phi}_2$ are different, both the container sector and the bulk sector have an incentive to trade emission permits. The sector with higher $\hat{\phi}_r$ will buy emission permits as long as the price is lower than $\hat{\phi}_r$. Any trading price h between $\hat{\phi}_1$and $\hat{\phi}_2$ will lead to a Pareto improvement for two sectors compared with the case without trading. In an efficient market, the trade of emission permit will continue until no sector has an incentive to trade, or equilibrium is reached when the shadow prices of the two sectors are equal. With loss of generality, we assume containership has higher shadow price and buy emission quota from dry bulk sector. Then following conditions hold, where $\overline{\Delta}$ denotes the amount of emission permit traded by each container carrier

$$\begin{cases} \theta\tilde{F}_1 + \overline{\Delta} = \dfrac{\sqrt[3]{2\lambda_1{\gamma_1}^2}D_1(2a_1U_1\rho - 3D_1\sqrt[3]{2(\eta+\bar{h})\lambda_1{\gamma_1}^2})}{4\sqrt[3]{(\eta+h)^2}U_1^2\rho^2 b_1[(N_1+1)+\nu_1]} & (3.19.1) \\ \theta\tilde{F}_2 - \dfrac{N_1\overline{\Delta}}{N_2} = \dfrac{\sqrt[3]{2\lambda_2{\gamma_2}^2}D_2(2a_2U_2\rho - 3D_2\sqrt[3]{2(\eta+\bar{h})\lambda_2{\gamma_2}^2})}{4\sqrt[3]{(\eta+h)^2}U_2^2\rho^2 b_2[(N_2+1)+\nu_2]} & (3.19.2) \end{cases}$$

When the container sector and the bulk sector trade emission permit at equilibrium price $\bar{h}$, the traffic quantity, speed and fuel consumption are, respectively:

(3.20)

$$\hat{q}_r = \frac{2a_rU_r\rho - 3D_r\sqrt[3]{2(\eta+\bar{h})\lambda_r{\gamma_r}^2}}{2U_r\rho b_r[(N_r+1)+\nu_r]}, \hat{S}_r = \sqrt[3]{\frac{\gamma_r}{2(\eta+\bar{h})\lambda_r}}, \hat{F}_r = \frac{\sqrt[3]{2\lambda_r{\gamma_r}^2}D_r(2a_rU_r\rho - 3D_r\sqrt[3]{2(\eta+\bar{h})\lambda_r{\gamma_r}^2})}{4\sqrt[3]{(\eta+\bar{h})^2}U_r^2\rho^2 b_r[(N_r+1)+\nu_r])}$$

Equations (3.20) are similar to equilibrium results in the open ETS case (equation (3.10)), except that the exogenous permit price in (3.10) is replaced by the equilibrium permit trading price $\bar{h}$. This also implies that the impact of the equilibrium permit trading price will have the same effects on the performance of the two sectors.

Intuitively, since the emission permit is a valuable resource (binding constraint), shadow prices in both sectors shall increase as a smaller proportion of emission permit is freely allocated, which in turn will lead to a higher trading price. This can be illustrated by Figure 3-1, where the black curves stand for the shadow prices in the two sectors with a proportion of θ_2 free allocation, whereas the red curves are those with lower free allocation $\theta_1<\theta_2$. It is clear that a lower proportion of free allocation will lead to a higher trading price of emission permit.

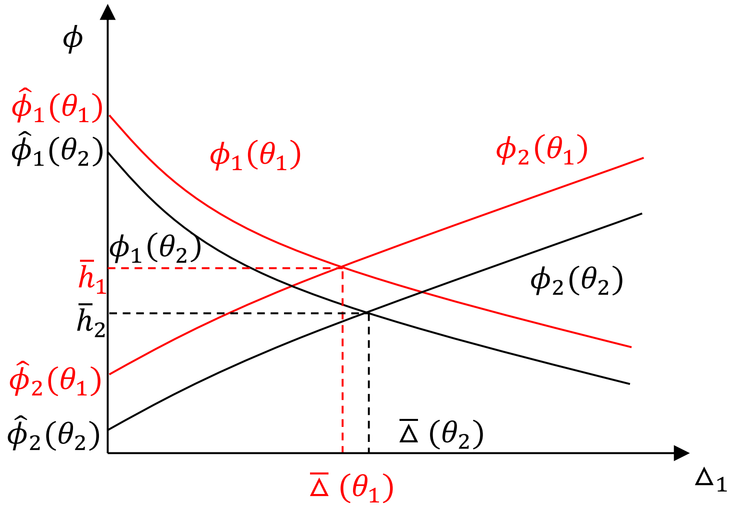

Figure 3-1. Change of $\bar{h}$ with θ $(\theta_1 < \theta_2)$

To see how market structure affects the emission trading price, by (3.5.3), equation (3.19.1) can be rearranged as

$$\frac{\sqrt[3]{2\lambda_1{\gamma_1}^2}D_1}{4U_1^2\rho^2 b_1[(N_1+1)+\nu_1]}\left[\frac{\left(2a_1U_1\rho-3D_1\sqrt[3]{2(\eta+\phi_1)\lambda_1{\gamma_1}^2}\right)}{\sqrt[3]{(\eta+\phi_1)^2}}-\theta\,\frac{2a_1U_1\rho-3D_1\sqrt[3]{2\eta\lambda_1{\gamma_1}^2}}{\sqrt[3]{\eta^2}}\right]=\Delta_1.$$

Thus, for any $\Delta_1 > 0$, ϕ_1 increases when $\nu_1$decreases (see Figure (3-2)), and thus the resultant $\bar{h}$ is higher. Similarly, by rearranging (3.19.2), it can be proved that ϕ_2 and resultant $\bar{h}$ rise in ν_2.

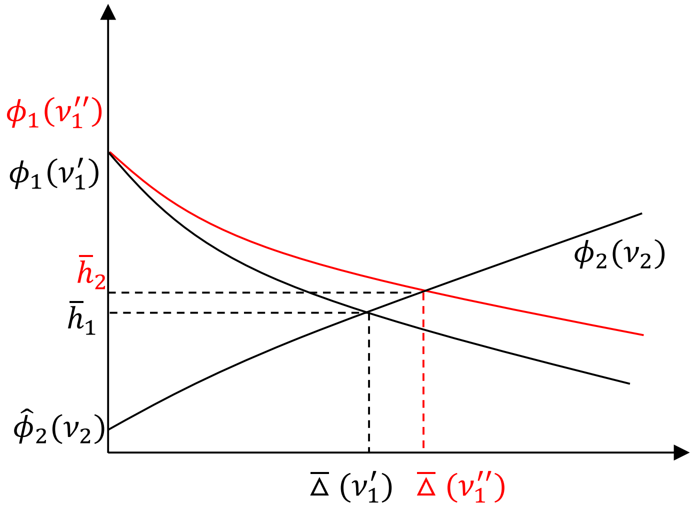

Figure 3-2 Change of $\bar{h}$ with ν_1 $(\nu_1^{''} < \nu_1^{'})$

The effect of degree of competition among carriers can be interpreted with the effects of conduct parameters ν_i. For the sector buying emission permit, when carriers compete more intensively (as measured by a smaller ν_i), the emission permit will be traded at a higher price, as carriers are more aggressive in output expansion and thus acquires more emission permits. For the sector selling emission permit, increased market collusion and reduced output making any further output reduction costly (i.e. higher shadow price). This of course pushes up the trading price in the market.

Finally, comparing the results of the open ETS and METS, it is clear that the impacts on the shipping industry are the same only if the emission trading prices in these two schemes are equal to each other. Of course, emission price χ is exogenous in an open ETS, whereas h is determined by the trades between shipping sectors as well as by the emission reduction target 1-θ.

3.5. SUMMARY AND CONCLUSIONS

Emission trading schemes have been proposed to reduce the CO_2 emission from the international shipping industry. However, despite the successful implementations of ETSs such as the US SO_2 program and the EU ETS in previous years, there has been rather limited progress in reducing CO_2 emissions from the international shipping industry. Whereas numerous political and institutional factors might be blamed for such a slow progress, some important issues remain to be studied and evaluated concerning the ETS itself. An ETS involving the shipping industry can be either "open" or "closed", which would have differential impacts to the shipping industry. In addition, the shipping industry is not composed of homogeneous carriers. The market structure and firm conduct are also different across shipping sectors. Therefore, the ETSs under consideration would have differential impacts on the various shipping sectors, and thus, differential effects to international trade.

This essay analyzes and benchmarks the economic implications of two alternative ETS mechanisms, namely an open ETS vis-à-vis METS. The analytical solutions suggest that an ETS, whether open or maritime only, will decrease ship speed, carrier outputs and fuel consumption for both the container and bulk sectors, even in the presence of "wind-fall" profit to shipping lines. The increased ship operation cost will deteriorate this output reduction under ETS. To overcome this negative impact, carriers have more incentive to improve fuel efficiency through technical and operational measures. Under an open ETS, the emission reduction target is a non-binding constraint since carriers can trade their permits with other industries. Under a METS, the emission reduction limit will definitely be reached and the permit price is endogenously determined by the trading behavior and market structure of both the container and dry bulk sectors. The degree of competition in a sector will have spill-over effects to the other sector under the METS. Specifically, when the sector that sells (buys) permits is more collusive (competitive), the equilibrium permit price will rise.

As economic analysis on market-based measures (MBM) to reduce shipping CO_2 emission has been quite scanty, our research provides timely insights for both regulators and industry practitioners to evaluate the effects to introduce ETS in shipping sectors. It offers a framework to identify the moderating effects of market structure and firm competition on emission reduction schemes, and emphasizes the importance of understanding the differential impacts of ETSs brought to individual sectors within an industry. Of course, our study is also subject to several limitations leading to possible future research. First, shipping network can change if an ETS is implemented regionally. Shipping firms might re-configure routes to avoid the emission charge. Second, shipping demand can be uncertain due to external economic situation. Thus a stochastic demand can be a more realistic assumption, which may lead to different choices of emission reduction targets. These investigations are natural extensions of our study, although beyond the scope of the present chapter.

CHAPTER 4

COOPERATION OR COMPETITION? FACTORS AND CONDITIONS AFFECTING REGIONAL PORT GOVERNANCE IN SOUTH CHINA

4.1 INTRODUTION

Being part of the traditional trade-based economy, the port of Hong Kong was historically regarded as one of the main pillars of the development of the city's economic development. Indeed, Hong Kong had been traditionally an international (pre-dominantly container) port heavily influenced by the laissez-faire approach, or the so-called 'active non-interventionist' (Wong, 2007), and until recently, largely isolated from China's national and regional planning. This was mainly due to the city's special political, economic and social status; from being a British colony to a Special Administrative Region (SAR) under China's 'One Country, Two Systems' policy.

However, since the turn of the century, Hong Kong's port has faced considerable challenges. These include increasing trades between China and overseas markets (like the abolition of textile quota of US and Europe to Chinese textile exports, in effect since 2005), challenges from its geographical proximate, and initially peripheral, neighbors, notably Shenzhen and Guangzhou, the increasing importance of intra-Asian trade (like the "10+1" Asian Free Trade Zone between ASEAN and Northeast Asia), and the economic turmoil in 2008-09 which accelerated the industrial transformation of the Pearl River Delta (PRD) (Wang & Ng, 2011). Therefore, port development in South China had entered a regionalization phrase (Notteboom & Rodrigue, 2005), and that the stated factors had challenged the expected forecasts regarding the future (and even current) development of the port of Hong Kong, notably its shrinking hinterland size within PRD. Indeed, in the past half decade, in terms of container throughputs, Hong Kong's ranking had gradually slipped from 1st to 3rd behind Singapore and Shanghai, with the combined ports of Shenzhen, notably Yantian and Shekou, rapidly snapping upon its heels. According to Wang (2010), the annual container throughputs of Shenzhen had grown five to seven times faster than those of Hong Kong.

As a consequence, Hong Kong port was forced to undergo strategic changes, notably its gradual integration within China's national and regional planning. For instance, the National Development and Reform Commission of China had recently included the port of Hong Kong in The Outline of the Plan for the Reform and Development of PRD (2008-20) (Chapter 11, Article 2) (Government of PRC, 2009). Also, according to the Framework Agreement on Hong Kong/Guangdong Co-operation (2010), signed between the Hong Kong SAR and Guangdong Provincial Governments, Hong Kong is expected to integrate within the PRD port clusters so as to help in establishing a port system within PRD, with its port functions complementary to each other (Chapter 9, Article 4). The increasing need for cooperation between PRD ports was well-recognized by various scholars (for instance, Sit, 2009; Wang & Olivier, 2007; Ng, 2011).

However, while what Hong Kong had been transformed in the past years had been mentioned, how it should be transformed so as to achieve complementary and mutually-beneficial outcomes, and how such a transformation would proceed, notably how to sustain PRD's role as the southern gateway and maritime logistics centre of China, is still rather ambiguous. This is complicated by the increasingly needs of ports to transform themselves from simple sea-land interfaces to 'maritime logistics centres'. Since the 1990s, technological and economic developments had required ports to transform from simple sea-land interfaces to complex distribution nodes along multimodal supply chains emphasizing on enhancing and sustaining coherent flows and transition of cargoes between origins and destinations. Inevitably, this would require synchronization and close cooperation between different stakeholders, e.g., transport service providers, ports, freight forwarders, etc. This transition has clearly contributed to Hong Kong port's 'self-reinvention' process, of which major functions would likely to vary significantly (Notteboom & Winkelmans, 2001). The appropriate direction of such transformation, however, has never been very clear. What exactly a maritime logistics centre should be, as well as the necessary conditions for it to prosper (especially when there is a need to cooperate with neighbouring ports) has yet to be satisfactorily answered. Such shortage is not only due to a lack of systematic, scientific studies on this issue, but also the non-existence of a regional governance system in place within PRD.

Moreover, given the current development trend, Hong Kong needs to compromise its traditional active non-interventionist policy to port operations and management (or pre-dominantly private-led co-operative initiatives, see Wang & Olivier, 2007). It will be increasingly influenced by China's strategic (both national and regional) planning and, of course, its institutional framework and political system, thus significantly affecting our conventional understanding of regional port governance. This is clearly something new to Hong Kong's traditional governance approach. As noted by Sit (2009), given their geographical proximity but isolated from each other in terms of planning and management, as well as significant institutional diversification, how such a regional port 'cluster' should be developed, notably the division of responsibilities of cargo flows between Hong Kong and other major PRD ports, until now, is still rather ambiguous.

Regional port governance is actually not something new, with the existence of Dutch regional port cluster (mainly Amsterdam / Rotterdam) and the establishment of Copenhagen / Malmo port authority being notable examples. However, it is to be re-examined that the ways of how an effective regional port governance system should be established and operated under regional idiosyncrasies due to China's 'One Country, Two Systems' commitment. For example, at what levels (say, port or terminal) should co-operation and/or competition take place? Should co-operation (and thus planning) take place partially or wholly? How should responsibilities be 'shared' between the ports? How to strike a balance between co-operation and competition so as to achieve complementary and mutually-beneficial outcomes? Should a 'trans-regional' port authority be established in co-ordinating cargo flows between ports within PRD? In this respect, Sit (2009) proposed three scenarios suggesting the possible relations amongst major PRD ports (Hong Kong, Shenzhen and Guangzhou). Until now, the three stated scenarios have remained largely hypothetical lacking scientific research in assessing their practicality, nor providing any strong reasons justifying why such scenarios will take place.

Subsequently, the need for research on this topic is not only desirable, but an urgent necessity. Ports within the same region may compete or cooperate, or partially cooperate while competing. Nevertheless, there are many factors influencing ports' choice over competition vs. cooperation. While considerable studies have investigated port competition (for instance, Jacobs, 2007; Ng, 2006; Song, 2002), few have convincingly answered why ports compete in the first place. In theory, if profit allocation is not an issue among alliance members, ports should always prefer cooperation to competition, as alliance profits are usually larger than the profits achievable with competition. In general, firms usually prefer collusion to competition. But such alliance / cooperation is not always possible in oligopoly market, as anti-trust and competition agencies often forbid firms to form alliance or to merge with each other. In ports, however, such competition concern has not been evident. Instead, government agencies have been encouraging ports to cooperate with each other. Therefore, one may wonder why many ports still could not form alliances despite of the potential economic gains in the absence of anti-trust regulation.

In many cases the difficulties in cooperation forming may be due to various institutional or political constraints. Ports may be regarded as strategic assets that have to be controlled by local citizens / investors[13]. Thus, if may not be possible for ports to fully merge or to be under the control of one single authority even if such a cooperation may allow participating ports to make substantially higher financial return. In general, where full merger / integration are not feasible, firms may choose to form strategic alliances thus that they can coordinate their pricing and operation strategies. Such alliances are often achieved with cross-shareholding. Still, cross-sharing holding is not always possible, especially when investors are from another country. Where neither full merger nor partial cross share holding are possible, in theory, alliance may still be formed via commercial agreements / contracts / negotiations. Port volumes and port charges are usually public information, thus it is relatively easy for alliance members to monitor and verify whether alliance members have followed their agreements. In addition, since many port operators are global players, if they cheat or break the commercial agreements without proper justification, they may face various forms of penalties in other markets from the alliance members. These conditions are favorable to alliance formation and sustention, as long as it is beneficial to all participating ports.

Based on the stated background, this study investigates the factors and conditions affecting regional port governance, notably the possible alliance formation between geographically proximate ports serving partially overlapped hinterlands. To reflect

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[13] For a more detailed analysis on the impacts of institutions on port operation and management, see Ng & Pallis (2010) and Tongzon & Ng (2011).

institutional and political constraints ports face in many regions, we focus on port alliance via commercial agreement. Most commercial agreements such as revenue / profit sharing and capacity pooling often involve a transfer payment. However, absent of merger and cross-share holding, transfer payment between ports is rather rare. To reflect such practical constraints, we will investigate the conditions when alliance can be achieved without transfer payment among ports. In terms of methodology, we develop a game theory model where two ports providing differentiated services choose from two possible strategies: either to compete with each other, or to form an alliance. In the ‘Port Alliance Scenario’, the two ports jointly set their respective outputs and resultant prices in order to maximize their total profit (profit of the two-port-alliance). However, as there is no transfer payment between ports, each port’s profit share in the port alliance is solely determined by its own price structure and volume of cargo-handling. In the ‘Port Rivalry Scenario’, each port chooses its outputs so as to maximize profits. Market equilibriums in the two scenarios are then solved, so that each port’s profit in the two scenarios can be compared. If each port’s profit under alliance is at least as large as the case of port rivalry, then port alliance may be explored or formed if the institutional and political constraints ports face in practice can be resolved.

This essay is structured as follows. Section 4.2 consists of the literature review, of which major concepts on competition and cooperation, and the impacts of institutions, are reviewed and discussed. Section 4.3 introduces the economic model which is calibrated in the case of PRD in section 4.4. Finally, section 4.5 provides the discussions and conclusions.

4.2 LITERUATURE RVIEW

Being the formal rules, procedures and patterns of behavior in shaping political, social or economic interactions, the significance of institutions in the development of industrial activities had been well-established within the literature (Acemoglu & Robinson, 2008; Hall, 2003; North, 1990; Williamson, 2000). By giving and enforcing credibility to paths of change, institutions structure the relationship between various stakeholders within particular economies (Hall, 1986) and affected the way societies evolved overtime. Indeed, institutions aimed to promote efficiency among transacting partners, minimized distributional conflicts, and monitored compliance. Any new conditions that (thought to have) caused structural contradictions would be addressed within established framework via path-dependent re-organizations (Boyer & Hillingsworth, 1997), thus restricting an established economic structure from moving too far away from its initial form by 'embedding' itself reflecting long term institutional characteristics (Williamson, 2000).

Hence, any arrangements forming the constructs within which a particular sector of the economy (or industry) operated represented a subset of the institutional framework, and might have profound impacts on the ways that the sector (or parts of it) evolved. In other words, these arrangements existed in cultural and political contexts that define their form. Institutions might be forced to change by economic or political pressure that were neither sector specific, nor implied by changes within broader social structures. In this respect, the impacts of institutions could be positive or negative. Efficient institutions could add values to assets and promote wealth creation through allowing economic players to invest and specialize. Conversely, inefficient institutions can increase transaction costs, e.g., excessive bureaucracy, corruption, time wastage, insecurity among economic agents, etc., thus reducing the incentives of economic players to invest and trade (Coase, 1992). Notably, where aspects of the institutional framework were weak, they would become vulnerable to manipulation by dominant groups. Jessop & Oosterlynk (2008) pointed out that when economic forces seek to redefine specific subsets of economic activities, such as subjects, sites, and stakes of competition and/or as objects of regulation and to articulate strategies, projects and visions, they tended to manipulate power to secure results. As suggested by Martinsons (2002), therefore, any government's failure in providing an appropriate institutional environment may drive economic players to rely on informal, relationship-based, and often less efficient practices.

The need for the effective implementation of this new cooperative, but at the same time competitive, relation between different PRD ports (Song, 2003) requires us to review and define a new system diversified from our traditional understanding on port management and governance which mainly emphasized on individual ports, as reflected by the World Bank's Port Reform Toolkit (World Bank, 2000; 2007). Having moved into the era for the port industry being undergone a rationalization process over the past decades, port management and operations were being taken over by multinational firms. Many port operators who previously only ran their local business now extend their business scope to the regional or global scale; today's many port operators can be regarded as multinational firms. In an era of globalization, ports can no longer enjoy natural monopoly, as was the case in the past. To cope with this changing environment, a certain form of competition and co-operation is necessary so as to provide services that fit into the strategies shipping service providers. Thus, ports need to concentrate on new ways for co-operation in an effort to establish a countervailing power.

Subsequently, a new strategic option known as 'co-opetition' for the port industries was suggested as a potential way forward. It is a term coined by Noorda (1993) meaning a mixture of competition and co-operation, thus having a strategic implication that those engaged in the same or similar markets should consider a win-win strategy, rather than a win-lose one. If business is regarded as a game, who are the players and what are their roles in the market? There are several parties involved in the market: customers and suppliers. Business cannot be carried out without them. As a consequence, there exist natural 'competitors'. However, there is one more important group which is often overlooked but equally important – those who provide complementary rather than competing services. Brandenburger & Nalebuff (1996) call this group 'complementors', a counterpart to 'competitors'. This concept stems from an idea initiated by Jorde & Teece (1989), who noted that: "...whereas co-operation among firms was once a subject confined to anti-trust case books, it is increasingly a topic for discussion..." Indeed, ways in which firms can 'co-operate to compete' are receiving considerable attention" (p. 25). This argument is in line with the current phenomenon in the container shipping industries characterised by a movement towards strategic alliances between major international companies. UNCTAD (1996) and Juhel (2000) initiated a co-operative concept between ports so as to adapt themselves to a flexible traffic distribution pattern through several port outlets. Again, Avery (2000) proposed strategic alliances between adjacent container ports – 'port strategic alliances' – as a counter-strategic option against their counterparts in shipping lines, in order to survive the ever-increasing competitive business environment.

In port co-opetition, Song (2003; 2004) proposed a framework based on Porter's competitive forces (Porter, 1980). To gain competitive edges, ports must be able to respond rapidly to market changes and found a way to enhance firm market power. Rather than utilizing competitive strategies alone, port operators adopted co-opetition as a new strategic option to build up a stronger position in their markets, so that they could enhance market power. Such strategy was formalized through the formulation of a set of objectives and the choice from a variety of co-operative arrangements. Combining competition and cooperation as a corporate strategy for global port players would lead to a coherent and consistent strategic option because it searched for a market opportunity in a way that creates competitive advantages (Aaker, 1984). Cooperation through joint venture or similar forms yielded flexibility in responding to market competition (Porter, 1986). Moreover, Starr (1991) agreed that joint ventures or other cooperative forms could access to a power without losing the flexibility.

In this respect, Song (2004) further elaborated the concept by investigating the motivations behind such a strategic movement. Having identified the five motivations (viz., strategic, financial, economic, operational and marketing motivations), he indicated that the main reason for establishing a certain form of co-opetition in PRD was strategic matters. These included the penetration (by Hong Kong-based operators) into a new market (in this case, Shenzhen) so as to expand their relative market volumes. This motivation was supported by the fact that the combined ports of Shenzhen had become an increasingly active player within global container trade, and were recently ranked as the fourth largest container port in the world after Singapore, Shanghai and Hong Kong. Such a trend was largely because PRD had already become the second largest production site in China after the Yangtze Delta Region, and stimulated Hong Kong-based operators to install their portion on the site as part of their long term business plan. Hence, marketing issues stood up as another important reason for co-opetitive formation within the region. The last important motivation came from operational issues, followed by financial and economic motivations. The premise of port complementarity and competition was investigated by Notteboom (2009) and Lam & Yap (2011) regarding to these factors. In their work, Lam and Yap (2011) argued that the decision by liner services to call at particular ports can be influenced by the joint competitive offering of a group of ports in PRD, instead of one individual entity. Port authorities, port operators and other stakeholders should thus further explore opportunities that could be capitalised via complementary relationships between ports.

4.3 THE ECONOMIC MODEL

We consider the case where two ports compete with differentiated services. The differentiation may be due to differences in service quality, or simply the two ports have overlapping but not identical hinterlands, or they have different facilities to serve different market segmentation. The inverse market demand functions for the port 1 and port 2 can be illustrated as follows:

$$
\begin{cases} p_1 = a_1 - b_1 q_1 - s\,q_2 \\ \\ p_2 = a_2 - b_2 q_2 - s\,q_1 \end{cases} \tag{4.1}
$$

It is assumed that $b_i > s > 0$ $(i = 1{,}2)$.[14] Note the demand function can be rewritten as

$$
\begin{cases} q_1 = \frac{1}{b_1 b_2 - s^2}\left((b_2 a_1 - s a_2) - b_2 p_1 + s p_2\right) \\ \\ q_2 = \frac{1}{b_1 b_2 - s^2}\left((b_1 a_2 - s a_1) - b_1 p_2 + s p_1\right) \end{cases} \tag{4.2}
$$

Thus, positive outputs at both ports imply that:

$$
b_2 a_1 - s a_2 > 0,\ b_1 a_2 - s a_1 > 0 \text{ and } a_i > c_i \tag{4.3}
$$

---

[14] Note such an assumption is not as restrictive as it appears if demand is considered as deterministic. In such case, even if one considers there is a per unit capital cost, the cost function can be rewrite as constant marginal costs since capacity will always be fully utilized.

Case I. Port Rivalry

In the simplified model, we consider the case when two ports compete with each other in Cournot, as it is well known that capacity pre-commitment and price competition yield the Cournot outcome (Kreps & Scheinkman 1983)[15]. Thus in the case of port rivalry, each port chooses their respective output to maximize its own profit $(p_i - c_i)q_i$. Each port's profit maximization problem is specified as the following problem:

$$Max_{q_i}\,\pi_i = (p_i - c_i)q_i \tag{4.4}$$

Where $p_i = a_i - b_i q_i - sq_j$ as specified in (4.1). Solving the FOC for both ports, the equilibrium port throughputs, port charges and port profits are as follows, where the superscript *r* denotes the case of port rivalry.

$$q_1^r = \frac{2b_2(a_1-c_1)-s(a_2-c_2)}{4b_1b_2-s^2}, \quad q_2^r = \frac{2b_1(a_2-c_2)-s(a_1-c_1)}{4b_1b_2-s^2} \tag{4.5.1}$$

$$p_1^r = \frac{[b_1(2b_2a_1-sa_2)+sb_1c_2+(2b_1b_2-s^2)c_2]}{4b_1b_2-s^2}, \tag{4.5.2}$$

$$p_2^r = \frac{[b_2(2b_1a_2-sa_1)+sb_2c_1+(2b_1b_2-s^2)c_1]}{4b_1b_2-s^2}$$

$$\pi_1^r = \frac{b_1\,[2b_2(a_1-c_1)-s(a_2-c_2)]^2}{(4b_1b_2-s^2)^2}, \quad \pi_2^r = \frac{b_2\,[2b_1(a_2-c_2)-s(a_1-c_1)]^2}{(4b_1b_2-s^2)^2} \tag{4.5.3}$$

---

[15] Our adoption of Cournot assumption to analyze inter-port competition should be realistic to reflect observed ports competition pattern. In practice, as the port capacity investment is capital intensive and not feasible to change at later stage, ports normally plan and determine their capacity expansion projects very carefully and strategically. Later, after the capacity has been established, ports thus compete in price (Bertrend competition) in the short run with this capacity cap. This Cournot assumption or two stage game approach (with first stage capacity decision and second stage price competition) have also been used to analyze the inter-port competition such as Luo, Liu and Gao (2012) and Zhuang, Luo and Fu (2013).

Case II. Alliance to Maximize the Joint Profit

We now consider a case where two ports cooperate with each other to jointly set their port throughputs in order to maximize their total joint profit $\pi_1 + \pi_2$. The profit maximization problem can be specified as:

$$Max_{q_1 q_2}(\pi_1 + \pi_2) = (p_1 - c_1)q_1 + (p_2 - c_2)q_2 \tag{4.6}$$

Solving this problem allows us to obtain the market equilibrium as follows, where superscript a denotes for joint profit maximizing alliance:

$$q_1^a = \frac{b_2(a_1-c_1)-s(a_2-c_2)}{2(b_1 b_2-s^2)} \ , \ q_2^a = \frac{b_1(a_2-c_2)-s(a_1-c_1)}{2(b_1 b_2-s^2)} \tag{4.7.1}$$

$$p_1^a = \frac{(a_1+c_1)}{2}, \quad p_2^a = \frac{(a_2+c_2)}{2} \tag{4.7.2}$$

$$\pi_1^a = \frac{(a_1-c_1)[b_2(a_1-c_1)-s(a_2-c_2)]}{4(b_1 b_2-s^2)} \ , \quad \pi_2^a = \frac{(a_2-c_2)[b_1(a_2-c_2)-s(a_1-c_1)]}{4(b_1 b_2-s^2)} \tag{4.7.3}$$

We define the parameter $a_i - c_i$ as η_i. η_i is called "net absolute advantage". A port is able to have higher η_i either with larger market potential a_i or with lower unit operating cost c_i. Higher net absolute advantage contributes to larger profit margin in the sense that c_i is lower and / or port can charge higher price *ceteris paribus* when a_i is high.

The two ports will participate in the alliance to maximize joint profit only if both of them are better off with the alliance. ($\pi_i^a > \pi_i^r, i = 1,2$). Below we scrutinize the conditions on parameters η_1,η_2, b_1, b_2,s,so that the joint profit maximizing throughput (q_1^a, q_2^a) can simultaneously increase two ports' profits ($\pi_i^a > \pi_i^r, i = 1,2$). It turns out that the parameter net absolute advantage η_i plays a determining role.

The condition to have positive throughputs and resultant profits in both rivalry and alliance cases require

$$\frac{s}{b_1}\eta_1 < \eta_2 < \frac{b_2}{s}\eta_1 \tag{4.8}$$

For both ports to participate the joint profit maximizing alliance, their profits must increase simultaneously compared to the rivalry case, i.e., $\Delta\pi_1 = \pi_1^a - \pi_1^r > 0$ and $\Delta\pi_2 = \pi_2^a\text{-}\pi_2^r > 0$. Substituting equations (4.5.3) and (4.7.3) into these two inequalities, it can be shown that the inequalities hold only when the following condition is satisfied:

$$A\eta_1 < \eta_2 < B\eta_1 \tag{4.9}$$

Where $A = \frac{s\sqrt{8b_1b_2+s^2}+(4b_1b_2-s^2)}{2b_1\sqrt{8b_1b_2+s^2}} > \frac{s}{b_1}$, $B = \frac{\sqrt{8b_1b_2+s^2}(4b_1b_2-s^2)-s(8b_1b_2+s^2)}{8b_1(b_1b_2-s^2)} < \frac{b_2}{s}$

Therefore, both ports increase profits by forming the joint profit maximizing alliance (i.e., $\pi_1^a\text{-}\pi_1^r > 0$ and $\pi_2^a\text{-}\pi_2^r > 0$) only when their net absolute advantages (η_1, η_2) fall into **area (I)** shown in Figure 4-1.

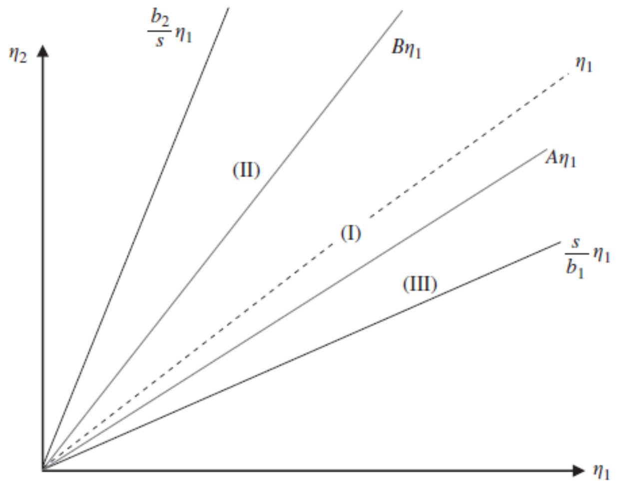


Figure 4-1. Conditions for $\eta_i, i = 1,2$ to form joint profit maximizing alliance

The market equilibrium outcomes in different areas (Figure 4-1) are summarized in following Table 4-1.

Table 4-1. Comparison of Equilibrium Outcomes: Alliance (Joint Profit Maximization) vs. Rivalry

Area	$q_1^a - q_1^r$	$p_1^a - p_1^r$	$\Delta\pi_1 = \pi_1^a - \pi_1^r$	$q_2^a - q_2^r$	$p_2^a - p_2^r$	$\Delta\pi_2 = \pi_2^a - \pi_2^r$
(I)	−	+	+	−	+	+
(II)	−	+	−	− or +	+	+
(III)	− or +	+	+	−	+	−

As summarized in Table 4-1,

- In **area (I)**, $\pi_1^a - \pi_1^r > 0$, $\pi_2^a - \pi_2^r > 0$. The alliance **CAN** be formed;
- In **area (II)**, $\pi_1^a - \pi_1^r < 0$, $\pi_2^a - \pi_2^r > 0$. Port 1 will **NOT** join the alliance;
- In **area (III)**, $\pi_1^a - \pi_1^r > 0$, $\pi_2^a - \pi_2^r < 0$. Port 2 will **NOT** join the alliance.

In addition, as shown in **area (I)**, with alliance formed to maximize total joint profit, port service charge will increase in both ports, but port throughputs in both ports will always decrease under the alliance. Mathematically, in **area (II)** and **area (III)** where joint profit maximizing alliance cannot be formed, we have the following results, where $C = \frac{2b_1b_2+s^2}{3b_1s} \in (B, \frac{b_2}{s})$ and $D = \frac{3b_2s}{2b_1b_2+s^2} \in (\frac{s}{b_1}, A)$

(4.10.1) $q_2^a - q_2^r < 0$ if $\eta_2 < C\eta_1$ and $q_2^a - q_2^r > 0$ if $\eta_2 > C\eta_1$ in **area (II)**;

(4.10.2) $q_1^a - q_1^r < 0$ if $\eta_2 > D\eta_1$ and $q_1^a - q_1^r > 0$ if $\eta_2 < D\eta_1$ in **area (III)**.

The alliance to maximize joint profit can be formed only when the difference of net absolute advantage between the two ports ($\Delta\eta = \left|\eta_j - \eta_i\right|$) is small (i.e. **area (I)**). When the difference of net absolute advantage is high, meaning that one port owns significant stronger net advantage over the other one (i.e. **area (II)** and **area (III)**, the port with lower net absolute advantage prefers to competing rather than cooperating, making the joint profit maximizing alliance impossible.

The intuition for above result is as follows: joint profit maximizing alliance requires both ports to increase their prices. This "Price Rising Effect" reduces traffic volumes in both ports. Meanwhile, the "Output-switch Effect" requires the alliance to relocate output from port i with lower net absolute advantage to port j with higher net absolute advantage. The port j always benefits from both "Price Rising Effect" and "Output-switch Effect", and has a higher profit under alliance. For port i with lower net absolute advantage, however, if difference between η_i and η_j is very high, joint profit maximization will require switching too much amount of outputs from port i to port j . Without transfer payment or compensation, the benefits of increased price with alliance cannot compensate the throughput loss in port i . As a result, port i would rather compete than losing traffic. However, when the difference of net absolute advantage between the two ports is small, only a limited amount of traffic will be switched from low net absolute advantaged port to the other port. Such a small traffic switching can be fully compensated by "Price Rising Effect". As a result, only when the difference of net absolute advantage between the two ports is small will **BOTH** ports simultaneously achieve profit increase.

$$(4.11.1)\quad \frac{\partial\Delta\pi_1}{\partial\eta_1} = \frac{s^2\left(8b_1b_2+s^2\right)(2b_2\eta_1-s\eta_2)}{4(b_1b_2-s^2)(4b_1b_2-s^2)^2} > 0 \qquad \frac{\partial\Delta\pi_1}{\partial\eta_2} = -\frac{s^2[s\left(8b_1b_2+s^2\right)\eta_1+8b_1\left(b_1b_2-s^2\right)\eta_2]}{4(b_1b_2-s^2)(4b_1b_2-s^2)^2} < 0$$

$$(4.11.2)\quad \frac{\partial\Delta\pi_2}{\partial\eta_2} = \frac{s^2\left(8b_1b_2+s^2\right)(2b_1\eta_2-s\eta_1)}{4(b_1b_2-s^2)(4b_1b_2-s^2)^2} > 0 \qquad \frac{\partial\Delta\pi_1}{\partial\eta_2} = -\frac{s^2[s\left(8b_1b_2+s^2\right)\eta_2+8b_2\left(b_1b_2-s^2\right)\eta_1]}{4(b_1b_2-s^2)(4b_1b_2-s^2)^2} < 0$$

In addition, (4.11.1) and (4.11.2) imply that within the feasible range of η_i,η_j to form the joint profit maximization alliance, one port can achieve increased profit in the alliance once itself (the other port) has higher (lower) net absolute advantage. In other words, port has more incentive to participate in the alliance when its net absolute advantage is higher than the other port. The impacts of service differentiation on the joint profit maximizing alliance formation, reflected by the signs of $\frac{\partial\Delta\pi_1}{\partial s}$ and $\frac{\partial\Delta\pi_2}{\partial s}$, however, they cannot be determined analytically. Numerical examinations of $\frac{\partial\Delta\pi_1}{\partial s}$ and $\frac{\partial\Delta\pi_2}{\partial s}$ can be achieved utilizing real operational data in Shenzhen and Hong Kong ports of year 2010. The results are presented in following model calibration section.

4.4 MODEL CALIBRATION: THE PEARL RIVER DELTA (PRD)

Empirical evidence has been sought to verify our analytical results. In this part, PRD (Hong Kong and Shenzhen) is explored. This pair of ports is spatially close serving overlapping but not identical hinterlands. They are thus ideal to be subjects for our numerical analysis.

Denote Shenzhen as port 1 and Hong Kong as port 2 corresponding to our model. We collected port output (port throughput) and service charge (terminal handling charge[16]) data for both ports in year 2010. Specifically, the throughput for Shenzhen port is $q_1 = 22{,}510$ thousand TEU, and $q_2 = 23{,}532$ thousand TEU for Hong Kong port. The terminal handling charge serves as reasonable proxy for port service charge. The charge for 20 feet Dry is used in our numerical analysis, thus that $p_1 = 1{,}170$ HKD for Shenzhen and $p_1 = 2{,}100$ HKD for Hong Kong. It is assumed that market demand elasticity for port services in the region is -1.5. With above data and assumptions, the model can be calibrated as follows:

(a). b_1, b_2 and s: In the model, it is required that $b_i > s > 0$. As Hong Kong provides higher quality port services than Shenzhen, users of Hong Kong port should be more price inelastic than those of Shenzhen port. So we have $b_2 > b_1 > s$. We thus set $s = tb_2$ $(0 < t < 1)$, so that if $t = 0$, the two ports service are not substitutes at all, while $t = 1$

---

[16] We adopted the THC set by CSAV shipping line, assuming that the THC charged by shipping line to its shippers can largely reflect the port service levied by the port to the shipping line.

means two ports produce homogenous services. For the Hong Kong and Shenzhen cases, we consider two base cases where $t = 0.9$ and $t = 0.7$, respectively. If $\mathrm{t} = 0.9$, services provided by Hong Kong and Shenzhen ports are highly substitutable, while if $\mathrm{t} = 0.7$, their services are moderately substitutable. To meet the restriction that$b_2 > b_1 > s$, assumption that $b_1 = \frac{1}{2}(b_2 + s)$ is also specified.

(b). The market equilibrium outputs and prices for rivalry case $q_1^r = 22{,}510, q_2^r = 23{,}532$, $p_1^r = 1{,}170,\ p_2^r = 2{,}100$

(c). Market aggregate output$\mathrm{Q} = q_1^r + q_2^r = 46{,}042$; market service charge$p = \frac{p_1^r q_1^r + p_2^r q_2^r}{Q} = 1{,}645$; market demand elasticity $e = -1.5$

(d). When the market service charge change by $dP = dp = dp_1^r = dp_2^r$, then from demand function (1), the total change in market output is $\frac{dQ}{dp} = \frac{dq_1^r}{dp} + \frac{dq_2^r}{dp} = \frac{2s - b_1 - b_2}{b_1 b_2 - s^2}$. Since the market demand elasticity $e = \frac{dQ}{dp}\frac{P}{Q}$ is known by previous assumption, b_2 can be obtained as $b_2 = \frac{-2P}{(1+2t)Qs}$, and $s = tb_2,\ b_1 = \frac{1}{2}(b_2 + s)$, can also be derived.

With this calibration process, parameters associated with the model can be obtained and illustrated in Table 4-2.

Table 4-2. Base case model results for t=0.9

Parameter	b_1	b_2	s	a_1	a_2	c_1
Value	0.02424911	0.02552538	0.022972844	2256.44	3217.76	624.2
Parameter	c_2	η_1	η_2	π_1^r	π_2^r	π_1^a
Value	1499.3	1632.3	1718.4	12,286,700	14,134,808	9,784,259
Parameter	π_2^a	$\Delta\pi_1$	$\Delta\pi_2$	q_1^a	q_2^a	Δp_1
Value	19,651,836	-2,502,442	5,517,027	11,988.48	22,871.74	270.3

Parameter	Δp_2	Δq_1	Δq_2			
Value	258.56	-10,521.20	-660.30			

When $t = 0.9$, the model calibration shows that $\eta_1 < \eta_2$. That is, the net absolute advantage for Hong Kong port is higher than that of Shenzhen. The revealed relation between η_1 and η_2 corresponds to the area (III) in the analytical part, where π_1^a-π_1^r<0 π_2^a-π_2^r >0. In this case, port alliance would require Shenzhen port to increase its service charge by 23.10% or HK$ 270.3 ($\Delta p_1 = 270.3$). Such a price increase would diminish throughput in Shenzhen by 46.74% or 10,521.20 thousand TEU ($\Delta q_1 = -10{,}521.20$). Such a dramatic traffic loss cannot be offset by the price increase, leading to reduced profit ($\Delta\pi_1 = -2{,}502{,}442$) to Shenzhen port. Therefore, Shenzhen port is unlikely to join the alliance.

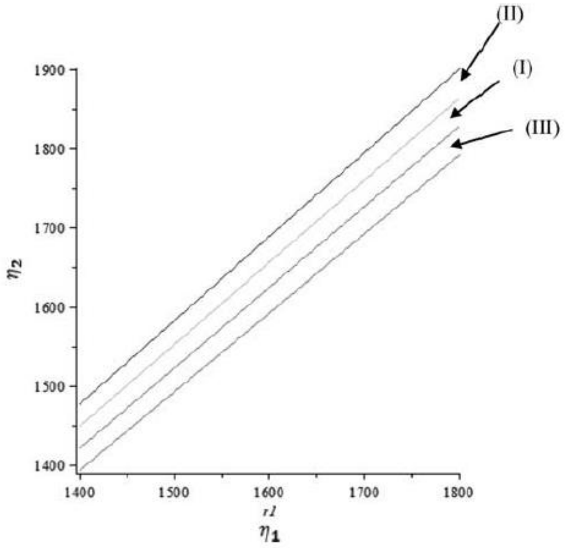


Figure 4-2. Conditions for $\eta_i$to form alliance (joint profit maximization), t=0.9

As the analytical analysis reveals, however, the alliance is made possible when gap of η_1 and η_2 shrinks (η_1 is increased or η_2 is decreased, thereby (η_1, η_2) moves to **area (II)**), thus Shenzhen port can experience less throughput reduction caused by "Output

Switching Effect". This is exhibited by following numerical simulation. Fixing η_2 and gradually increasing η_1 from its current level 1,632.3, Δp_1 is still positive, but the magnitude for Δq_1 is getting smaller, indicating less lost throughput for Shenzhen under the alliance. Finally $\Delta\pi_1$ turns to positive, implying that Shenzhen port has incentives to join the alliance. The same happens when we decrease η_2 (Table 4-3).

Table 4-3. Sensitivity test on net absolute advantage of Shenzhen Port, t=0.9

η_1	Δp_1	Δq_1	$\Delta\pi_1$
1632.3	270.3	-10521.2	-2,502,442
1642.3	268.9	-9388.7	-1,585,059
1652.3	267.6	-8251.6	-653,329
1662.3	266.2	-7114.5	289,061
1672.3	264.9	-5977.3	1,242,113

The calibration also enables us to empirically explore how service differentiation affects the formation of joint profit maximizing alliance. For Shenzhen port, when $s < 0.0148$, $\Delta\pi_1$ increases with s, implying Shenzhen port is more likely to cooperate with Hong Kong port when their services become more substitutable. This is because, when service substitutability is getting greater but still remain insignificant, alliance can help alleviate increasing port competition and bring evident "Price Rising Effect" over "Output Switch Effect" to Shenzhen port. However, as s further increases ($s > 0.0148$), the "Output Switching Effect" will finally prevail and result in too much output loss for Shenzhen port, thereby reducing its profit under alliance. This phenomenon is better explained by the extreme case where Shenzhen port provides homogenous service as Hong Kong port ($s = b_2 = 0.0255$). The "Output Switching Effect" requires relocating all throughputs from Shenzhen to Hong Kong whose net absolute advantage is higher and who can bring higher profit for the whole alliance. Therefore, if either port can further differentiate their port services, the alliance might be feasible as Shenzhen port could own larger market power, thus alleviating possible severe “Output Switching Effect” under the joint profit maximizing alliance.

For Hong Kong port, $\frac{\partial \Delta\pi_2}{\partial s}$ is always positive, implying that it is more willing to form alliance when its service becomes more substitutable to that of Shenzhen port. The intuition for Hong Kong port to benefit from higher service substitutability is straightforward: first, alliance can always relieve intensified competition and bring significant “Price Rising Effect” to Hong Kong port. Second, as Hong Kong owns higher net absolute advantage, “Output Switching Effect” will force Shenzhen port to convert more business to Hong Kong port, given that their services are rather substitutable.

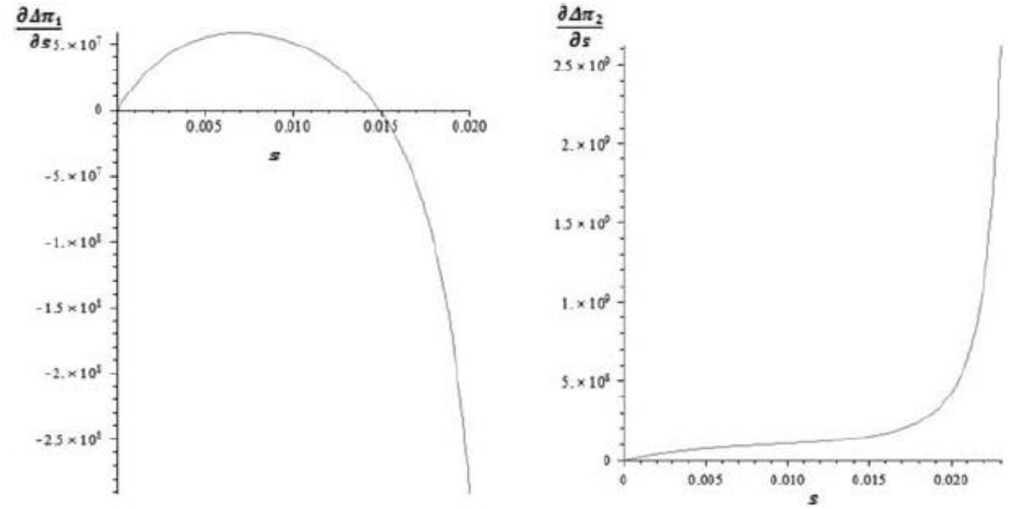


Figure 4-3. Effects of service differentiation s on the $\Delta\pi_1$ and $\Delta\pi_2$, t=0.9

Next, we test the effects of service substitutability by assuming t = 0.7. Using the same calibration process, the model parameters can be found in Table 4-4.

Table 4-4. Base case model results for *t* = 0.7

Parameter	b_1	b_2	s	a_1	a_2	c_1
Value	0.02531267	0.029779612	0.020845728	2230.32	3270.00	600.2
Parameter	c_2	η_1	η_2	π_1^r	π_2^r	π_1^a
Value	1399.2	1630.1	1870.8	12,825,590	16,490,610	12,185,401
Parameter	π_2^a	$\Delta\pi_1$	$\Delta\pi_2$	q_1^a	q_2^a	Δp_1
Value	19,591,794	-6,401,190	3,101,184	14,950.47	20,945.1	245.3
Parameter	Δp_2	Δq_1	Δq_2			
Value	234.6	-7,559.2	-2,586.9			

If $t = 0.7$ meaning the port services between Shenzhen and Hong Kong ports are moderately substitutable, based on the observed market equilibrium in 2010, the calibration result shows that Hong Kong port still has significantly higher net absolute advantage than that of Shenzhen port ($\eta_2 > \eta_1$). As same as the case where t=0.9, the gap between η_1 and η_2 is quite clear as well, making (η_1, η_2) to locate in **area (III)** where the alliance to maximize joint profit is infeasible (π_1^a-π_1^r<0 π_2^a-π_2^r >0) . As Hong Kong port has clear net absolute advantages over Shenzhen, the "Output Switching Effect" calls for dramatic throughput reduction (33.58%) in Shenzhen port so that the "Price Rising Effect" cannot justify this tremendous throughput loss.

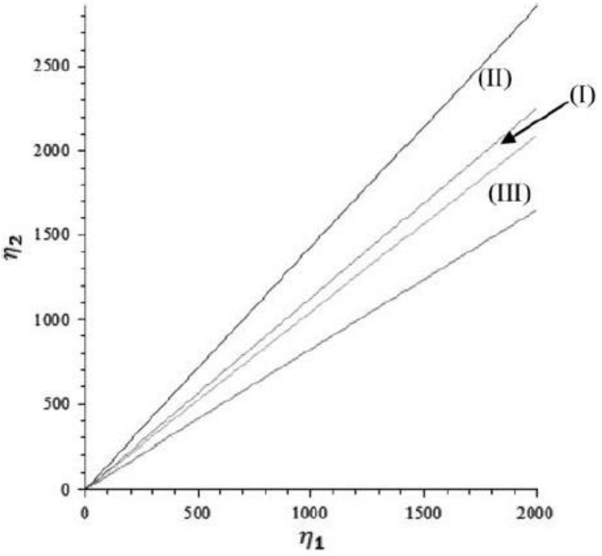


Figure 4-4. Conditions for η_i to form alliance (joint profit maximization), t=0.7

When *t*=0.7, just as the case *t*=0.9, the empirical investigation on how service differentiation affects joint profit maximization alliance formation could also be carried out, and the similar conclusions were obtained. Also, it should be noted that the assumption on port price elasticity may not be accurate. To test the robustness of our calibrated results, sensitivity tests are conducted. Our numerical results suggest that for any elasticity in the range of -1.1 to -2, there will be no qualitative change in our numerical simulation results (i.e., when t=0.9 or 0.7, $\Delta\pi_1 < 0$ and $\Delta\pi_2$>0).

4.5 DISCUSSION AND CONCLUSION

Hong Kong is an international port heavily influenced by the 'active non-interventionist' policy and, until recently, largely isolated from China's national/regional planning due to its special political and economic status. However, recently, the port is facing considerable challenges, notably increased trade between China and overseas markets, challenges from neighboring ports, the increasing importance of intra-Asian trade and the economic turmoil in 2008 which accelerated the industrial transformation of PRD. All such development has put the expected forecasts regarding the current and future development of Hong Kong into question, notably its shrinking hinterland size within South China. Hence, Hong Kong is compelled to undergo strategic changes, notably its gradual integration within China's national and regional planning, and integrate within PRD so as to establish a system with the functions of different PRD ports complementary to each other. How such a newly-developed regional port cluster should develop, however, notably the division of responsibilities of cargo flows between Hong Kong and other major PRD ports is still rather ambiguous. Although a number of scholars have provided different possible scenarios, they remain largely hypothetical, lacking scientific research in assessing their practicality, and do not provide any convincing reasons justifying why such scenarios should/would take place. The need for research on this topic is clearly an urgent necessity.

Hence, by developing a game theory model, this chapter investigates the factors and conditions affecting alliance formations for ports serving partially overlapped hinterlands. To reflect institutional and political constraints ports face in real life, and calibrate the model in PRD (Hong Kong and Shenzhen). Our analytical results suggest that where institutional and political factors prohibit usual business practices in alliance formation, such as merger, cross-share holding and transfer payments, alliance formation becomes much less likely. In particular, the likelihood of forming an alliance aiming to maximize the total profit of participating ports is dependent on many factors, such as service differentiation among the ports, relative cost efficiency and market potential among the ports. In general, there are two major effects affecting alliance formation: to maximize the joint profit of the alliance, participating ports have incentives to increase their prices. Such 'Price Raising Effects' benefit participating ports in terms of higher prices but meanwhile reduce each other's throughputs. Meanwhile, to increase the aggregate profits of participating ports, it is better for the alliance to switch some of the throughputs from high cost ports to low cost ones. Such 'Output Switching Effect' will change the distribution of profit among alliance members. As a result, without usual commercial arrangements to properly relocate the benefits of cooperation, port alliance will be established only when there is a balance between the 'Price Raising Effects' and 'Output Switching Effects', and thus all participating ports can benefit from the cooperation. Our analytical results also suggest that institutional and political factors will not only inhibit alliance formation directly, but will also introduce new challenges for ports to exploit economic gains which would otherwise be achievable.

Based on actual market data observed in 2010 and assumptions on service substitutability, our analytical model is calibrated thus that possible alliance between Hong Kong and Shenzhen ports is evaluated. Our results suggest that a joint profit maximizing alliance would coordinate price increases at both ports. This is favorable to Hong Kong port which is likely to prefer alliance over competition. If the services offered in the two ports are closely substitutable, then such price increase would lead to dramatic throughput loss in Shenzhen port, which cannot be compensated by higher price. As a result, at current costs, Shenzhen port is unlikely to join the alliance. However, if Shenzhen port further reduces its cost, increased cost leadership and accompanied 'Output Switching Effects' would possibly alleviate its traffic loss. In this case, Shenzhen may prefer alliance to rivalry. If the services offered in the two ports are not very substitutable, then even with the price increase required by the alliance, throughput loss in Shenzhen port will be relatively moderate. As a result, Shenzhen can improve its overall profit with the alliance price increase, so that it will prefer alliance to rivalry. In summary, to make the port alliance more likely, Shenzhen shall further increase cost leadership, or the two ports should try to differentiate their services.

It is important to note that, however, there is only a thin line between cooperation and competition. In practice, cooperation may bring some efficiency gains in firms' production process, which is beneficial to the society. On the other hand, any cooperation involving coordination of competition strategy may, at least, perform some major functions of cartel. In this sense, we may yet to be in a position to recommend port cooperation in general which is still subject to further research. Nevertheless, for many regions there have been some signs of over-investment, which may lead to oversupply of capacity in the near future. In addition, the marine shipping industry is heavily influenced by business cycle. During a recession, ports may engage in cut-throat competition, which may not be good to the long term growth of the industry. Our study has focused on the competitive effects of alliance, which are of key consideration in alliance formation and choice. This will help us to understand the overall effects of port cooperation. This does not necessarily imply that collusion among ports is recommended. Instead, our findings can facilitate a comprehensive assessment of the effects of port alliance, thus that port policymakers and managers can make the best decisions for themselves and the industry.

Indeed, this study possesses substantial potential for wide academic and practical values. It is well observed that a port becomes a crucial player in regional and global supply chain systems. This is particularly true to Hong Kong. With the city's gradual, but accelerating, integration within PRD, especially in its port region and supply chains, and China's recently released national and regional planning, imposes a challenge as well as creates an opportunity. Hence, this study can play a very important role in complementing Hong Kong SAR's government's 'Hong Kong-Shenzhen Metropolis' concept which emphasizes regional integration including transport and logistics development. Such future strategic direction and development of Hong Kong port will inevitably be significantly affected by China's institutional framework and political system. Indeed, South China would serve as the pioneer showpiece of what kind of regional port governance is taking place under highly diversified institutional frameworks. Hence, this study does not only offer substantial insight into policy implementation in South China, but also provides a new, original perspective towards the establishment of a 'best practice' template to the rest of the world in governance, regional planning and development. Moreover, given that the port and logistics developments often require substantial financial investments (for instance, according to China's 11th Five-Year Plan, 7.1 billion RMB is going to be invested in developing logistics parks around Shenzhen port), our analysis can potentially save massive resource wastage due to inappropriate decisions and development direction. Being nodal points of multimodal supply chains, the existence of a good regional port governance system is a highly important first step in developing an effective, fully-integrated regional transportation system within PRD, so as to help this region to achieve the ambitious goal of becoming the largest, most convenient and most efficient logistics hub in China, as well as the most open, convenient, efficient and secure hub within Asia-Pacific (Sit, 2009). By doing so, we have offered constructive advices to policymakers in establishing an effective, pragmatic and sustainable regional governance structure for PRD. Hence, this study serves as a very important first step in developing an effective, fully-integrated regional transportation system within PRD.

Globally, analyzing port development and identifying the relationship of their evolution to particular economic and social contexts have real potentials to inform national, regional or local governments of the costs and benefits of such developments. This will bear very significant implications for any evaluation of capital-intensive infra- and superstructure investments. Therefore, substantial stakeholders, both public and private sectors, will benefit from our analysis, especially in the identification of the determinants of success, as well as the ways and reasons that these may diversify on the basis of different economic and social contexts. Hitherto, this does not only imply a prescription of success maximization, but also offers invaluable opportunities for sophisticated operators to tailor-made design configurations which can fit diversified, regional and local conditions. In a nutshell, the beneficiaries of our analysis would range from academic communities, policymakers in transportation, economic and regional planning, to managers and decision-makers in transport and logistics as well as associated economic sectors involved in substantial, capital-intensive investments on public facilities.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 CONCLUSIONS

This thesis investigates some of the important policy changes in the transport industry and also benchmarks alternative options so that the optimal policies and best industry practices can be identified. Empirical and analytical investigations have been conducted selectively depending on the market structures involved and data availability. Essay one in chapter 2 examines Chinese airlines' competitiveness and benchmarks it to other leading airlines in the world. Essay two in chapter 3 develops an analytical model to analyze and benchmark two different ETS mechanisms (open ETS vis-à-vis METS) for the international shipping industry. Easy three in chapter 4 adopts both analytical solutions and numerical simulations to study strategic choice of cooperation and competition among neighboring marine ports. The key findings and implications obtained from these three essays are summarized as follows.

Essay one shows that Chinese airlines' efficiencies have improved during the last decade, but their productivities still lag behind that of industry leaders. Chinese airlines' profitability is attributable to high yields and low input prices in the domestic market. But unit cost advantage enjoyed by Chinese airlines has been diminishing over time. These investigation results lead to following policy implications: The Chinese government's policy reforms are steps in the right direction, but the deregulation efforts have been incomplete and inadequate. The Chinese government should embrace the global trend of deregulation and liberalization more enthusiastically, and allow more competition in airline markets. Moreover, airline input market in China shall be further liberalized so as to lower Chinese airlines' unit costs and to enhance their existing cost advantage against foreign carriers.

Essay two finds that an ETS, whether open or maritime only, will decrease ship speed, carrier outputs and fuel consumption for both the container and bulk sectors, even in the presence of "wind-fall" profit to carriers. The increased ship operation cost will deteriorate this output reduction under ETS. To overcome this negative impact, carriers have stronger incentive to improve fuel efficiency through technical and operational measures. In addition, the degree of competition in a sector will have spill-over effects to the other sector under the METS. Specifically, when the sector that sells (buys) permits is more collusive (competitive), the equilibrium permit price will rise. This study provides a framework to identify the moderating effects of market structure and firm competition on emission reduction schemes, and emphasizes the importance of understanding the differential impacts of ETS schemes brought to individual sectors within an industry.

Essay three uses the South China region as a case to examine factors and conditions affecting regional port governance. A game theory model is developed and calibrated for the Pearl River Delta. It investigates the port governance options, notably alliance formation for ports serving partially overlapping hinterlands. The study demonstrates that the likelihood to form a port alliance is dependent on many factors, such as service differentiation among ports, relative cost efficiency and market potential of neighbouring ports. Therefore, both the Hong Kong government and the China central government should carefully design long-run ports development strategy taking into account of these factors that affect port governance.

5.2. RECOMMEDATIONS FOR FUTURE RESEARCH

Some recommendations on future research have already been made in each of the aforementioned essays. Still, further improvement may be achieved in some areas. To investigate and evaluate the effects of alternative ETS schemes for the international shipping industry, dynamic economic models may be considered since there may be repeated (annual) allocation of emission quota. Therefore, a carrier's emission/output in the last round (previous year) could affect its free emission quota in the following round (year). Therefore carriers must behave strategically in every period to maximize their aggregate profits or the net present values of profit. This problem may be either modeled as a multi-stage game or a repeated game. A dynamic analysis will be a very useful extension to our current static model. In our ETS study alternative emission permit allocation methods can also be considered. For example, auction has been proposed as an efficient allocation mechanism. In addition, in essay three, demand uncertainty can be incorporated into economic modeling. Intuitively, *ceteris paribus,* ports will have stronger incentives to cooperate in the presence of demand uncertainty so as to lower risk. Meanwhile, demand uncertainty may also result in strategic changes in port pricing and capacity investment. These abovementioned future studies will be very valuable and make additional contributions to the literature

APPENDIX A. SECOND-ORDER DERIVATIVE CONDITION FOR MAXIMIZATION PROBLEM (3.3) AND (3.8)

SOC for the optimization problem in equation (3.3)

$$\begin{vmatrix} \dfrac{\partial^2 \pi_{r,i}}{\partial q_{r,i}^2} & \dfrac{\partial^2 \pi_{r,i}}{\partial q_{r,i} \partial S_{r,i}} \\ \dfrac{\partial^2 \pi_{r,i}}{\partial S_{r,i} \partial q_{r,i}} & \dfrac{\partial^2 \pi_{r,i}}{\partial S_{r,i}^2} \end{vmatrix} = \begin{vmatrix} -b_r(2+v_r) & -\dfrac{D_r}{U_r\rho}(2\eta\lambda_r S_{r,i} - \dfrac{\gamma_r}{S_{r,i}^2}) \\ -\dfrac{D_r}{U_r\rho}(2\eta\lambda_r S_{r,i} - \dfrac{\gamma_r}{S_{r,i}^2}) & -\dfrac{2q_{r,i}D_r}{U_r\rho}(\eta\lambda_r + \dfrac{\gamma_r}{S_{r,i}^3}) \end{vmatrix}$$

Off diagonal is equal to zero by the first order condition (3.6.1). Therefore, for the SOC to hold, the product of the diagonal elements should be positive. $-\frac{2q_{r,i}D_r}{U_r\rho}\left(\eta\lambda_r + \frac{\gamma_r}{S_{r,i}^3}\right) < 0$, and $-b_r(2+v_r)$ is also negative because $v_r \geq -1$. So the SOC is satisfied.

SOC for maximization problem (3.8)

$$\begin{vmatrix} \dfrac{\partial^2 \pi_{r,i}}{\partial q_{r,i}^2} & \dfrac{\partial^2 \pi_{r,i}}{\partial q_{1,i} \partial S_{r,i}} \\ \dfrac{\partial^2 \pi_{r,i}}{\partial S_{r,i} \partial q_{r,i}} & \dfrac{\partial^2 \pi_{r,i}}{\partial S_{r,i}^2} \end{vmatrix} = \begin{vmatrix} -b_r(2+v_r) & -\dfrac{D_r}{U_r\rho}[2(\eta+\chi)\lambda_r S_{r,i} - \dfrac{\gamma_r}{S_{r,i}^2}] \\ -\dfrac{D_r}{U_r\rho}[2(\eta+\chi)\lambda_r S_{r,i} - \dfrac{\gamma_r}{S_{r,i}^2}] & -\dfrac{2q_{r,i}D_r}{U_r\rho}[(\eta+\chi)\lambda_r + \dfrac{\gamma_r}{S_{r,i}^3}) \end{vmatrix}$$

Similar to the proof of SOC for (3.3), it can be proved that the SOC for (3.8) is also satisfied.

APPENDIX B. PROOF OF RESULTS IN (3.7)

As $\tilde{q}_r = \frac{2a_rU_r\rho - 3D_r\sqrt[3]{2\eta\lambda_r\gamma_r{}^2}}{2U_r\rho b_r[(N_r+1)+v_r]}$, it is evident that $\frac{\partial \tilde{q}_r}{\partial \eta} < 0$, $\frac{\partial \tilde{q}_r}{\partial \lambda_r} < 0, \frac{\partial \tilde{q}_r}{\partial D_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0$.

$$\frac{\partial \tilde{q}_r}{\partial U_r} = \frac{3D_r\sqrt[3]{2\eta\lambda_r\gamma_r{}^2}}{2U_r^2\rho b_r[(N_r+1)+v_r]} > 0$$

As $\tilde{S}_r = \sqrt[3]{\frac{\gamma_r}{2\eta\lambda_r}} > 0$, it is evident that $\frac{\partial \tilde{S}_r}{\partial \eta} < 0$, $\frac{\partial \tilde{S}_r}{\partial \lambda_r} < 0, \frac{\partial \tilde{S}_r}{\partial \gamma_r} > 0$

$\tilde{F}_r = \frac{\sqrt[3]{2\lambda_r{\gamma_r}^2}D_r(2a_rU_r\rho-3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2})}{4\sqrt[3]{\eta^2}U_r^2\rho^2b_r[(N_r+1)+\nu_r]}$, thus, it is clear that $\frac{\partial\tilde{F}_r}{\partial\nu_r} < 0$

As we have $2a_rU_r\rho > 3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2}$ from (3.6), thus

$$\frac{\partial\tilde{F}_r}{\partial\eta} = -\frac{\sqrt[3]{2\lambda_r{\gamma_r}^2}D_r(4a_rU_r\rho-3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2})}{12\eta\sqrt[3]{\eta^2}U_r^2\rho^2b_r[(N_r+1)+\nu_r]} < 0$$

$$\frac{\partial\tilde{F}_r}{\partial\lambda_r} = \frac{\sqrt[3]{2{\gamma_r}^2}D_r(a_rU_r\rho-3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2})}{6\sqrt[3]{\lambda_r\eta^2}U_r^2\rho^2b_r[(N_r+1)+\nu_r]} > \text{ or } < 0$$

$$\frac{\partial\tilde{F}_r}{\partial U_r} = -\frac{\sqrt[3]{2\lambda_r{\gamma_r}^2}D_r(a_rU_r\rho-3D_r\sqrt[3]{2\eta\lambda_r{\gamma_r}^2})}{2\sqrt[3]{\eta^2}U_r^3\rho^2b_r[(N_r+1)+\nu_r]} > \text{ or } < 0$$

APPENDIX C. TABLE AND FIGURE

Table A1. Freighter fleet for major Chinese and foreign cargo airlines

	Airlines	**Number of freighters**	**Aircraft type**
China	China Southern	8	B747-400, B777
	Air China Cargo	10	B747-400
	China Cargo Airlines	19	B747-400,B757-200,B777,A300-600,MD11
	China Postal Airlines	16	B737-300, B737-400
	Yangtze River Express	14	B737-300, B747-400
	Jade Cargo	6	B747-400
	SF Express	7	B737-300, B757-200
Foreign	Korean Air	24	B747-400
	Cathay Pacific	21	B747-400, B747-8
	China Airlines	20	B747-400
	Martinair	13	B747-400, MD11
	Nippon Cargo Airlines	8	B747-400
	Cargolux Airlines International	15	B747-400, B747-8

Singapore Airlines	12	B747-400
Aerologic	8	B777
UPS	523	Boeing, Airbus, MD, DC
FedEx	688	Boeing, Airbus, MD, DC, ATR, Cessna

Source: Report on Chinese air cargo industry development published by Industrial Securities.

Table A2. Revenue per employee (1000 USD per person) with PPP adjustment for Chinese airlines

Year	**China Eastern**	**China Southern**	**Air China**	**China A.V.E**	**American**	**Delta**	**United**	**Continental**	**Air Canada**	**North America A.V.E**
2001	271.44	310.96	268.06	282.84	180.77	181.96	192.12	209.07	165.59	186.37
2002	253.79	322.32	291.08	292.42	158.94	184.63	198.42	191.39	155.61	178.40
2003	263.48	301.59	278.03	281.64	180.91	202.66	213.43	235.40	167.26	200.07
2004	307.11	383.83	335.66	342.33	202.44	220.32	237.11	258.76	256.50	228.55
2005	278.38	322.72	363.06	325.56	234.30	295.87	262.28	283.53	284.60	267.71
2006	290.21	292.65	396.37	327.84	260.54	341.75	298.89	319.49	324.24	303.77
2007	297.46	330.88	395.80	343.42	268.25	347.98	309.73	335.90	385.01	320.50
2008	248.70	313.09	422.56	333.67	282.59	378.78	341.92	376.69	400.19	348.22
2009	227.50	291.38	344.52	293.03	252.43	346.00	299.40	317.51	346.93	311.49
2010	327.65	297.91	401.26	343.96	283.32	398.51	414.80	414.80	439.22	386.15

Note: Chinese airlines' revenues expressed in USD have been adjusted by PPP.

Table A3. Airlines Yield Regression Result

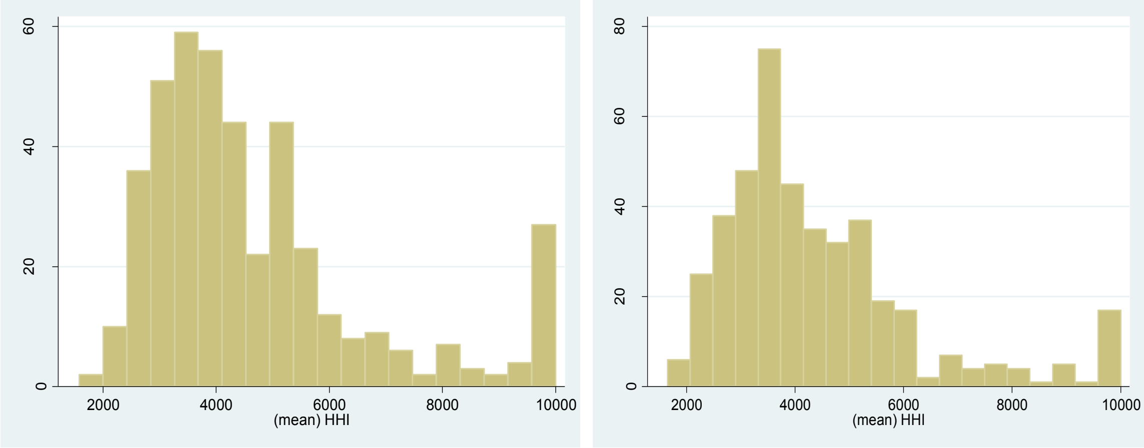
Yield	**Coef.**	**Std. Err.**	t	P>t	[95%	Interval]
Distance	-0.0011	0.0002	-5.38	0.00	-0.002	-0.001
_cons	10.5455	0.4263	24.74	0.00	9.702	11.389

Number of obs = 139

F(1,137) = 28.97

R-squared = 0.175

Adj R-squared = 0.169



(a). Year 2010 (b) Year 2011

Figure A1. The frequency distribution of route level HHI for Chinese Top 500 routes

Source: calculated by author using OAG data
Note: Top 500 routes are selected based on the ranking of route total scheduled seats.

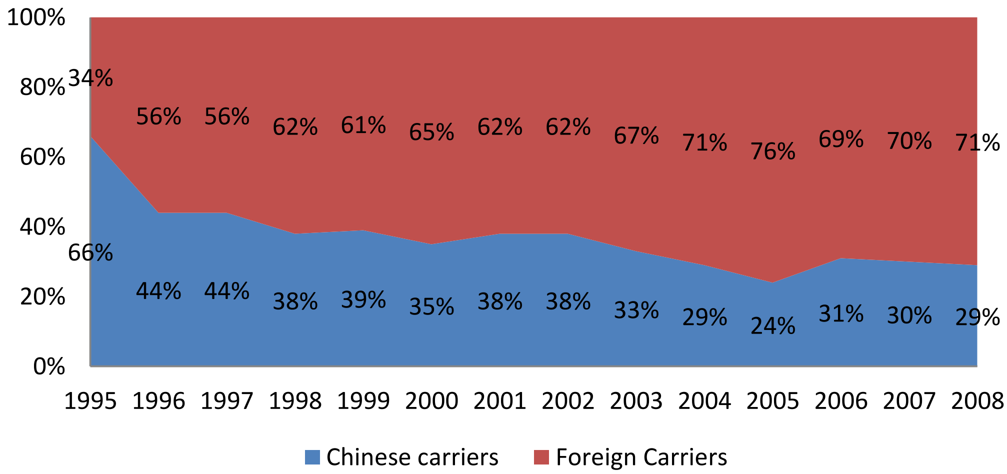


Figure A2. Share comparison between Chinese and foreign carriers in the Chinese international air cargo market

Source: Report on Chinese air cargo industry development published by Industrial Securities.

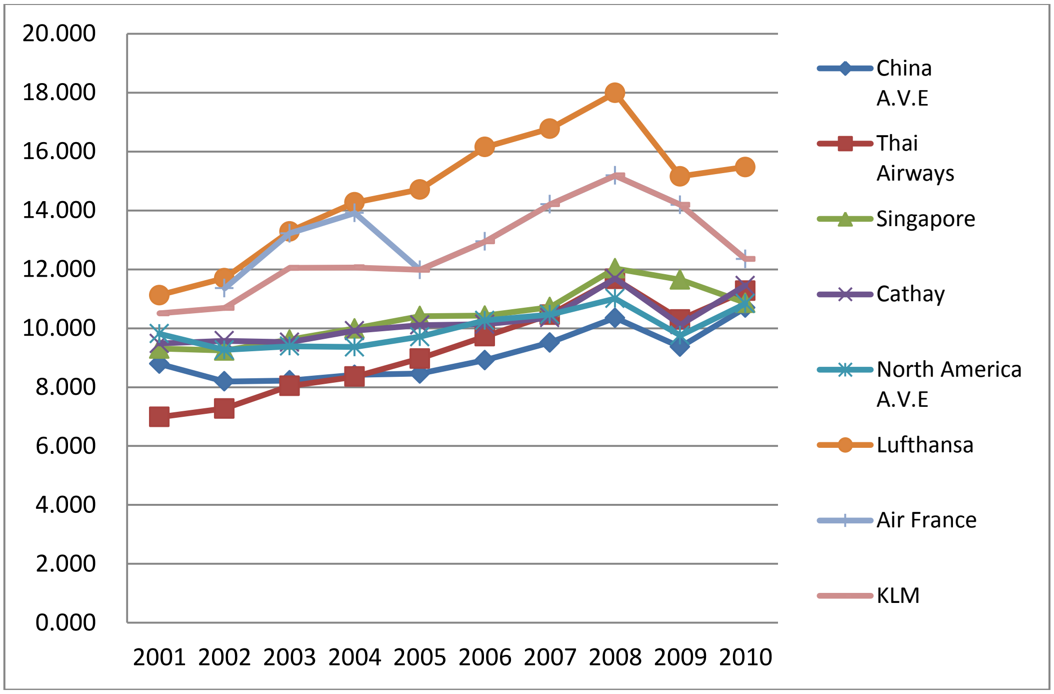


Figure A3. The stage length adjusted yields comparison

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