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The Effects of Joining a Strategic Alliance Group on Airline Efficiency, Productivity and Profitability

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Abstract

A global airline strategic alliance group is a larger cooperation formed by several airlines in order to obtain strategic advantages in their business operations. Nowadays, airline strategic alliance groups have become an important sector of the airline industry and also tend to have dominance in airline business. Airlines want join a strategic alliance group in order expand their business and reduce their costs – and expect to. However, the true benefits of the effects of a strategic alliance group still remain unclear. Little research has been done on how airline alliance strategic groups affect changes in airline performance. This study adopts three different empirical quantitative analyses to reveal the effects of a strategic alliance group on airline performance. The performance indicators included airline technical efficiency, productivity and profitability. The research focuses on 20 international airlines during the 1995–2005 periods from two major categories: allied airlines, which included three global airline strategic alliance groups, and non-allied airlines. The research used data envelopment analysis and stochastic frontier analysis to assess the airlines’ technical efficiency, while panel regression analysis for airline productivity and profitability.

The results suggest that joining an airline strategic alliance group generally will have positive effects on its member airlines’ technical efficiency, productivity and profitability. However, the results are not statistically significant. This implies that the effects of an airline alliance group are practically unimportant to the airline performance, particularly during the study period. Thus this research reveals that airlines joining the alliance group may not necessarily achieve significant improvements in their performance. During the pre-maturity stage of the alliance group, joining an alliance does not necessary bring positive effects to the airlines’ performance. Secondly, the research suggests that alliance group membership numbers do not always have a positive impact on the airline performance, so alliance groups should consider their size. For newly entering airlines, choosing a relatively smaller alliance group can reduce the entry cost. Moreover, the research also shows that there is a minimum membership duration before an airline can receive alliance group membership benefits. It implies that airlines who seek to join the alliance group as a quick solution will not have their expectations met. Further, the research has confirmed the strong year effect existing in the airline industry, which further suggested that alliance group effects are limited and should not be considered as a universal solution.

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Glossary of Abbreviations / Acronyms

AA = American Airlines

AC = Air Canada

AF = Air France

AI = Air India

ATAG = Air Transport Action Group

BA = British Airways

BC = Before Christ

BCC = Banker – Charnes – Cooper

BMI = British Midland International

CCR = Charnes – Cooper – Rhodes

CD = Cobb – Douglas

CP = Cathay Pacific

CRS = Constant Returns to Scale

CZ = Czech Airlines

DE = Delta Air Lines

DEA = Data Envelopment Analysis

DMU = Decision Making Unit

drs = decreasing returns to scale

EQA = European Quality Alliance

FA = Finnair

FFP = Frequent Flyer Programme

FSCs = Full – Service Carriers

FTK = Freight Tonne Kilometres

GDP = Gross Domestic Product

GPE = Ground Property and Equipment
IATA = International Air Transport Association
IB = Iberia Lines
ICAO = International Civil Aviation Organisation
irs = increasing returns to scale
KA = Korean Airlines
LCCs = Low – Cost Carriers
LF = Load Factors
LU = Lufthansa
MA = Malaysia Airlines
Mgteff = Airline’s Management Efficiency Change
MLE = Maximum Likelihood Estimation
MPI = Malmquist Productivity Index
MPSS = Most Productivity Scale Size
OAG = Official Airline Guide
OLS = Ordinary Least Squares
PP = Proportion of Passenger Business
PRA = Panel Regression Analysis
Prod = Airline’s Productivity Change
PTE = Pure Technical Efficiency
RPK = Revenue Passenger Kilometres
RTK = Revenue tonne kilometres
SARS = Severe Acute Respiratory Syndrome
SAS = Scandinavian Airlines
Scaleff = Airline’s Scale Efficiency Change
SE = Scale Efficiency
SFA = Stochastic Frontier Analysis

SIA = Singapore Airlines

SL = Stage Length

TA = Thai Airways

TE = Technical efficiency

Techgl = Airline's Technical Efficiency Change

THY = Turkish Airlines

TL = Trans – Log Production Function

U.S.A. = United States of American

UA = United Airlines

UK = United Kingdom

US = United State

VA = Virgin Atlantic Airways

VRS = Variable Returns to Scale

YR = Year

1. Introduction

1.1 Background

This research provides empirical evidence of the benefits that airlines obtain by joining a strategic alliance. The research particularly focuses on analysing the airlines' performance concerning the action of joining a strategic alliance group. Currently, there are three major passenger service-oriented airline alliance groups, which are Star Alliance, OneWorld and SkyTeam. These three airline alliance groups have accounted for more than half of the total world air traffic as at 2010. There are many reasons for an airline to join an alliance group. For instance, over the last 20 years, the business environment for airlines has become more and more complex, especially with the continuing progress of globalisation. The threats from the external environment, including increasing business complexity, the scarcity of resources and intensive market competition, have meant that forming a single partnership alliance no longer satisfies the business development aims of many airlines.

In such conditions, in order to survive and continually expand, the strategic alliance group business model has emerged and has become a valuable strategy for airlines. This new strategy has quickly become a remarkable phenomenon in the business world. The model helps airlines to extend their business networks considerably without huge costs and to create economies of scale to promote their business and to increase their competitive advantage greatly. The basic definition of an alliance group fits with that of a normal alliance, where the alliance is an agreement between two or more parties, made in order to advance common goals and secure common interests. The strategic alliance group is, however, more complex and raises the level of cooperation between the partners to the strategic level.

In the past, two airlines usually had a bilateral cooperation with each other. However, forming a large alliance group was rare and unsuccessful. The modern airline strategic alliance group emerged at the end of the last century. In 1997, five airlines, which included

Air Canada, Lufthansa, Scandinavian Airlines, Thai Airways International and United Airlines, formed the world's first truly global airline strategic alliance group: Star Alliance. Two other strategic alliance groups have followed. SkyTeam, currently the second largest airline alliance group, was founded by Aeromexico, Air France, Delta Air Lines and Korean Air in 2000. OneWorld was founded by American Airlines, British Airways, Canadian Airlines, Cathay Pacific and Qantas in 1999. The following table shows some facts about the three global airline strategic alliance groups, based on 2012 facts.

Table 1.1: Airline Strategic Alliance Group Facts

Alliance Name	Star Alliance	SkyTeam	OneWorld	Total
Membership	25 full members	15 full members	12 full members	52 airlines
Year founded	1997	2000	1999	
Passengers per year	648.85 million	487 million	336 million	1478 million
Destinations	1293 airports	926 airports	871 airports	1472
Revenue (billion \$US)	160.89	97.9	89.4	348
Market share	29.3%	20.6%	23.2%	73.1%

Note: The table has been constructed using figures from the Star Alliance, SkyTeam and OneWorld official websites (Star Alliance, 2012; SkyTeam, 2012; OneWorld, 2012).

1.2 Research Questions

Airlines generally consider that joining an alliance will bring a lot of benefits to the company. However, the formation of business alliances does not always succeed as a business strategy. An early study by James (1985) suggested that forming alliances to protect long-term independence may weaken, rather than strengthen, a company's activities, since a company can lose the ability and capacity to produce a fully integrated product, and also because alliances hold up only as long as the conditions which favoured their formation remain in force and the interests of the partners are homogeneous. Losing an independent strategic

approach could bring difficulties for a partner company. This may be the reason why some organisations are questioning the effectiveness of business alliances. Devlin and Bleackley (1988) suggested that an alliance should have a true strategic perspective, rather than just be seen as an option to fix specific business problems quickly. Das and Teng (2000) reported that more than 50% of strategic alliances fail. McCutchen *et al.* (2008), in their study of biopharmaceutical alliances, reported that a strategic alliance is more likely to be terminated and have poor performance when it involves research and development, and marketing elements, has domestic partners, has partners with limited prior strategic alliance experience and where there is a high level of strategic alliance experience disparity between the partners. In the real world, a number of alliance groups have failed due to various reasons. So the question should be asked whether joining an alliance group is a good choice for airlines.

In order to answer this question, this research will analyse airlines' changes in performance that result from alliance effects. The main question here is how an airline's performance has changed after joining an alliance group. To answer this, the study will provide an analysis of several aspects. Firstly, the study will provide an analysis of the relationship between airline performance and joining an alliance group. Secondly, the study will compare the performance of two different groups of airlines: those that are part of an alliance group and those that are not. Thirdly, the study will address an airline itself, and whether its performance has improved after joining an alliance group. The study will compare the performance of sample airlines during their pre-alliance period and their post-alliance period. Lastly, the study will explore, within the alliance group, whether the number of members and membership duration will affect an airline's performance.

1.3 Research Gaps

To date, there are some research gaps within the airline alliance literature. Firstly, the airline alliance studies lack quantitative empirical evidence. Many alliance studies are based on theoretical analysis but lack quantitative analysis. Moreover, especially for the alliance analysis, most studies are out of date. Secondly, many research articles contain a mix of various forms of airline cooperation. Airline cooperation is complex and multiplex. A lot of

researches on airline alliances have taken several different types of agreements into account. Thirdly, the existing literature seldom contains have rarely conducted an analysis of global alliance groups, which only emerged in the late 1990s. Some research in the early 2000s is mostly based on four alliance groups. However, with the demise of Wings Alliance – officially defunct in September 2004 – there are only three alliance groups left. Thus, as the world airline alliance market share and membership has changed, those studies have become less useful in terms of assessing individual member performance. Finally, most contemporary airline performance research has focused solely on one of the following methods: data envelopment analysis (DEA), stochastic frontier analysis (SFA) and econometric regression. However, almost no research has been conducted comparing the three methods.

1.4 Research Objectives

This study aims to establish the following two main objectives, described below.

Firstly, the study aims to redefine and reclassify the strategic airline alliance. The term ‘strategic alliance’ has been widely used in many areas, from military and diplomatic settings to business operations. When concerning business, many other form of business strategy have been derived from the strategic alliance and mixed together. Currently, the term ‘strategic alliance’ has been used to describe many different situations. Concerning the airline industry, the chaos of misusing ‘strategic alliance’ becomes more complicated. Thus, in order to dissect the benefits that a strategic alliance has brought for its members, it is necessary to redefine and reclassify the strategic airline alliance.

Secondly, the study aims to reveal changes in the airlines’ performance relative to their alliance activity and then to clarify the economic benefits obtained from joining a strategic alliance. This will be done using three different methods, including DEA, SFA and econometric panel regression analysis (PRA). In the existing literature, most airline alliance performance studies have used empirical qualitative analysis. There is, however, a lack of quantitative evidence. Moreover, there are rare studies that can be found that use DEA and SFA methods for analysing the airline alliance effects. Thus, by constructing models and

comparing these three methods, the results will provide an insightful view into the benefits of airline strategic alliances.

1.5 Hypotheses

1.5.1 The Effects of Strategic Alliance Groups on Airline Performance

This research will explore whether joining or forming an airline strategic alliance group can improve the productivity and profitability of the member airlines. Firms' productivity can be measured by the ratio of outputs to inputs (Farrell, 1957). According to this definition, a firm can improve its productivity by reducing inputs, increasing outputs or both. As the literature suggests, an alliance group will help airlines to reduce the inputs through resource pooling or sharing and joint activities, and to increase outputs through synergy, and cooperation between partner firms. For example, airlines can minimise inputs by reducing overseas expenditure and maximise product/service outputs through the whole alliance group network, thereby increasing productivity. Thus, the strategic alliance group will improve the productivity of its member airlines.

According to basic economic theory, in order to increase their profitability, firms have two ways to achieve this: by increasing revenue, reducing operating costs or both. An airline can increase its revenue by increasing the price of its product or the quantity of the product sold. However, both are hard to achieve and are not realistic in practice. The main reason for this is that the air travel market is very price sensitive and most airlines face competitors who provide very similar products. Increasing the price will almost certainly result in an airline losing market share because customers can easily find a similar product elsewhere. Moreover, increasing the quantity of the product sold is also hard to achieve because travel demands are mostly fixed throughout the year.

Therefore, reducing operating costs will be the only way to increase profit. By entering a strategic alliance group, airlines can achieve cost reductions through increasing operational efficiency, achieving economies of scale and scope, cost/risk sharing, knowledge sharing and learning, and access to greater resources and skills (Harrigan, 1986). The alliance group will also improve bargaining power over suppliers through the bulk purchase of such items as materials, equipment, and parts (Porter, 1980). Moreover, as a member of a strategic alliance group, airlines will increase their competitive market advantage by quickly introducing new products or services, building entry barriers, increasing brand recognition and getting access to new markets without too much investment (Eisenhardt and Schoonhoven, 1996).

If an airline can achieve all of the above by joining an alliance group, its production efficiency will certainly be improved. Thus, based on the arguments mentioned above, the research proposes that:

Hypothesis 1: Strategic alliance group membership will help airlines to improve their performance, which includes operational efficiency, productivity and profitability.

1.5.2 Effects of Alliance Group Membership Numbers and Membership Duration

Membership numbers refers to the number of airlines in an alliance group. Membership duration is the total number of years that an airline has been in an alliance group. As time goes on, more and more airlines want to join existing alliance groups. As a group gets bigger and bigger, its member airlines may achieve better economies of scale and improve their profitability and productivity. For example, with an increase in membership numbers, the member airlines can extend their routes, reduce unnecessary competition, increase aircraft utilisation and increase passenger load factors. Those activities are expected to increase an airline's productivity gains. With respect to airlines' profitability, by increasing passenger numbers, reducing operational costs through the sharing of overseas facilities and increasing their bargaining power over suppliers, membership in an alliance group could potentially increase operating profits.

However, many airlines have a desire to expand continually. In order to dominate the market, many airlines try to consolidate their market share by providing more flights on almost saturated routes. As a result of this, an alliance group as an entity may struggle with a similar problem brought on by competition from other alliance groups. Although alliance group membership is a good solution for avoiding the cut-throat competition between individual airlines it may simultaneously raise the competition to a new level between different alliance groups. When the competition arises between the alliance groups, airline performance will decrease accordingly. Thus, the study proposes its next hypothesis:

Hypothesis 2: Alliance group membership numbers, membership duration and the continuing increase in membership numbers will have diminishing marginal positive impacts on the member airlines' performance.

1.6 Importance of the Research

This study is designed to provide economic and financial analysis regarding various aspects of global strategic alliances. Airline performance in this study is defined in terms of productivity and profitability. The results are expected to provide basic information for use in airline decision making in terms of joining an alliance group, and to add valuable findings to the existing literature on airline strategic alliances. Strategic alliances are usually confused with ordinary business alliances. No single definition of a strategic alliance has yet been agreed upon by researchers in this field. Most researchers form their own views of what defines a strategic alliance. The question is whether a strategic alliance really exists and whether we can distinguish a strategic alliance from other forms of alliance.

Within the research context, it is usually considered that all alliances between airlines are strategic alliances. There are a large number of studies into strategic alliances. However, most of these confuse the notion of a strategic alliance with straightforward business cooperation. For example, Rhodes and Lush (1997) questioned the use of the term *strategic alliance* to describe everything from simple single-route code-sharing to a complex agreement. In terms of the airline industry, the term strategic alliance becomes more complex, meaning that it is

almost impossible to demonstrate whether or not an alliance relationship between two airlines is a strategic one. Most alliances in the airline industry claim to be strategic alliances. For instance, Air India and Lufthansa formed a strategic alliance relationship in 2004 that specifically focused on India–Europe–USA routes based on signing a strategic alliance agreement, which mostly focused on code-sharing, and sales and marketing cooperation. Can this alliance be seen as a true strategic alliance? Some other alliances also use the term strategic alliance in the title. For instance, Jet Airways and Kingfisher Airlines formed an alliance in 2008, which has been referred to as a strategic alliance in the news media, similar to reports about global airline strategic alliances such as Star Alliance SkyTeam and One World.

How can we distinguish between ordinary alliances and strategic alliances? Considering the scope of such alliances, the degree of alliance between airlines cannot be used as the criterion to distinguish a strategic alliance from an ordinary one. For example, Jet Airways and Kingfisher Airlines formed an agreement in 2008 for the formation of an alliance of wide-ranging proportions, from common code-sharing to cross-utilisation of crew on similar aircraft. The exchange of flight crews rarely occurs in the aviation industry because aircraft have been considered the most valuable assets for the company. On the other hand, some other forms of alliance are more common, such as that of Delta Air Lines and Alaska Air Group in 2008, where they announced an expanded marketing alliance. Can both of these types of alliances be referred to as strategic alliances?

This research makes a contribution to this debate through analysing changes in the performance of an airline as a result of joining a strategic alliance group, as well as the performance of different strategic alliance groups. The previous studies seldom analysed the performance of airlines joining a strategic alliance group. The main reason for this omission is that the emergence and development of global airline strategic alliance groups only occurred in the late 1990s. This timing was a result of the globalisation process. Most previous studies only focused on aspects of alliance groups other than economic performance. The widespread use of the term '*alliance*' in previous studies focused the analysis on bilateral alliances, rather than on alliance groups. Thus, this study will analyse

and compare the performance of individual airlines in relation to changes in their alliance status.

This research will add to the airline business literature in the area of comparing three different scientific analytical methods measuring airline performance. It will address some of the gaps that exist in current literature, particularly by providing empirical evidence of performance change in relationship to the formation of an alliance group. This study will aid policy and decision making by providing a framework for an understanding of (1) the costs and benefits of joining an airline alliance group; (2) the empirical evidence of how airlines' performance changes upon joining an alliance group; (3) the effects of alliance-related factors on airline performance. Thus, airlines will benefit through an understanding of how an alliance relationship will affect an airlines' performance.

The research aims to achieve the following outcomes:

- A systematic review of the strategy, partnership and business alliance literature in the aviation industry and the wider business context, and the clarification of the term *strategic alliance*;
- An empirical analysis of an individual airline's performance using the multilateral index method;
- A review of previous studies on airline performance and reconstruction of the model used to compare airlines' performance related to alliance issues; and
- To use three different analytical methods to identify any changes in performance related to an airline joining an alliance group.

1.7 Research Limitations

There are some limitations to this research. The major problem is insufficient data. Airlines deal with a lot of sensitive data, which they generally do not publish. Moreover, the International Civil Aviation Organization (ICAO) database this research uses has a voluntary reporting system where airlines provide their annual operational results in a particular format. Unfortunately, some data cannot be located because an airline did not report any data at all or only reported incomplete data. Moreover, because the ICAO database has a special reporting format, it is hard to find the missing data through other resources. This means that this research was limited to particular airlines and a particular timeframe. The sample size and study period may create some bias during the analysis. Possible future studies have been suggested in later chapters.

2. An Overview of the Airline Industry and Airline Alliances

2.1 Introduction

This chapter provides a brief overview of the airline industry and some background knowledge. The chapter firstly provides an historical overview of the airline industry and then outlines some characteristics of this very special industry. The opportunities for and threats to the airline industry also have been addressed in the first part of this chapter. The second part of the chapter mainly outlines the development of the airline alliances. It provides detailed information of the development of airline alliances and the benefits that they may bring to their members. Moreover, the cost-effectiveness and risks of joining a strategic alliance have also been addressed.

2.2 History of the Airline Industry

Since modern aviation began in 1903 with the Wright brothers' first successful flight in the Kitty Hawk, aircraft have gradually become dominant in global mass transportation. In human history, it took almost 8000 years for mankind to increase the average long-distance mass transit speed from 8 miles per hour by camel caravan in 6000 BC to 100 miles per hour with the invention of an improved steam engine¹. However, it took only 60 years for humans to invent a new transportation tool whose speed reached 4000 miles per hour in the 1960s (Rhoades, 2008). As aircraft completely changed the way humans travel and their mass transportation capability, they soon created a whole new industry, which is the airline industry (Morrison and Winston, 1995).

¹ Long-distance mass transit speeds did exceed 8 miles per hour in this period, with sea transport attaining approximately double this speed in the 1800s.

The history of the modern airline industry only started at the beginning of the last century. At the very beginning of the 1900s, however, aircraft were not considered as a travel option due to their lack of safety and comfort. It was not until 1914 that the first scheduled commercial airline was established in the United States of America (U.S.A.), providing flights on the Saint Petersburg route (Heppenheimer, 1998). Others, including Braniff Airways, American Airlines, Delta Air Lines, United Airlines (originally a division of Boeing), Trans World Airlines, Northwest Airlines and Eastern Air Lines, launched passenger services during the early 1920s.

The aviation industry benefited from development of military aircraft during the two world wars. World War I assisted the initial development of the air transport industry, but commercial air transport did not begin operations until after that war, with the availability of military aircraft making it more feasible (Canner, 1986). In 1925, the Ford Motor Company bought out the Stout Aircraft Company and began construction of all-metal airliners with a 12-passenger capacity. This development made passenger services potentially profitable. At the same time, Pan American World Airways created an air network linking the US to the rest of world, operating fleets flying between Los Angeles and Shanghai, and between Boston and London (Clouatre, 2002).

An important thing happened during this period. In order to speed up the nationwide mail delivery, in 1926, the Postmaster-General began granting route authorities to airlines based on their bids to provide airmail service (Morrison and Winston, 1995). By 1927, the Post Office Department had contracted out all airmail service to private carriers, because of the Kelly Airmail Act of 1925, which allowed private airlines to become mail carriers. Through the use of airmail profits, many private companies were able to expand and eventually include passengers in their operations. With the introduction of the Boeing 247, the Douglas DC-2 and later the Douglas DC-3 in the 1930s, the US airline industry was, in general, profitable, even during the Great Depression (Allaz, 2004). The US Postal Service became one of the biggest factors in the growth of the air transportation industry. In 1935, the best known plane in the series, the DC-3, had set a new standard in passenger travel. By the 1940s, approximately 90% of the passenger aircraft flying in the US were either DC-2s or DC-3s (Clouatre, 2002)

The outbreak of World War II became a turning point in the airline industry (Mattimoe, 2012). The technical innovations and the individual and collective achievements that occurred during the war has changed the nature and sharpened the popular perception of the airline industry as it moved into the second half of the twentieth century (Morrison and Winston, 1995). The war helped to generate support for research and development into airplanes, eventually leading to improvements in commercial aviation. For example, the introduction of a four-engine aircraft significantly reduced flying times. World War II also brought new life to the airline industry. Many airlines in the Allied countries were able to gain large revenues from leasing contracts with the military, which foresaw the future explosive demand for civil air transport, for both passengers and cargo (Heppenheimer, 1998).

A vast amount of growth in the airline industry was occasioned by major technical innovations, such as the introduction of jet aircraft for commercial use in 1950s, followed by the development of the wide-body jumbo jet in the 1970s (Grant, 2002). Due to the large investment by the government into research and development for the new technology, originally for military aircraft, civil aviation benefitted heavily after the war. Aircraft were continually modernised by the technological improvements from military usage (Clouatre, 2002). For example, the 1959 release of the DC-8, which was equipped with four engines, had a seating capacity of 260 passengers and was capable of speeds over 600 miles per hour, which appeared to provide the blueprint of future air transportation (Clouatre, 2002). Later in the 1970s, the introduction of the wide-body jumbo jet became another milestone for the aviation industry. The newly designed Boeing 747, McDonnell Douglas DC-10 and Lockheed L-1011 inaugurated wide-body services for international travel. With this development, airlines were able to provide safer and more comfortable travel for passengers. Over the following 30 years, the aviation industry entered into the second jet age, with a variety of more efficient jet engine aircrafts having been introduced to the commercial airline industry, including the A320 family and the Boeing 7 series (Davies, 2011).

2.3 Airline Business Models

Currently, the airline industry has evolved into a mature industry with two business models, which are represented in terms of how the carrier generates revenue, and its product offering, value-added services, revenue sources and target customers (Cento, 2009). The two main competing airline business models are:

- Full-service carriers (FSCs) and
- Low-cost carriers (LCCs).

An FSC is usually defined as an airline company developed from the former stated-owned flag carriers (Wald *et al.*, 2010; Cento, 2009; Holloway, 2008). Cento (2009) suggested following characteristics that define a FSC:

- It often represents a country's image and pride.
- The core businesses include passenger, cargo and maintenance.
- It is usually operated under a hub-and-spoke network, where the major objective is to achieve full coverage of as many demand categories as possible through the optimisation of connectivity in the hub.
- It is a global network provider which operates in domestic, international and intercontinental markets with short-, medium- and long-haul flights from the hubs to other continents.

Most FSCs attract a large amount of attention from their global alliance partners because no individual airline has developed or has the ability to develop a truly global network. Thus, it is necessary to cooperate with other partner carriers.

The FSC uses different in-flight and ground services, electronic service and travel rules to cover all possible market segments in order to achieve vertical product differentiation. The typical FSC usually has a loyalty programme called a frequent flyers' programme (FFP) to attract frequent flyers to fly and stay with it. The FFP helps the carriers to manage their customers through the introduction of reliable processes and procedures for interacting with

customers. At the same time, the FFP also enhances the passengers' buying and travelling experience in order to personalise the carriers' services (Cento, 2009).

Compared with the FSC, the LCC is a new concept only begun in the 1970s (Wald *et al.*, 2010; Cento, 2009; Holloway, 2008). It originated in the US with Southwest Airlines and spread to Europe in the 1990s (Bamber *et al.*, 2009). Its main operational goal is to achieve a competitive advantage in term of costs over the traditional carriers. It is characterised by providing a point-to-point network and most routes are within the same continent (Bjelacic, 2007). It commonly uses secondary airports in order to reduce the landing fees and aircraft handling fees. Moreover, operating at secondary airports can avoid congestion in the busy airports. In general, an LCC operates with only one type of aircraft, such as Boeing 737 or Airbus A320, in order to achieve lower maintenance costs. It usually has a high aircraft utilisation rate compared to the FSCs (Cento, 2009).

For cost-saving purposes, LCCs usually do not offer lounge services, use a single seat configuration, do not have an FFP and have minimum in-flight service (Gross and Schröder, 2007). Moreover, it also minimises sale and reservation costs by using direct channels such as Internet or telephone sales centres. Additionally, an LCC also obtains revenue from non-ticket sale related activities, such as commissions from hotels and car rental companies, credit card fees, excess luggage charges, in-flight food and beverages, and advertising space. Those revenues account for a large part of its operational revenue (Cento, 2009).

Currently, FSCs are facing serious competition from the LCCs. The LCC sector has continued to grow over the years and has nibbled at the market share of the FSCs, especially in the domestic routes and on large continents such as America and Europe. As Mintel International Group (2006) pointed out, the airline market has reached a certain level of maturity so that customers are more and more price-sensitive rather than service-oriented. The LCCs have provided just what customers have really desired. The European LCC market continues to grow strongly, with Ryanair accounting for 23% and EasyJet accounting for 16% of the total air travel passengers carried (Cento, 2009). Moreover, because of the cost

structure and operation procedures, competitive price reductions by FSCs are not a viable option (Hanlon, 2007).

2.4 Global Airline Operations: Big, Fragile and Resilient

After a century of development, there is no doubt that the airline industry has already developed into a large industry, and is an important sector of the global economy (Rhoades, 2008). An airline is a company that provides air transport services for travelling passengers and freight between two different locations. The core of the business is providing special services that transfer objects and people to different places. The route taken could simply be between two points domestically or internationally between continents. Nowadays, the global airline industry provides services that almost cover every country in the world. A large international airline can operate hundreds of aircraft and transfer thousands of passengers worldwide each day. According to O'Connell and Williams (2011), in 2009, there were around 200 airlines globally, with a combined fleet of nearly 22,000 aircrafts serving some 1670 airports. The data from OAG Aviation (2010) indicated that in 2010, the global airline industry operated around 2.6 million flights per month and provided 317 million seats per month to travellers around the world.

Over the past 60 years, the growth rate of the airline industry has been consistently well above world gross domestic product (GDP) growth. Between 1945 and 2000, world passenger traffic grew at an average annual rate of 12%; from 1960 to 2000, the growth in passenger traffic was at an average rate of 9% per annum (Hanlon, 2007). Since 2005, airlines have transported more than 2 billion passengers every year and the numbers continue to grow. For example, in 2010, international scheduled air traffic showed an 8.2% increase in passenger business, versus a 4.4% increase in passenger carrying capacity (International Air Transport Association (IATA), 2010).

The global airline industry has provided services to fulfil the requirements of the rapidly increasing worldwide transportation network, such as increasing the levels of global business and tourism travel, and it has also played an important role in economic growth. For instance, According to the Air Transport Action Group (ATAG) (2008), the airline industry can help a country participate in the global economy and trade by increasing access to international markets and allowing the globalisation of its production. The total value of goods transported by air has reached 35% of all international trading. Moreover, with globalisation, intercontinental travel has become more and more common. Tourism in some countries, especially in developing economies, is an important driver of economic development. The airline industry contributes to this, as over 40% of international tourists now travel by air (ATAG, 2008). Overall, the airline industry accounts for approximately 7.5% of world GDP, draws almost 11% of consumer spending. The total impact of the whole global airline industry, including direct, indirect and catalytic effects is estimated at US\$ 3560 billion (Hanlon, 2007).

In terms of the labour market, the operation of airlines generates a total of 32 million jobs globally (ATAG, 2008). This total can further be disaggregated. Firstly, there are 5.5 million jobs from direct employment in the airline, airport and civil aerospace sectors, such as the manufacture of aircraft systems, frames and engines. Secondly, there are 6.3 million indirect jobs created by purchases of goods and services from companies in the supply chain. Thirdly, there are 2.9 million induced jobs through spending by industry employees. Lastly, an estimated 17.1 million jobs are created by the spending of tourists carried by the airlines.

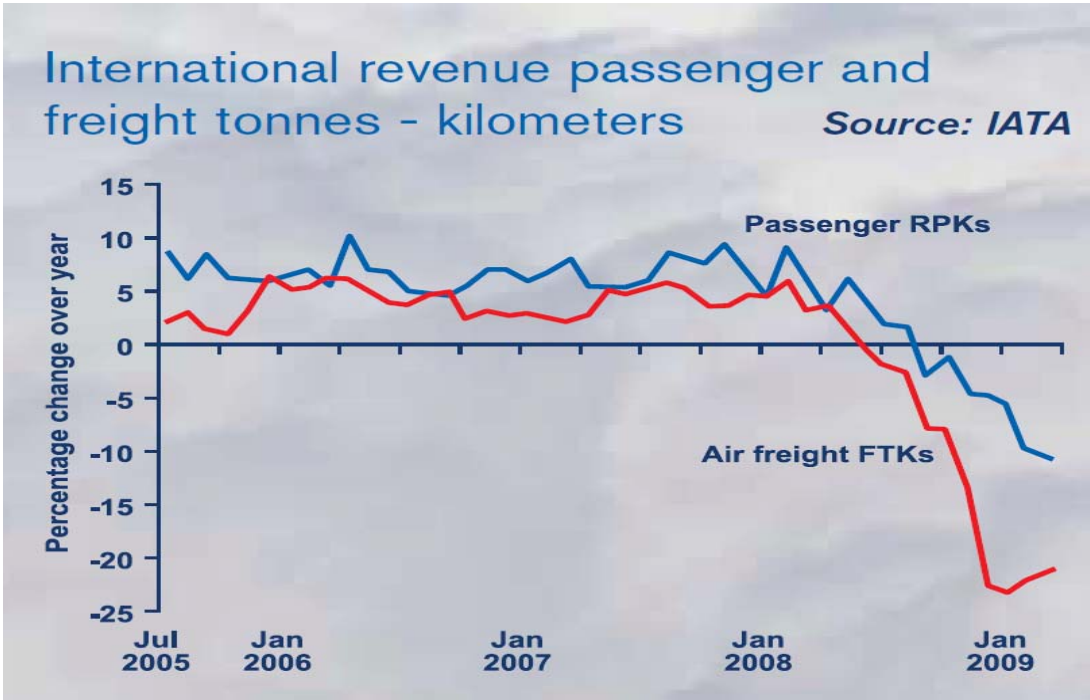
The airline industry is also a fragile industry. It is quite vulnerable and can be affected by various factors. Internally, the airline industry faces the problems of strong seasonal factors, highly constrained rules and regulations, and conflicts of interest between safety and business. For example, after the '9/11' incident, American authorities spent approximately \$6 billion on security precautions for aviation, both on airport security and new equipment. Those extra security measures increase the time costs of a trip (Belobaba *et al.* 2009). According to the US Congress, each extra minute of trip time is equivalent to a monetary cost of 63 cents and the total sum will be several billion per year (Joint Economic Committee, 2008).

Moreover, the airline industry also relies heavily on the external environment. For instance, since 1960, there have been only two occasions when world air traffic experienced a decrease: the Gulf War in 1991 and the 9/11 attacks on the US mainland in 2001 (Hanlon, 2007). Even in the 21st century, the airline industry continues to suffer pressures from the external environment, such as fuel price increases, Severe Acute Respiratory Syndrome (SARS), terrorist alarms and global recessions. The most current and obvious evidence of this is the intensification of the global recession, which has resulted in the collapse in air travel demand. This has led to a \$16 billion loss in 2008 and a \$9.9 billion loss in 2009 for the airline industry (D'Altorio, 2011).

The airline industry is no stranger to bankruptcy. In the US, the first passenger on a regularly scheduled airline flew from Tampa Bay to St Petersburg, Florida, on January 1, 1914. The airline chalked up another first when it folded four months later after running into financial difficulty (Wells, 1994). In Europe, the Great Depression of the 1930s and 1940s led to the nationalisation of many of the continent's premier carriers as a means of ensuring their survival (Graham, 1995; Sinha, 2001). In the US, commercial aviation continued to expand in fits and starts, aided by airmail contracts from the US Postal Service; however, it still experienced a financial crisis in each decade. For example, the losses in the early 1990s because of the Gulf War and the resulting global recession amounted to about \$10 billion (Rosen, 1995). The losses for the industry in 2001 alone totalled about \$ 7.7 billion and were estimated to be approximately \$8 billion for 2002 (Foss, 2002). IATA has estimated the US airline losses for 2001–2005 to be US\$42.4 billion (IATA, 2005).

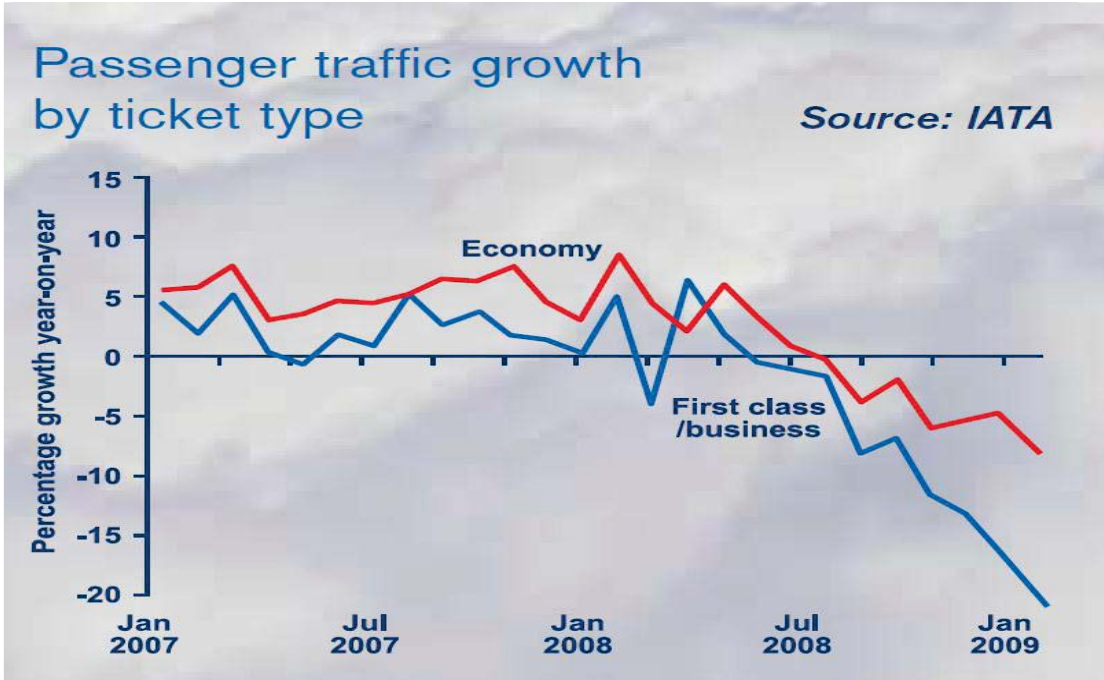
The following two figures show the impact of the global recession on the airline industry in 2009. Figure 2.1 shows the international revenue passenger kilometres (RPK) and freight tonne kilometres (FTK) experienced a significant drop in 2009. The total loss in RPKs is around 10%, while FTKs fell by about 23%. Figure 2.2 shows that passenger traffic growth by ticket type also significantly dropped in 2009. The world total economy passenger traffic growth dropped by about 10% and the first class/business passenger growth dropped by more than 20% (IATA, 2009).

Figure 2.1: International Revenue Passenger and Freight Tonnes during the Recession



Note: Sourced from IATA (2010)

Figure 2.2: Passenger Traffic Growth by Ticket Type during the Recession

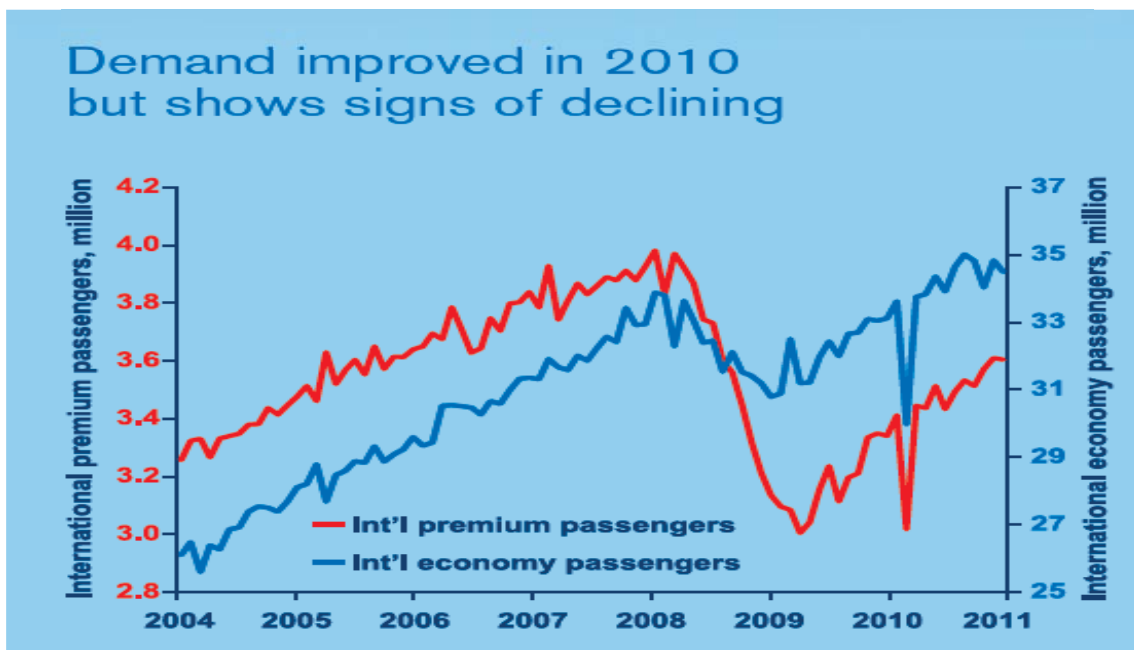


Note: Sourced from IATA (2010)

The airline industry also is a resilient industry. With the deregulation and liberalisation of the industry, the characteristics of a monopoly have been removed from its operations. For example, after a \$9.9 billion loss in 2009, the airline industry has recovered \$72 billion in revenue and achieved \$18 billion in profits in 2010. The total capacity expanded by 5.2%, demand increased by 10.3% and average passenger yields improved by 6.1% (IATA, 2011). Air travel markets quickly recovered during 2010. IATA (2011) reported that worldwide air travel, which is measured by the number of passenger-kilometres flown, rose by 7.5% following a 1.9% decline in 2009. International air travel grew by 8.3% after a 2.5% fall in 2009. Domestic air travel was up 6.1% following a 0.9% decline. By the end of 2010, the US and Japanese domestic markets, in particular had exceeded their prerecession peaks, and this expansion was ongoing in the year 2011.

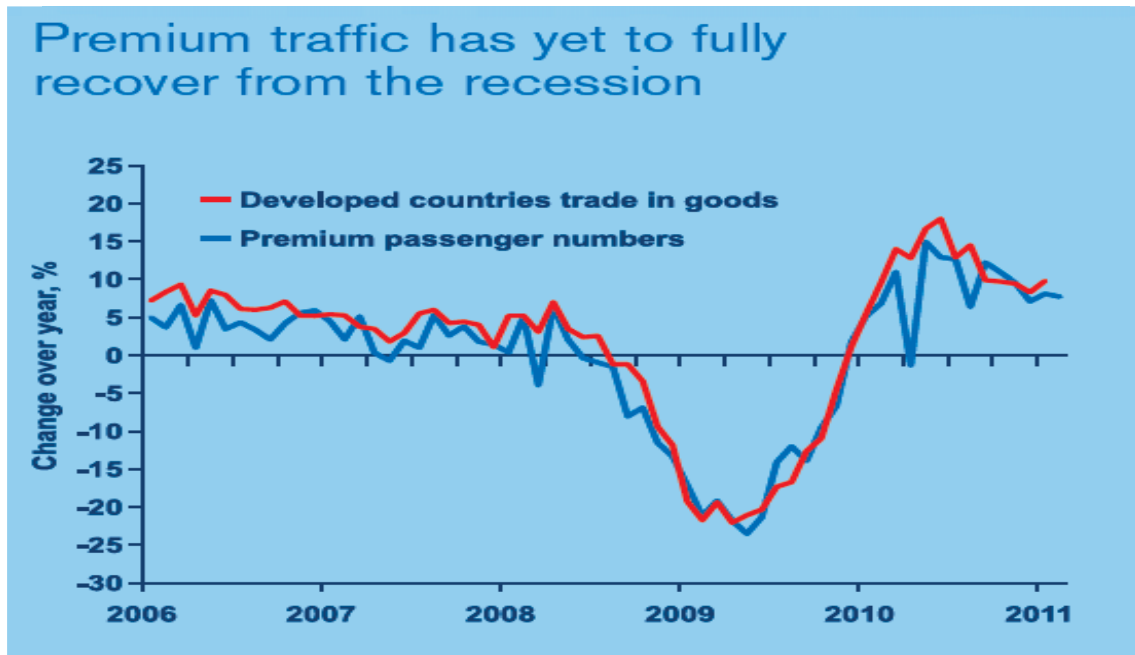
As Figure 2.3 shows, air traffic demand improved in 2010 compared to 2009. Even with a sudden drop in demand in the early part of 2010, demand soon recovered during the rest of the year. Figure 2.4 shows that both air freight (trade in goods) and premium passenger numbers have recovered from the worldwide economic recession of 2009. Thus, even with huge uncertainty, the airline industry can quickly adjust itself and recover from unexpected external impacts.

Figure 2.3: Change in International Passenger Demand during 2004–2011



Note: Sourced from IATA (2011)

Figure 2.4: Change in International Premium Passenger Demand during 2004–2011



Note: Sourced from IATA (2011)

2.5 Airlines as a Special Industry

The airline industry is a specialised industry which cannot simply be categorised as an international business (Rhoades, 2008). It has very specialised rules and standards. These unique characteristics act as a double-edged sword, protecting and promoting the industry to allow it to continue progressing and developing, but also making the industry become complicated and disordered. There are several special characteristics worth mentioning here because these are the key factors that affect the development of an airline business.

Firstly, an airline has closely binding ties with its country of origin. When necessary, the airline can be co-opted easily into national defence. The airliner is an efficient mass transportation tool that can be used for both civil and military purposes. Under programmes such as the US Civil Reserve Air Fleet plan, civilian fleets could be used during times of military action to ferry troops and supplies (Rhoades, 2008). For example, during “Desert Storm”, the US military used the civil airlines to shift army personnel to Iraq. The US

government gets a reserve fleet for times of emergency without the cost of purchasing, renting or maintaining the fleet, while the airlines get paid a higher rate. The American airlines were paid 1.75 times the original seat miles or cargo miles during Desert Storm (Kane, 1998). Moreover, as Rhoades (2008) also suggested, national defence was also cited as the reason for insisting on home country ownership of these airlines and their manufacture on the premise that home country nationals would be made to cooperate in the defence of their country.

Furthermore, an airline can also become the symbol of a country. The airline is special because it can represent national achievement and pride. International airlines usually are the flag carriers of their countries around the world. They represent the image of a country and its people. For example, when the bankruptcy and subsequent grounding of the Swissair fleet forced the Swiss football team to fly with the Russian carrier Aeroflot to a qualifying match in Moscow, one article reported this event as a 'further humiliation for the Swiss flag carrier'(Hall *et al.*, 2001). The uproar that occurred in Great Britain over the replacement of the Union Jack on the tail of many British Airways planes by the ethnic tails intended to show British Airways as the airline of the world was motivated by similar nationalistic sentiment (BBC News, 1999). Likewise, the debate in Belgium over the bankruptcy of Sabena and the need for a national carrier to serve the interests of the people of Belgium has more to do with nationalistic pride than with airline economics (Sparaco, 2001).

Secondly, there is a big misunderstanding that airlines are free to fly their airplanes to other countries. In fact, an airline needs to obtain a permit to operate a new route to another country and it must follow the International Civil Aviation Organisation (ICAO) regulations (Doganis, 2002). As is commonly known, the main business of the airline industry is to transfer people and cargo from A to B. However, the distance between these two places could be a thousand-mile domestic flight, but it could also involve a flight between two independent countries. Most countries will not tolerate other countries' flight equipment freely flying in their airspace. This is especially the case for some sensitive areas, such as military-controlled zones and government buildings. It is also frequently asked whether an airline can freely fly to another country to make profit and close any routes when they are no longer profitable. The answer to this is 'no'. Airlines have to apply for permission at a

diplomatic level between the two countries to fly on particular routes. Without an agreement between the two countries, the airline will not be able to fly their aircraft commercially between these destinations. This arose from the Paris Convention of 1919, which defined the status of international airspace, with sovereignty over national airspace being granted to specific countries (Erotokritou, 2012). Thus, private airlines are subject to the regulations of particular countries, degrees of economic freedom, political concerns and safety issues.

Here, it is also necessary to mention the most important regulations for an airline, which are the Freedom of Air Rights. Because of the specialised nature of aviation and the increased demand after the Second World War, an international intergovernmental conference was held in Chicago in 1944 in order to create a more openly competitive regime of minimal regulation for the operation of international air transport (Doganis, 2006). Although full agreement could not be reached, the Chicago Convention did establish the technical and legal framework for the operation of international air service. The Freedom of Air Rights were formulated as a result of disagreement over the extent of liberalising aviation among countries. They provided the basic guideline of granting a country's airline the privilege to enter and land in another country's airspace. Initially, there were five freedoms. The first two freedoms have been agreed to by all countries, while the third to fifth freedoms have to be negotiated between states. Since then, several other freedoms have been added, but these are unofficial rights (ICAO, 2012).

Table 2.1: International Freedoms of the Air for Commercial Aviation

Freedom of the Air Rights	Descriptions
1	The right to fly over a foreign country without landing there
2	The right to refuel or carry out maintenance in a foreign country on the way to another country
3	The right to fly from one's own country to another
4	The right to fly from another country to one's own
5	The right to fly between two foreign countries during flights when the flight originates or ends in one's own country
6	The right to fly from a foreign country to another one while stopping in one's own country for non-technical reasons
7	The right to fly between two foreign countries while not offering flights to one's own country
8	The right to fly between two or more airports in a foreign country while continuing services to one's own country.
9	The right to fly inside a foreign country without continuing services to one's own country

Note: Sourced from ICAO (2013)

The first freedom is also known as technical freedom, which grants the privilege of flying over the territory of a treaty country without landing. Member states of the International Air Service Transit Agreement grant this freedom to other member states, subject to the transiting aircraft using designated air routes. Until 2007, 129 countries were parties to this treaty, including such large ones as the US, India, and Australia. However, Brazil, Russia, Indonesia, and China never joined, and Canada left the treaty in 1988 (ICAO, 2013). Since the end of the Cold War, the first freedom has been almost become completely universal, although most countries require prior notification before an overflight and charge substantial fees for the privilege (Mulrine, 2008). For example, an Air New Zealand flight from Auckland to Shanghai, as a New Zealand company, can overfly Australia. The second freedom allows the airline to stop in one country solely for refuelling or other maintenance on the way to another country. For example, Air New Zealand flights from Auckland to Shanghai can stop for fuelling purposes in Australia. The third and fourth freedoms confer commercial rights that

foster airline business operations and are almost always granted in bilateral agreements between countries. For instance, the Auckland to Sydney route can be operated by both New Zealand airlines and Australian airlines.

Among the original five air freedoms, the fifth one is the most controversial. The fifth freedom, also referred to as “beyond rights”, allows an airline to carry revenue-generating traffic between foreign countries as a part of services connecting to the airline’s own country. It is the right to carry passengers from one’s country to a second country and from that country to a third country, for example, an Air New Zealand flight from Auckland to London in the UK via Los Angeles in the US. Tickets can be sold for any or all of the sectors along the flight path. Passengers in America can purchase tickets from Los Angeles to London and fly with a New Zealand airline. The fifth freedom still plays an important role in today’s airline business, especially for long-haul, transit intercontinental routes. It helps to increase operational efficiency and load factors, as well as boosting profits (Hanlon, 2007).

Moreover, under the fifth freedom, an airline is able to take up the unserved and underserved routes, or airlines that already have flights in a certain area are able to make technical stops at a location as allowed by the second freedom (Luigi, 2004). Although the fifth freedom was sanctioned by the Chicago Convention members, it often requires very difficult negotiations between countries before it is granted to airlines. The main reason is that if the stop-by country allowed foreign airlines to drop or pick up passengers, its own airlines will suffer serious losses (Doganis, 2002). Thus, most countries do not allow foreign airlines to apply for the fifth freedom to operate stop-by flights. Airlines have to seek other ways to obtain stop-by benefits.

Thirdly, the airline industry operates within a highly cyclical environment, which is greatly affected by not only external issues, such as economic business cycles, but also internal operational cycles (Vasign *et al.*, 2008). The airline industry does not exit routes on a whim, and is driven by supply and demand patterns. During a steady economic period, the demand for air travel, including business and leisure, will increase. Thus, airlines will experience a profitable period. When there is an economic downturn, or some special societal event such

as a terrorist alarm or the outbreak of disease, the demand for air travel will be greatly reduced. For example, between the mid-1990s and the beginning of the new century, the airline industry enjoyed many years of high profitability due to a long period of global economic expansion and greater demand for travel. In contrast, it can also easily suffer a huge setback from economic downturn and external factors, such as the terrorist threats after 2001 (Cento, 2009).

The airline industry's cyclical nature also arises from the way it operates and the service it provides (Hanlon, 2007). For very simple domestic travel, few people are willing to take an early morning or late night flight, especially during weekends. For international travel, considering the time difference – which may be several hours – passengers do not want to fly to Australia from New Zealand in a three hours flight at 2300 hours in the evening, because they will arrive at 0400 hours in Australia (0200 hours for New Zealand time) in the morning, which most passengers consider to be an undesirable arrival time. Cyclical factors become more significant when considering holiday travel (Evans *et al.*, 2003). Most holidays occur during summer, when the weather is better and children have their school vacations. Air cargo also possesses cyclicity and has a strong directional factor (Doganis, 2002). For example, heavy load cargos of fresh food products are transported from New Zealand, but planes are fairly empty on return flights. This pattern also occurs on routes from Asia to North America, making it difficult for airlines to achieve high levels of efficient aircraft use.

Fourthly, as mentioned above, the airline industry has faced many external challenges which have had a huge impact on its operation and profit returns (Rhoades, 2008). Here, the study outlines some of the important factors which have significantly shaped the airline industry in recent years. The airline industry has strict barriers to entry, which arise from the nature of the industry. Despite a huge investment in labour, flight equipment, group supports and licences, a new entrant faces pressure from national concerns. In recent years, however, many countries have deregulated their airline industries. The deregulation of civil aviation in the US in 1978 and in Europe in the early 1990s induced great changes in the airline industry (Doganis, 2002). In comparison, prior to deregulation, governments controlled airfares, routes networks, and other operational requirements of airlines. Since deregulation, airlines have been largely free to negotiate their own operating arrangements with other airports,

enter and exit routes easily, and levy airfare and supply flights according to market demand rather than government requirements (Doganis, 2002; Ott and Neiddl, 1995). Although the entry barriers for new airlines may be lower after deregulation than before, this has resulted in greater competition in the market, which has led to price cutting. New entrants to the industry have more price freedom and lower operating costs than do legacy carriers (Shaw, 2011). This means that profitability for airline companies in the deregulated market is not evenly distributed and forces the major legacy companies into situations of heavy loss.

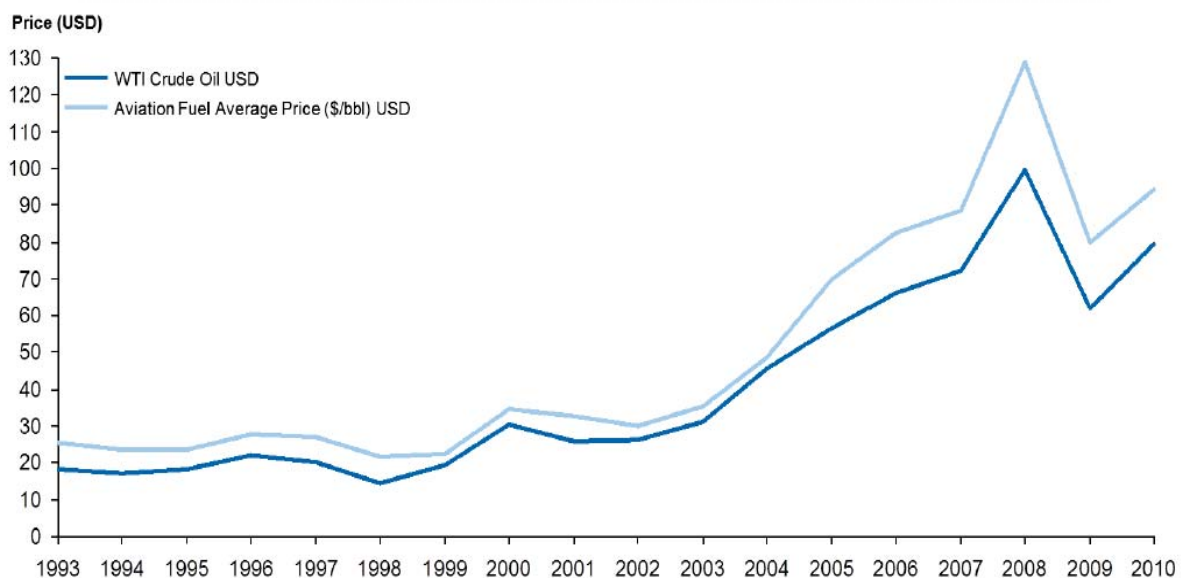
After entering the new century, the airline industry has suffered from many unexpected social events which have had some serious effects on the industry. In September, 2001, two commercial airliners, one from American Airlines and one from United Airlines, were hijacked by terrorists and crashed into the Twin Towers in New York City; a third American Airlines aeroplane was diverted and crashed into the Pentagon in Washington. The entire North American air space was closed for the next few days (Cento, 2009). Prior to the September 11 incident, the airline industry was already experiencing a downturn due to economic recessions (Brauer and Dunne, 2012; Morrell, 2007). For example, data on world air traffic before the September 11 event show that both passenger traffic and air freight were already experiencing a downturn in demand (IATA, 2008), and before the terrorist attacks, the RPK between Europe and North America had zero growth (Harvey, 2007).

The September 11 events converted the ongoing business downturn into a major slump. The financial losses, directly and indirectly, were in billions of dollars. Because of the huge setback in trans-Atlantic traffic, British Airways recorded its biggest loss, amounting to about £200 million since its privatisation in 1987, while Virgin Atlantic also faced a loss of £94 million (Harvey, 2007). As Cento (2009) pointed out, after 9/11, the RPK of total world traffic dropped 26% in October, 2001 and reached its lowest point in November, when it dropped by 33%. The European carriers reacted to adjust their capacity in November by reducing about 15% of total flights. The capacity continued to be reduced until January 2002, when it reached the lowest point during the crisis at a level about 26% lower than before the attacks (Cento, 2009). In general, carriers reduced their capacity supply by cutting frequency and the aircraft size in order to cope with the huge traffic losses. While airline companies were struggling financially before the attack, the event was the key to some major airlines

declaring bankruptcy, for example, Sabena in 2001 and Air Canada in 2003 (Brauer and Dunne, 2012).

Another factor that has significantly impacted the airline industry has been fuel costs. Fuel costs constitute a large part of the operation costs. Fuel accounts for about 20–29% of total operation costs, depending on the year (Heracleous *et al.*, 2006; IATA, 2008). However, the unstable and high level of the fuel price causes lots of trouble for airlines. For example, Air New Zealand had a NZ\$96 million net profit after tax in 2006. Although the company still maintained positive returns, its profits had actually fallen by approximately 47% from 2005. This reduction in profit was mainly due to an overall increase in fuel prices of about 44%. Fuel costs have become a large part of the total operational costs. Fuel costs rose from 21% of operating expenditure in 2005 to 30% in 2006, when they were estimated to rise to over 35% of total operating expenditure in 2007 (Air New Zealand, 2006). Figures 2.5 and 2.6 provide an overview of the change in fuel price from 1994 to 2011.

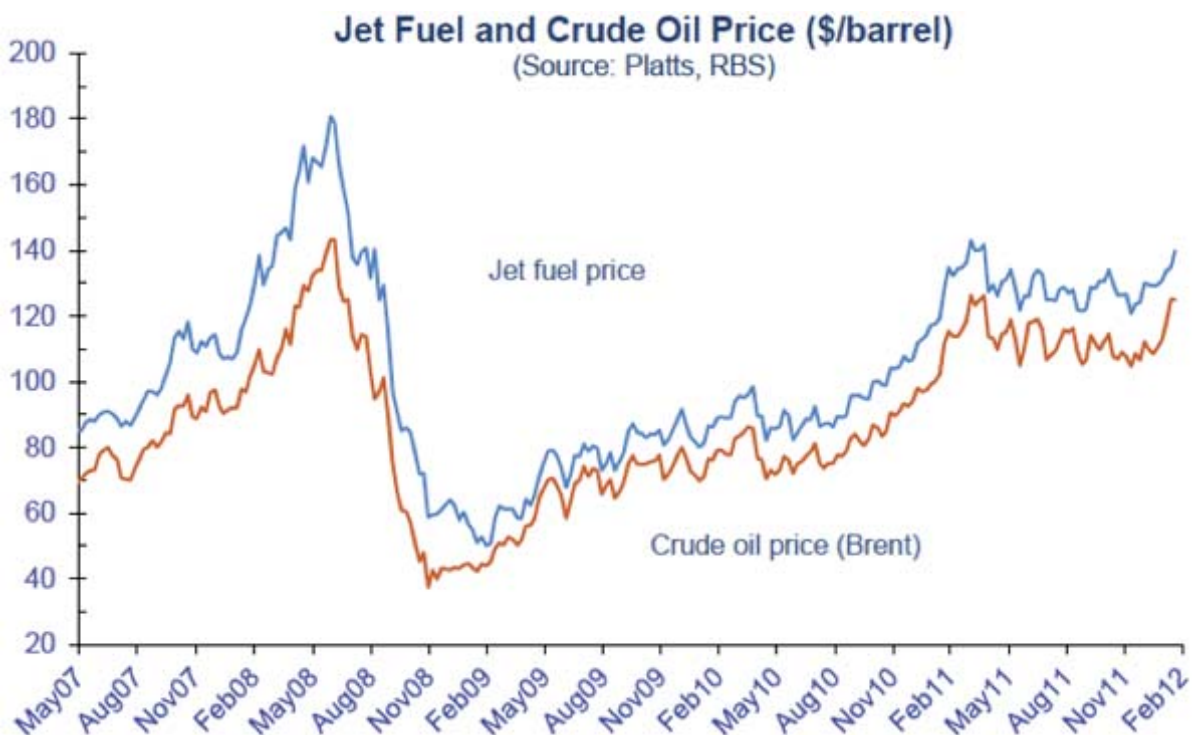
Figure 2.5: Annual Crude Oil and Jet Fuel Prices (Nominal Prices), 1993–2010



Note: Sourced from US Energy Information Administration (2012)

Figure 2.5 presents the annual crude oil and jet fuel prices from 1993 to 2010 in US dollars. The figure shows that both crude oil and jet fuel prices trended upward between 1994 and 2008. Both crude oil and jet fuel reached the peak price in 2008 and dropped dramatically in late 2009. The jet fuel price fell back to \$80 per barrel in 2009. Jet fuel price increased from around \$25 per barrel in 1993 to more than \$US 125 per barrel in 2008, almost five times higher. Figure 2.6 shows the comparative prices of crude oil and jet fuel between 2007 and 2012. In this figure, the most noticeable thing is that both crude oil and jet fuel prices reached their highest in mid-2008 and then started dropping sharply. In mid-2008, the crude oil price reached a historical high point of more than \$140; accordingly, the jet fuel price also reached its highest point, more than \$180 per barrel. However, because of the huge global recession, within six months, from May to November in 2008, the fuel price quickly dropped from US\$140 per barrel to US\$40 per barrel, accordingly affects the drop of jet fuel. Many airlines had already hedged their jet fuel price at more than \$100 per barrel. The unexpected drop in the fuel price had a negative impact on airline operations.

Figure 2.6: Comparative Prices of Crude Oil and Jet Fuel from Mid-2007 to Early 2012



Note: Sourced from IATA (2012)

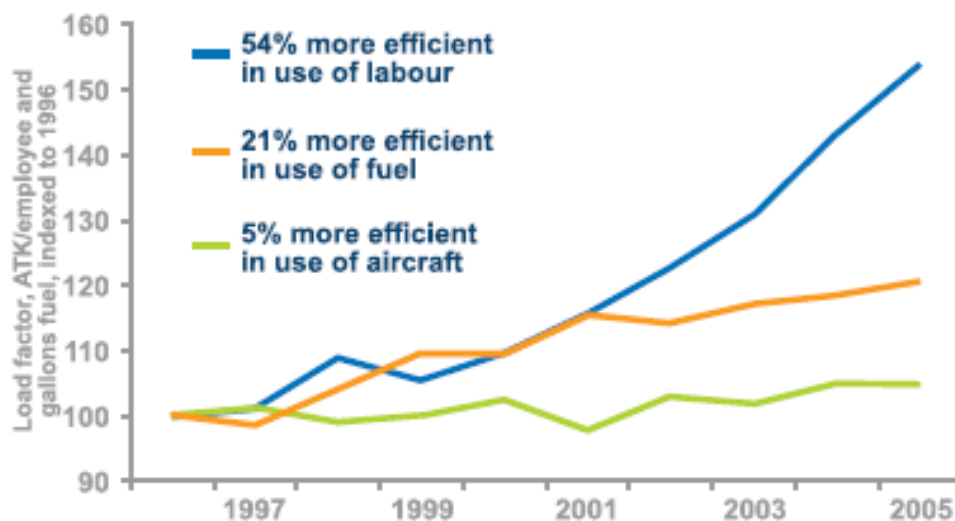
In general, from 2005, the issue of fuel price started to emerge as a major problem for the airlines. For example, in 2004 IATA reported that airlines had faced a US\$17 billion increase in fuel costs (IATA, 2004) and another US\$14 billion in 2005 (IATA, 2005). In 2008, crude oil prices hit the highest point in history at US\$146 per barrel in July and averaged at US\$99. This brought the total fuel bill to US\$168 billion, compared with only US\$61 billion in 2004 (IATA, 2005; IATA, 2008). In order to cope with such high fuel prices, many airlines adopted fuel price hedging programmes. Fuel price hedging is the practice of making advance purchases of fuel at a fixed price for future delivery to protect against the shock of an anticipated rise in price. All the major airlines have hedged fuel prices since the 1980s. For example, British Airways reported a large gain of nearly £300 million from fuel hedging for their financial year ending 31 March, 2001. Korean Airlines reported a gain of Korean Won ₩282 million (about US\$ 0.2 million) from forward fuel contracts in the 2003 financial year, reducing their average fuel price paid by 34% (Morrell and Swan, 2006). Qantas offset 73% of their 2003/2004 increase in fuel price through various unspecified hedging activities. Singapore Airlines were able to offset almost all the price elements of their 2002/2003 increase in fuel costs by hedging (Morrell and Swan, 2006).

However, many airlines are finding it increasingly difficult and expensive to access credit for fuel hedging purposes. As Cento (2009) points out, some of the major airlines have run into financial difficulties in recent years so they no longer have the cash to play the oil futures market. With the oil price remaining at a high level for so long, no investment bank is willing to cover the high price of oil in the hedging contract, no matter how much cash the airlines can provide (Cento, 2009). Moreover, hedging the risk of strong upward pressure on the fuel cost can also easily result in a big loss due to sudden oil price changes. There are several instances of unsuccessful fuel hedging programmes. For example, British Airways reported a loss of \$75 million in 2005 due to the failure of fuel hedging. Singapore Airlines also reported a fuel hedging loss of \$212 million for the financial year of 2001 (Morrell and Swan, 2006). As a result, fuel hedging itself is risky and also costly for airline cash flow. Most airlines only choose to hedge part of their fuel consumption. Thus, fuel cost remains as the most uncertain and also the biggest challenge for airlines in the future.

Besides fuel hedging, airlines have taken other approaches to deal with the increases in fuel price. Airlines have tried to increase the fuel efficiency of their operations (Morrell, 2007). This has been achieved by changing some of the operating procedures, such as cruise speed or attitude, or changing tanking policies. In recent years, airlines have also been gradually replacing existing aircraft with more fuel-efficient modern aircraft. Moreover, in order to cope with high fuel costs, airlines have passed fuel increases on to the customers of both cargo and passenger services. For example, Lufthansa and others published an index of fuel prices, the trigger points and resulting surcharge amounts for cargo. FedEx simply does not hedge fuel prices at all, since it simply charges extra when the fuel price goes up (Morrell and Swan, 2006). On the passenger side, a new term called ‘fuel surcharge’ has appeared on airline tickets (Dennis, 2011).

Another large cost component in airline operations is human resources, which can account for up to 40% of total costs. In recent years, airlines have been forced to reduce their staffing numbers. Due to this situation, airlines have applied various methods to improve their operational efficiency. For example, in the decade to 2005, the industry became 54% more efficient in its use of labour, 21% more efficient in its use of fuel and 5% more efficient in its use of aircraft (IATA, 2006); see Figure 2.7.

Figure 2.7: Factors in Improved Airline Efficiency



Note: Sourced from IATA (2006)

These efficiency gains are reflected in the industry's control of unit costs, despite inflation in salaries and in the price of other inputs, not the least of which is fuel. Adjusting for currency effects due to the fall in the US dollar, non-fuel unit costs have dropped by an estimated 14% since 2001 (IATA, 2006). There is, however, a limit to possible efficiency improvements. In other words, operational efficiency cannot be improved indefinitely. Operational efficiency will reach its best possible level in the short term. This means that airlines have to seek other ways to deal with increases in fuel prices (IATA, 2006). Facing growing cost pressures and, as a result of fierce competition, an inability to continue to increase fares, major airlines have been forced to change their business priorities towards redesigning their business concepts and developing alternative models for their operations, in order to increase efficiency and cost-effectiveness.

In recent years, the airline industry has experienced a slowdown in progress and is facing many crises (Rhoades, 2008). Rhoades (2008) suggested that the airline industry is currently facing problems such as little or no evolution in key technologies, the impact of the information age and globalisation, a lack of product differentiation and price-oriented competition. Comparing with the beginning of the jet age, there is no major advantage in terms of change in the air transportation. Besides the strong inherent culture, which is hard to change, most of the new ideas in airline operations can quickly be adopted by competitors (Andersen and Taylor, 2007). Customers have begun to expect lower prices and they start to focus more on low prices rather than value or benefits of the products (Miller, 1998). Thus, the airline industry needs to find a new way for future development and growth. One of the models chosen by the major airlines is that of forming or joining a global airline alliance in order to reduce competition, extend their network and increase operational efficiencies.

2.6 Appearance of Airline Alliances

2.6.1 Airline Alliance Development

The ultimate goal in operation for any airline is to establish a truly global network (Wald, Fay and Gleich, 2010). However, this is very hard to achieve (Iatrou and Oretti, 2007). The airline industry has traditionally been characterised by a high degree of regulation, from both technical and economic perspectives. On the international routes, airlines mostly operate within a very restricted framework set by different agreements. Air transport service agreements are intergovernmental agreements concerning traffic rights between two countries. Although the ICAO Freedom of Air Rights has provided guidelines for airline operations, air transport services between two countries are negotiated between governments (ICAO, 2013). The international market, in terms of fare charges, flight frequency and capacity offered, is usually restricted by the negotiated air service agreements between countries. Moreover, there is also heavy domestic regulation of air traffic rights in most countries (Kleymann and Seristö, 2004). Entering a foreign country's domestic airline market is very difficult. In practice, two countries that plan to set up air services between each other designate a specific airline (usually referred to as the flag carrier), which is usually owned by the relevant government, in order to serve the market from both perspectives. Additionally, acquiring control of foreign airlines, especially the flag carriers, is almost impossible and unnecessary (Hanlon, 2007). Thus, these barriers in investment and market entry preclude any single airline from building up a truly global network.

As a result, airlines, similar to other industries, has adopted a business alliance as a strategy for achieves a global coverage network. The alliance partnership can help an airline to expand the geographic scope of its network without undertaking sizeable capital investment, and to increase market share, to avoid the limitations of ownership and control, to follow the trend of globalisation and to survive under liberal bilateral regimes (Lu, 2003). Iatrou and Oretti (2007) stated that the first modern and large airline alliances began with the 'Wing', which was established in 1989, when Northwest and KLM Royal Dutch Airlines agreed to code-sharing on a large scale. A huge step was taken in 1992 when the Netherlands signed the first open skies agreement with the US, in spite of objections from the European Union

(EU) authorities. This gave both countries unrestricted landing rights in each other's territory. Normally, landing rights are granted for a fixed number of flights per week to a fixed destination.

With such an agreement, each adjustment requires much negotiation, often between governments rather than between the companies involved. The US was so pleased with the independent position that the Dutch government took vis-a-vis the EU that it granted anti-trust immunity to the alliance between Northwest and KLM. Other alliances would struggle for years to overcome trans-national barriers, with some still restricted by this issue today. The more recent international alliance, which more refer to the airline cooperation between two countries, was formed in 1986 between Air Florida and British Island, with Air Florida feeding US originating traffic to code-shared British Island's flights on the London to Amsterdam route. This was the first ever alliance concluded on trans-Atlantic routes, with this area going on to lead the liberalisation effort (Iatrou and Oretti, 2007).

2.6.2. Past Airline Alliances

The development of airline alliances is a long, creative and informative process. Because of various reasons, before 1995, the lifespan of airline alliances averaged less than three years (Iatrou and Oretti, 2007). This subsection will outline some of the famous airline alliance groups of the past.

2.6.2.1 European Quality Alliance (EQA)

In the 1980s, Scandinavian Airline (SAS), Swissair, Austrian Airlines and Finnair attempted to establish the European Quality Alliance (EQA) (Björnelid, 2011). In addition to code-sharing and joint marketing, the alliance was largely based around technical issues and using the EQA brand as a 'seal of quality' (Kleymann and Seristö, 2004). In October 1989, Swissair and SAS, which had already been partners in purchasing and maintenance ventures since 1958, signed a cooperation agreement, which led to the formation of the EQA, joined

later by Austrian Airlines and Finnair. Swissair had a 10% shareholding. On top of that, Swissair and SAS had a 7.5 % cross-sharehold in each other's stock. The alliance had joint operations around 30 airports. The EQA emerged largely because Swissair was seeking to diversify risk, secure long-term profitability and build critical mass. At that time, Switzerland was outside the EU and had a limited potential in its home market and high labour costs. Swissair needed to form a grand alliance group rather than small partnership cooperation. Thus, the EQA was born with two larger and two smaller airlines, whose contributions largely complemented one another (Iatrou and Oretti, 2007).

However, the alliance only lasted for about 5 years. The agreement between Lufthansa and SAS to connect their traffic systems and combine their route networks put an end to SAS's role in the EQA (Iatrou and Oretti, 2007). The main reason behind this breakup was the lack of a common goal. Swissair was the most influential member in the alliance and it pushed further for greater integration because of its global strategy. However, this goal was not adopted by all the members. Finnair and SAS dropped out because both airlines were not closely tied to the EQA and because linking up with Lufthansa provided them with a potentially better option, offering more benefit and greater value (Suen, 2002). Thus, from the beginning, the EQA was doomed to fail because of the lack of a common goal and uneven partnership status. This was also the first attempt at alliance participation by Swissair.

2.6.2.2 Global Excellence

Based on the information provided by Iatrou and Oretti (2007), Global Excellence was formed by Delta Air Lines, Swissair and Singapore Airlines in 1989, and was considered as the first truly global alliance. Each partner held up to 5% of equity in the shares of the other members. Since Swissair also was a member of the EQA, which effectively allowed the two alliance groups to join together to form an intercontinental and a European alliance. By combining the route networks of the EQA and Global Excellence, the constituent airlines were able to establish a hub-and-spoke pattern in the intercontinental arena and develop a strong presence in three important regions, including Europe, the US and the Asia/Pacific region. The beginning of the alliance was promising. All the members were quality-driven, enjoying a reputation for premium service and dedication to customer needs. The partners

had code-sharing and block space agreements, round-the-world fares and Frequent Flyer Programme (FFP) cooperation in addition to schedule coordination, which allowed connecting flights to operate more effectively.

The additional shared check-in and ticket offices, and joint passenger and cargo handling at some airports provided future benefits for the partner. On top of that, because Delta Air Lines and Swissair had similar fleet types made up of McDonnell Douglas, both airlines considered an interchange of flight deck crews, which is a very rare and trusting cooperation. Furthermore, the alliance aimed to achieve an alignment of the partners' reservation systems. A number of projects including package tours, a small parcel delivery service, more integrated passenger and cargo handling, combined use of ancillary services and broader, more intense cooperation on the commercial front were likewise being considered (Iatrou and Oretti, 2007).

The alliance dissolved because of the sudden withdrawal of Singapore Airlines (Iatrou and Oretti, 2007). In November 1997, Singapore Airlines signed a commercial agreement with Lufthansa which included code-sharing and joint marketing because it reckoned the alliance was less productive and Lufthansa could offer greater benefits by making Singapore its primary hub in Asia (Suen, 2002). Moreover, the concord behind the alliance collapsed mainly because the partners of this alliance had come together for different reasons and with different purposes in mind. The partners did not truly realize and understand that a strategic alliance needs to have common long-term goals (Doganis, 2006). The airlines within Global Excellence only limited themselves to propping up an entity which only focussed on commercial cooperation schemes, such as FFP, special pro-rate agreements and interlining. Furthermore, in its eight years of partnership, the alliance failed to achieve either trust, cooperation, or operational integration (Suen, 2002). For example, Delta Air Lines seemed overly reluctant to move quickly on issues of cross-access to customer databases, the rationalisation of fixed assets such as airport terminals and lounges, and distribution of the joint computer reservation systems. Swissair and Singapore Airlines never code-shared and even directly competed on trunk routes such as Zurich to Singapore (Iatrou and Oretti, 2007).

2.6.2.3 Atlantic Excellence

In 1998, Swissair, Sabena, Austrian Airlines and Delta Air Lines launched their alliance in the North Atlantic market (Doganis, 2006). It was considered as the most successful alliance agreement in the world at that time. During the alliance period, Delta Air Lines' alliance members in Atlantic Excellence also obtained US anti-trust immunity (Havel, 2009). At the same time, the other three European airlines were also members of the Swissair-led Qualiflyer Alliance. The major benefit of this alliance was its US anti-trust immunity and the open skies agreements between the US and the three European nations (Iatrou and Oretti, 2007). Moreover, the four partners also established a revenue pool for traffic crossing the North Atlantic, under which revenue generated by routes to and from the US and Zurich, Brussels and Vienna was divided up and shared according to a pre-established formula. Fixed quotas of seats were part of the agreement, introducing the 'free flow' method that is now quite customary in code-sharing agreements. The partners offered identical fares and used the same booking systems once the partnership became fully operational, and these greatly increased the traffic and booking numbers. They also established a common yield management structure in Atlanta (Iatrou and Oretti, 2007).

The alliance operated until 1999 when Delta Air Lines abandoned its major partner, Swissair, and the alliance itself. It formed an exclusive long-term strategic agreement with Air France that regarded Swissair as the major competitor (Iatrou and Oretti, 2007). Soon after, Austrian Airlines also left the alliance and joined the Star Alliance because Star Alliance offered a better deal. It is another example of an alliance that failed because of a lack of trust and long-term strategic goals.

2.6.2.4 Qualiflyer

Qualiflyer originally was an FFP which was created in 1992 by Austrian Airlines, Crossair and Swissair (Iatrou and Oretti, 2007). Qualiflyer was formed in 1998 around the SAir Group, Swissair's parent company, with other members being Sabena, Austrian Airlines, TAP Portugal, THY Turkish Airlines and AOM/Air Liberté (Malaval and Bâenaroya, 2002).

The Qualiflyer alliance agreement provided for joint purchasing programmes, including fleet, fuel and on-board consumables, common IT projects, cargo handling and marketing, aircraft maintenance and overhauls, passenger handling and duty free sales, FFP benefits and joint lounge facilities, as well as improved transfers at the alliance's multiple hubs (Iatrou and Oretti, 2007). The superiority of the Qualiflyer alliance is that it established a webbing system of routes and a multi-hub structure across the whole of Europe, which consisted of a series of several small hubs. The system was supposed to benefit customers by minimising total travel time and by offering a wider, denser range of destinations and frequencies. It was also the first multi-airline alliance to move beyond a joint FFP and code-share, establishing a joint subsidiary that was owned in equal proportions by all members. The purpose of the joint subsidiary was to develop, purchase and oversee the ground handling of member airline flights at several airports in Europe (Iatrou and Oretti, 2007).

There were also some drawbacks of Qualiflyer Alliance. For example, it lacked bilateral code-share agreements woven around a common commitment by its members, which is a unique feature of alliance cooperation. With the bankruptcy of Swissair in October 2001 and that of Sabena a month later, the core members of the alliance were no longer operational and the alliance ceased to exist (Iatrou and Oretti, 2007). It was officially dissolved in February 2002. The main reason behind the collapse is that Swissair's aggressive policy of acquisition failed. By insisting on acquiring stakes in small and financially unstable airlines, it was exposed to financial risk when the time came to sustain and subsidise those airlines. However, Qualifyer was one of the most interdependent and innovative alliance groups (Iatrou and Oretti, 2007).

2.6.2.5 Wings

According to Iatrou and Oretti (2007), Wings originally represented the airline alliance between KLM and Northwest Airlines, later joined by Alitalia and Continental Airlines. Northwest and KLM first cooperated in 1989. In 1992, Dutch KLM and Northwest Airlines established a cooperation and integration agreement covering code-shares and joint marketing, involving all of the respective partners' operations. The major impetus was that KLM had a domestic market and was looking for a powerful partner in order to attain global

reach and to secure access to the stream of trans-Atlantic traffic. As a result, KLM acquired 25% of Northwest Airlines' voting shares and 49% of its equity in order to establish a trans-Atlantic alliance. After obtaining anti-trust immunity in 1993, the two airlines were able to take joint decisions on capacity, scheduling and pricing.

In 1998, KLM and Alitalia, which was the biggest airline in Italy, concluded a parallel, complex agreement of cooperation which preserved the airlines' respective identities and also complied with regulatory demands. Then, in 1999, Northwest Airlines bought a stake in Continental Airlines to reach operational alignment which included code-sharing and FFP cooperation. In the same year, KLM merged its cargo operations with Alitalia. In December, Continental received regulatory approval to form a partnership with Alitalia, which officially brought the membership of the alliance to four. Thus, the alliance achieved a balance among its membership, whereby the Dutch accessed a larger market to feed their network, and the Italians obtained support in developing Malpensa International Airport from the long-haul scale and expertise that KLM brought. Alitalia had also been a long-standing code-share partner of Continental Airlines (Iatrou and Oretti, 2007).

In spite of such mutually beneficial cooperation, the alliance still had many problems. Northwest had taken a stake in Continental, which raised the hackles of anti-trust regulators in the US Department of Justice. KLM operated trans-Atlantic flights to Milan by using the new Malpensa International Airport, which displeased its partner Alitalia. Earlier, KLM had contributed \$95 million to the construction of the replacement for the overcrowded Linate Airport, but, the Italian government used the project to shore up Alitalia at the foreign carriers' expense by barring them from flying into the much more convenient Linate. Incidentally, the European Commission began its own anti-trust investigation into the relationship between KLM and Northwest. When the investigation closed in late July 2002, the alliance was dying a slow death on its own. Firstly, KLM and Alitalia ended their partnership in April 2000 and had completed de-merging by August of the same year. The tripartite code-share among KLM, Alitalia and Northwest Airlines was abandoned. In 2001, Alitalia left to join SkyTeam. At the same time, a trilateral alliance among Northwest Airlines, Continental Airlines and Delta Air Lines began to take shape. In 2003, KLM merged with Air France, which announced the dissolution of Wings (Iatrou and Oretti, 2007).

There are a few reasons for the demise of the Wings alliance. The principal reason is the common deficiency of other previous alliances, namely the lack of trust or any real long-term strategy. Although these airlines cooperated with one another through code-sharing and FFP coordination, no formal association was ever announced. Moreover, the alliance largely depended on KLM and Northwest Airlines cooperating. Additionally, the lack of members from other regions of the world meant the alliance could not achieve truly global coverage. At the same time, other alliance groups, such as Star Alliance and OneWorld, had already become truly global alliance groups. The dissolution of Wings is more evidence that under the old airline partnership relationship, the airlines focussed only on the short-term benefits rather than long-term development (Iatrou and Oretti, 2007).

2.7 The Modern Airline strategic alliance group

The dreams of a durable airline alliance were not realised until the formation of the first modern strategic airline alliance, Star Alliance (Star Alliance, 2012a). It has now become the world's largest airline alliance group. Besides Star Alliance, two other modern alliance groups also have been founded, which are OneWorld and SkyTeam. After the old alliance Wings broke up and the major partner Northwest Airline joined SkyTeam in 2006, SkyTeam surpassed OneWorld, becoming the second largest airline alliance group in terms of membership, passengers transferred and freight carried (OneWorld, 2012; SkyTeam, 2012). The following subsections present a brief history of the three airline alliances which are the objects of this study: Star Alliance, OneWorld and SkyTeam.

2.7.1 Star Alliance

Star Alliance is the world's first and the largest airline strategic alliance group (Iatrou and Oretti, 2007). Its original purpose was to create the first global airline network that better met the needs of the frequent international traveller. By January 2012, Star Alliance had 26 members around the world, with 4386 aircrafts, providing 21,230 daily departures. The Star Alliance network served 189 countries with 1290 airports with more than 990 airport lounges in the world. Its annual number of passengers carried reached about 653.62 million with the

total revenue being US\$167.18 billion (Star Alliance, 2012a). The major advantage for Star alliance is that has a strong geographical foundation and hub network throughout the world – including, Frankfurt, London-Heathrow, Chicago-O’Hare, Singapore and Bangkok – Star Alliance has become an airline alliance group that operates on a global scale (Iatrou and Oretti, 2007).

The alliance was founded in 1997 by five of the world’s leading airlines, Air Canada, Lufthansa, Scandinavian Airlines, Thai Airways International and United Airlines (Bryant, 1997). According to Star Alliance (2012a), the five-point star logo of Star Alliance represents the five original founding airlines. VARIG is the sixth member, which joined in October 1997, making it the gateway airline to South America. Ansett Australia and Air New Zealand followed in March 1999, which connected the alliance to Australia and the Pacific. However, Ansett ceased operations in March 2002, a loss which put Star Alliance at a disadvantage in Australasia. At the end of 1999, All Nippon Airways joined the alliance and became the group’s second Asian airline.





In the new millennium, the alliance group started with a major expansion. The Austrian Airlines Group, including Lauda Air and Tyrolean Airways, added its weight to the alliance in March 2000; Singapore Airlines followed in April 2000. British Midland International and Mexicana joined in July 2000. In the same year, the alliance also opened its first three business centres in Los Angeles, Frankfurt and Bangkok, as well as announcing the completion of its full-time Alliance Management Team. In 2003, the alliance recruited three new members, namely, Asiana Airlines in March, Spanair in May and LOT Polish Airlines in October. In 2004, Croatia Airlines, Blue 1 and Adria Airways joined the alliance’s regional network. In the same year, US Airways joined the alliance after a one-year joining process and became the alliance’s second US-based airline. In 2005, TAP Portugal joined the Star Alliance’s network and added a new African destination, followed by South African Airways in 2006, which was the first African airline to become a member of Star Alliance. In the same year, Swiss International Air Lines joined the alliance group. By the time of its tenth anniversary in 2007, almost 30% of global air travellers were using the services of Star Alliance member carriers. In the same year, it welcomed its Chinese airline partners, Air China and Shanghai Airlines, in December 2007 (Star Alliance, 2012a).

In 2008, Star Alliance admitted Turkish Airlines as its 20th member after an 18-month integration process that began in December 2006. Egypt Air joined in July of the same year and became the second African airline. Continental Airlines joined as a member in 2009, but exited the alliance in 2012, after only a three-year period of membership. In December 2011, Ethiopian Airlines joined the Star Alliance network and brought five new countries and 24 unserved destinations (Star Alliance, 2012a). The current membership and the year they joined are listed below in Table 2.2 (as at 2011).

Table 2.2: Star Alliance Member Airlines, Year of Joining and Country of Origin

Member Airlines	Year Joined	Country
Adria Airways 	2004	Slovenia 
Aegean Airlines 	2010	Greece 
Air Canada 	1997	Canada 
Air China 	2007	China 
Air New Zealand 	1999	New Zealand 
ANA 	1999	Japan 
Asiana Airlines 	2003	South Korea 
Austrian Airlines 	2000	Austria 
Blue 1 	2004	Finland 

<p>British Midland International </p> <p>BMI</p>	2000	United Kingdom 
<p>Brussels Airlines</p> <p></p>	2009	Belgium 
<p>Croatia Airlines</p> <p></p>	2004	Croatia 
<p>EgyptAir </p>	2008	Egypt 
<p>Ethiopian Airlines </p>	2011	Ethiopia 
<p>LOT Polish Airlines </p>	2003	Poland 
<p>Lufthansa </p>	1997	Germany 
<p>Scandinavian Airlines </p>	1997	Denmark, Norway and Sweden 
<p>Singapore Airlines</p> <p></p>	2000	Singapore 
<p>South African Airways</p> <p></p> <p>SOUTH AFRICAN AIRWAYS</p>	2006	South Africa 
<p>Swiss International Air Lines</p> <p></p>	2006	Switzerland 
<p>TAM Airlines </p>	2010	Brazil 
<p>TAP Portugal </p>	2005	Portugal 
<p>Thai Airways International</p> <p></p>	1997	Thailand 
<p>Turkish Airlines</p> <p></p>	2008	Turkey 

	1997	US 
	2004	US 

Note: Sourced from Star Alliance (2012a)

2.7.2 SkyTeam

SkyTeam was the last of the three strategic airline alliances to be formed, but it surpassed OneWorld to become the second largest airline alliance group in the world (Truxal, 2012). The alliance group started with the domination of the European market as its major advantage. With the addition of Air France’s and Korean Airline’s hub and the anti-trust immunity granted by the US Department of Transportation, a bright future was assured for the alliance group. Currently, the alliance group consists of 15 carriers from four continents, and it is also the only alliance group that operates a cargo alliance (called SkyTeam Cargo) (Kleymann and Seristö, 2004). As of February 2012, SkyTeam operated approximately 14,000 daily departures from 926 destinations with total fleet numbers of 2431 mainline carriers and more than 1100 related carriers. The annual number of passengers carried totalled about 487 million to and from 173 countries. The total FFP members reached 151 million and shared about 490 lounges around the world (SkyTeam, 2012).

Based on the facts from SkyTeam (2012), the alliance was founded by Aeromexico, Air France, Delta Air Lines and Korean Air in 2000. In September 2000, the alliance established its own cargo alliance SkyTeam Cargo. In the year 2001, the first new member to join the alliance group was CSA Czech Airlines in March, followed by Alitalia in July. In 2004, Continental Airlines, KLM and Northwest joined the alliance after the demise of the Wings alliance. SkyTeam experienced the largest expansion in airline alliance history, resulting in it surpassing OneWorld to become the second largest alliance, serving more than 341 million customers with 14,320 daily flights to 657 destinations in 130 countries (SkyTeam, 2012). Aeroflot joined the alliance group in 2006, becoming the first Russian airline to be associated with the alliance group. The largest carrier in the People’s Republic of China, China Southern

airlines, joined SkyTeam in November 2007, becoming the first carrier from mainland China to join SkyTeam. However, in 2009, two airlines left the alliance group: Continental Airlines and Copa Airline both moved to Star Alliance; in the same year, Alitalia-Linee Aeree Italiane relaunched operations as the new Alitalia. Another major expansion for the alliance group happened in 2011 when China Eastern Airlines joined the alliance in June, along with its subsidiary Shanghai Airlines, while China Airlines from Taiwan joined the alliance group in September. Also in 2012, Saudi Arabian Airlines become the 17th member of the alliance, and on 29 August 2012, Aerolineas Argentinas became the first South American and the second Latin American airline in joining the alliance, bringing the number of members to 18. Xiamen Airlines became the fourth member in Mainland China, with the overall number of members in the alliance rising to 19 (SkyTeam, 2012). The current membership and year of membership are listed in Table 2.3.

Table 2.3: SkyTeam Alliance Member Airlines, Year of Joining and Country of Origin

Member Airlines	Year Joined	Country
Aeroflot 	2006	Russia 
Aeromexico 	2000	Mexico 
Air Europa 	2007	Spain 
Air France 	2000	France 
Alitalia 	2009	Italia 

<p>China Airlines</p> 	2011	Taiwan 
<p>China Eastern Airlines</p> 	2011	China 
<p>China Southern Airlines</p> 	2011	China 
<p>Czech Airlines</p> 	2001	Czech 
<p>Delta Air Lines</p> 	2000	US 
<p>Kenya Airways</p> 	2007	Kenya 
<p>KLM</p> 	2004	Dutch 
<p>Korean Air</p> 	2000	Korea 
<p>TAROM</p> 	2010	Romania 
<p>Vietnam Airlines</p> 	2010	Vietnam 
<p>Middle East Airlines</p> 	2012	Lebanon 
<p>Aerolíneas Argentinas</p> 	2012	Argentina 
<p>Saudia</p> 	2012	Saudi Arabia 

 Xiamen Airlines 厦门航空 XIAMENAIR	2012	China 
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Note: Sourced from Skyteam (2012)

2.7.3 OneWorld

The OneWorld Alliance is the third largest airline alliance, after Star Alliance and SkyTeam (Truxal, 2012). Currently, the OneWorld airline alliance has 12 core members and 20 affiliates serving 900 destinations in 150 countries. The alliance group carried more than 340 million passengers in 2011 with operationally combined fleets totalling 2500 aircraft. It offered some 9500 flights a day and generated more than US\$90 billion in annual revenue. (OneWorld, 2012). It occupies something of a stronghold position at the much envied London Heathrow airport. There is no cargo alliance, nor is there any exchange of equity or any other form of multilateral cross-sharing. OneWorld member airlines and affiliates cooperate to provide an integrated service, usually around the use of common passenger terminals and standardisation of FFPs (Iatrou and Oretti, 2007).

Based on the facts from OneWorld (2012), the alliance was established in 1999 and includes a central management team not present in the other alliances. It features British Airways and American Airlines as core members, with Iberia, Finnair, Canadian Airlines, Cathay Pacific, and Qantas as additional partners. In 2000, Lan Chile and Aer Lingus joined the alliance. However, Canadian Airlines left OneWorld because of bankruptcy and was taken over by Air Canada. The alliance did not admit any new members until 2005, when Royal Jordanian, the first airline from the Middle East and Gulf region, joined the alliance group. That was followed by Japan Airlines and the Hungarian flag carrier, Malev², in the same year, which brought the total membership of the alliance group to 10. After celebrating its 10th anniversary with its 10 member airlines in 2009, it started to expand again. In 2009, the alliance welcomed Mexicana, which was a former member of Star Alliance and had left in 2004. In 2010, the alliance accepted the Russian airline S7 Airlines, which added 54 cities to

² Note: On 3 of February 2012, Malev stopped flying and on 14 of February, it was declared insolvent and liquidated. But during the study period (prior to 2005), Malev was a member of the OneWorld group. 47

the alliance map, 35 of them in Russia. In 2012, Air Berlin from Germany joined the alliance (OneWorld, 2012). The current members and year of membership are listed in Table 2.3.

Table 2.3: OneWorld Alliance Member Airlines, Year of Joining and Country of Origin

Member Airlines	Year Joined	Country
American Airlines 	1999	US 
British Airways 	1999	United Kingdom 
Cathay Pacific 	1999	Hong Kong 
Finnair 	1999	Finland 
Iberia 	1999	Spain 
Japan Airlines 	2007	Japan 
Lan Chile 	2000	Chile 
Malev 	2007	Hungary 
Mexicana 	2009	Mexico 
Qantas 	1999	Australia 
Royal Jordanian 	2007	Jordan 
S7 Airlines 	2010	Russia 

Note: Sourced from OneWorld (2012)

3. Literature Review

3.1 Introduction

This chapter has been separated into two main parts. The first part reviews the origin of strategy and alliances, as well as their application in general business and the airline industry. This part also discusses the importance of an alliance as a strategy for the airline business, and outlines the theoretical benefits and costs of airline alliances. The second part of this chapter discusses previous research into airline alliances. The chapter reviews three main research methodologies in the existing literature, which are DEA, SFA and econometric PRA.

3.2 Review of the Theoretical Literature

3.2.1 Origins of Strategies and Alliances

The terms '*strategy*' and '*alliance*' both originated in the military arena, but have been adopted in business organisational theory. *Strategy* originally referred to a plan of action designed to achieve a particular goal (Geel, 2011). In the military context, it differs from the term *tactics*, as *tactics* are concerned with the conduct of an engagement, while *strategy* is concerned with how different engagements are linked. Put more simply, the difference between *strategy* and *tactics* is how a battle is fought versus the terms and conditions of the fight and whether it should be fought. *Alliance* is a union or association formed for mutual benefit, especially between countries or organizations or a relationship based on similarity of interests, nature, or qualities (Oxford Dictionary of English, 2010). It is usually used to describe the relationship become countries, especially during wartime. For example, several countries allied as a group fought together against the Central Powers (the Allies or Allied Forces) in World War I, or those who fought against the Axis Powers in World War II. Those countries joined together in an association for mutual benefit or to achieve a common purpose, whether or not an explicit agreement had been worked out between them.

3.2.2 Adoption of Strategy and Alliance in Business

Within the business context, strategy is defined as the pattern of an organisation's responses to its environment (Inkson and Kolb, 2003), and as the decision and actions which determine the long-run performance of an organisation (Robbins *et al.* 2009). Strategy in the business setting has the following characteristics (Johnson *et al.*, 2005):

- Concern for the long-term direction of an organisation;
- Concern for the scope of an organisation's activities;
- An attempt to achieve advantages for the organisation over its competition;
- The organisation is helped to fit the business environment; and
- Opportunities created by building on an organisation's resources and competences.

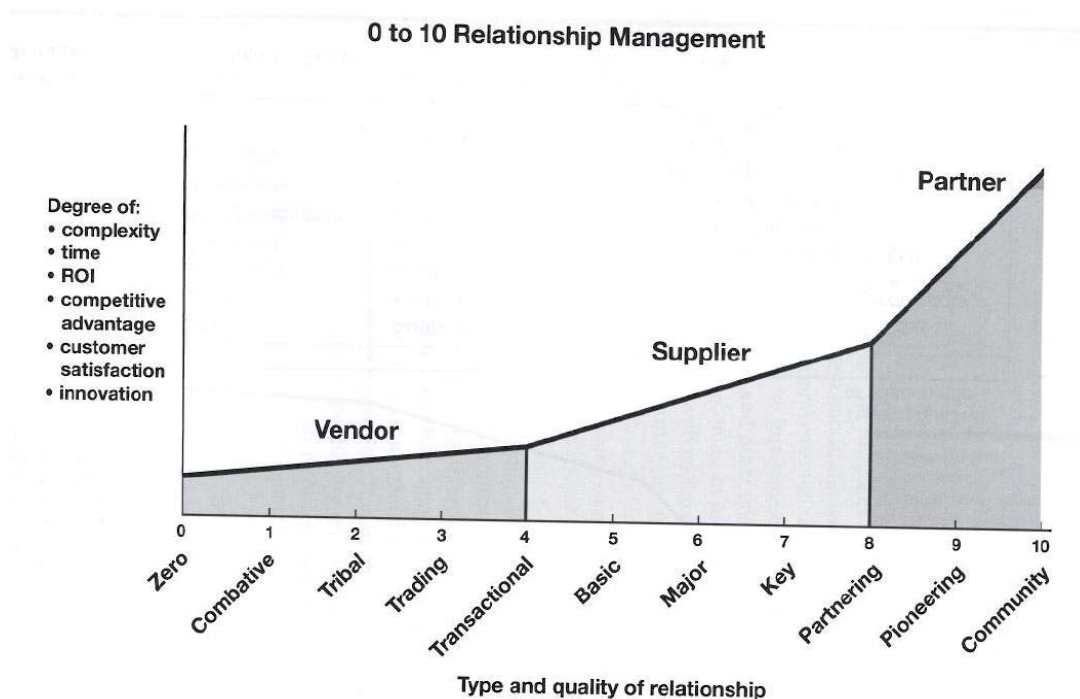
Moreover, strategy can help organisations to deal with different areas such as marketing, finance, production, research and development, and public relations (Certo and Trevis Certo, 2012). The organisational strategies can be separated into three major levels: corporate, business and functional. The organisation has to continually formulate and renew its strategies at each level to respond to environmental changes.

In the business context, alliance relationships represent collaboration between two or more businesses. To form an alliance with others can be considered to be a strategic option that is available to the organisation. Due to the increasingly complex market environments, individual firms are encountering greater difficulty in obtaining materials, skills, innovation, finance and markets. However, these issues can be lessened through cooperation with others. Thus, business alliances become a special feature of an organisation and help it to overcome such problems. Moreover, the purpose of an alliance is not only to improve the performance of the firm through risk-sharing and cost reduction, but also to allow easier acquisition of valuable knowledge, resources and capabilities (Jiang and Li, 2008). Many larger companies rely on this form of cooperation, which accounts for up to 25% of their business activities. The top 500 global companies have an average of 60 cooperative partners each (Dyer *et al.*,

2001). Most high-level strategic decision makers believe that alliances will be the primary vehicle for future business growth (Kalmbach and Roussel, 1999).

The complexity of an alliance depends on the degree of cooperation. Alliances can take many forms, ranging from simple agreements with no equity ties to more formal agreements involving equity ownership and shared managerial control over joint activities (Chan *et al.*, 1997). Lendrum (2003) also suggested 11 types of relationship according to the interaction between the sectors, using terms which were originally used to describe the relationship between customers and suppliers. However, the partnership relationship that he proposed can also be used to describe the relationship between companies. The relationships have been classified from zero relationship, indicating no relationship at all, to community relationships, indicating the highest level of relationship. It based on the degree of several operational factors, such as degree of complexity, time and ROI (Return on Investment). The latter can be grouped into three categories namely, vendor, supplier and partner (see Figure 3.2).

Figure 3.2: Degree of Cooperation in a Relationship



Source: Lendrum (2003)

There are a few noticeable points here. Firstly, if two sectors have no interaction, then there is no relationship between them. Secondly, the vendor relationships (which include combative, tribal, trading and transactional) are the most basic relationships between two sectors. There is no cooperation between them apart from normal business dealings. Thirdly, the Supplier relationships, which include basic, major and key, identify some responsibility between each sector, especially the Key relationship, which is a strategically important, complex, multi-dimensional and integrated service relationship (Lendrum, 2003). Lastly, in the partner relationships, which include partnering, pioneering and community, the degree of cooperation can vary. Among these three, the community relationship is the most advanced alliance relationship, with a high degree of competence, independence, character, integration, shared visions and common goals.

The formation of an alliance can take place in many ways. The term '*business network*' has been commonly used in conjunction with alliances where businesses have established such networks. Business networks allow firms to cooperate through joint marketing, joint sales or distribution methods, joint production, design collaboration, joint technology licensing, and joint research and development. For instance, such a relationship can be vertical (between a vendor and customer), or horizontal (between vendors at the local or global level). The whole idea of an alliance is the creation of a mature business network to deal with a complex business environment and competition. Alliances are often established formally through joint ventures, or partnerships, but the types of alliance can be varied. Alliances are often confused with mergers, acquisitions and outsourcing. While there are similarities in the circumstances in which a business might consider one of these solutions, these options are far from being the same. Wheelen and Hunger (2008) provide an overview of the various types of alliances, which range from mutual service consortia to joint ventures and licensing arrangements, and to value-chain partnerships.

- A mutual service consortium is a partnership of similar companies in similar industries that pool their resources to gain benefits that are too expensive to develop alone, such as access to advanced technology.
- A joint venture is defined as a cooperative business activity, formed by two or more separate organisations for strategic purposes, that creates an independent business

entity and allocates ownership, operational responsibilities, and financial risks and rewards to each member, while preserving their separate identity and autonomy (Wheelen and Hunger, 2008). Joint ventures are the most popular form of strategic alliance and often occur because the companies involved do not want to – or cannot legally – merge permanently. A joint venture provides a method of temporarily combining the different strengths of the partners to achieve an outcome of value to both.

- Licensing arrangements are agreements by which the licensing firm grants rights to another firm in another country or market to produce and/or sell a product.
- Value-chain partnerships are strong and close alliances in which one company or business unit forms a long-term arrangement with a key supplier or distributor for mutual advantage.
- A strategic alliance is the partnership between an organisation and a foreign company/partner(s) in which both share resources and knowledge in developing new products or building production facilities (Robbins *et al.* 2009).

This study will focus on analysing strategic alliances. A strategic alliance occurs where two or more organisations share resources and activities to pursue a business strategy (Johnson *et al.*, 2008). Devlin and Bleackley (1988) provided the first definition of a strategic alliance, which occurs in the context of a company's long-term strategic plan, when a company seeks to improve or dramatically change its competitive position. However, Contractor and Lorange (2002) suggested that strategic alliances were based on the degree of interdependency between the parties involved, which also suggests that they could involve mergers and acquisitions, joint ownership agreements, joint ventures, formal cooperative ventures and informal cooperative ventures at the high interdependence level (hard to reverse) through to the low interdependence level.

Lorange and Roos (1992) have defined the concept of a strategic alliance by examining the continuous scale between transactions in the free market and complete internalisation, suggesting that strategic alliances include mergers and acquisitions, joint ownership agreements, joint ventures, formal cooperative ventures and informal cooperative ventures. Child and Faulkner (1998) suggested that a strategic alliance enables two organisations to

jointly pursue a common objective through a cooperative business structure without losing their independence or compromising their own specific interests for as long as the alliance is economically viable. In this sense there, will be no agreement required and simply the existence of a common objective will be enough for the alliance to be formed. Wheelen and Hunger (2008) suggested that a strategic alliance is an agreement between firms to do business together in ways that go beyond normal company-to-company dealings but fall short of a merger or full partnership. These alliances range from informal handshake agreements to formal agreements involving lengthy contracts, in which the parties may also exchange equity or contribute capital to a joint venture corporation. Although there is no universal agreement about the definition of a strategic alliance, the characteristics of a strategic alliance are obvious, and they include the cooperation and agreements that have long-term goals.

3.2.3 Alliances and the Airline Industry

The airline industry is one of several industries that have adopted the alliance model into their operations. A survey conducted by the *Airline Business* journal in 1994 showed that there were more than 280 bilateral alliance agreements among 136 airlines (*Airline Business*, 1994). By 2000, which was only six years later than the first survey, this number had increased significantly, to 579 bilateral alliances agreements between 220 airlines (*Airline Business*, 2000). Nowadays, almost every airline cooperates in some manner with other airlines in various areas. The forms of cooperation have been catalogued differently by various researchers.

Park (1997) concluded there are two major types of alliance based on the operational routes within the airline context: complementary and parallel. The complementary alliances have non-overlapping routes, whereas parallel alliances have overlapping routes. Apart from routes, the most common areas of collaboration involve code-sharing, block spacing, shareholding and franchising (Morrish and Hamilton, 2002).

- Block spacing is an agreement under which one airline allocates a block of seats on its flights to a partner airline.

- Shareholding is usually subject to regulation if it involves an airline from another country.
- Franchising is more commonly adopted by other industries, with the franchisee paying a royalty to the franchisor in exchange for the privilege of using the latter's marketing package. In aviation, it allows major carriers to spread their brand name and generate revenues on thin routes without a commitment to major capital investments. This strategy has been widely used by British Airways.

Kleymann and Seristö (2004) differentiated airline alliances according to the type of cooperative link. The following are the most common forms of cooperation between airlines:

- Cost-sharing ventures involve two or more airlines jointly purchasing equipment and thereby benefiting from bulk discounts.
- Asset pooling often occurs in the area of maintenance, where airlines might pool the spare parts they store at out-stations or joint warehouses.
- A pro-rate agreement is an agreement on the revenue that airline A pays airline B if airline B carries airline A's passengers on a route operated by airline B. This is the simplest form of commercial agreement.
- Code-sharing networks. This can be on single routes or across larger parts of the respective networks. Airline A sells a flight under its own airline's designator code, even though that flight is operated by airline B. The advantage for airline A is that it gains access to new markets without having to physically operate its own aircraft there. For airline B, the advantage lies in being able to fill the aircraft it operates on that route for efficiently, namely with its own and airline A's passengers. As a result of this, airline B will eventually be able to operate a larger aircraft type on that route, thereby benefiting from the typically lower seat-mile costs associated with larger aircraft. In code-sharing, revenue is split between airline A and airline B according to an agreed formula. Distinction can be made among strategic, regional and point-to-point code-sharing.
- Feeder operations involve a special form of code-sharing between a larger and a smaller airline. This cooperation tends to be hierarchical. A smaller (typically

regional) airline flying under its own brand operates a code-share to a larger airline's hub.

- Marketing alliances, which include joint advertising, joint sales and joint FFPs. These typically go together with strategic alliances and regional code-sharing.
- A joint venture is where the partner airlines apply joint pricing and revenue sharing on a route or set of code-shared routes. It requires the partner airlines to seek anti-trust immunity.
- Integrated feeder operations involve an agreement between a larger carrier and a regional airline, where the regional airline operates fully and exclusively under franchise to feed the larger carrier.
- Equity stakes simply means two airlines swap their stakes. However, these often involve only minority stakes.

Oum *et al.* (2000) have established the following types of alliance:

- Code-share/joint operations;
- FFP cooperation;
- Joint use of ground facilities;
- Flight schedule coordination;
- Joint advertising and marketing;
- Ground handling coordination;
- Computer reservation systems or information technology sharing and development;
- Joint purchasing, such as fuel and aircraft;
- Joint maintenance;
- Block spacing agreements;
- Exchange of cabin crew.

Moreover, Iatrou and Oretti (2007) categorised alliance partnerships into two main areas, market-oriented alliances and strategic-oriented alliances. Market-oriented alliances focus mainly on improving the product offered to consumers in order to increase traffic flows, load factors and market share. The common types of marketing alliance include:

- Interline/pro-rate agreements;
- Lounge access/mutual ground handling;
- FFPs;
- Computer reservation systems;
- Joint engineering/maintenance;
- Code-share agreements;
- Pooling agreements.

On the other hand, a strategic-oriented alliance is one where the partners mingle their assets in order to pursue a single or joint set of business objectives. Usually, the alliance will be branded as a dedicated marketing entity. In addition to the activities presented under marketing alliances, strategic alliances also include the following areas of collaboration (Iatrou and Oretti, 2007):

- Coordination of network/schedules;
- Equity involvement;
- Joint venture flights;
- Franchising;
- Information technology sharing and development;
- Joint purchasing;
- Virtual mergers.

In addition to the previously discussed alliance relationships, a new form of airline cooperation has been the rising star within the airline industry, which is the global airline strategic alliance group. These are formed by several airlines and have continually absorbed new members. These members are looking for long-term and large-scale relationships rather than a single tactical agreement.

3.2.4 Alliances as a Strategy Option for Airlines

The airline industry has always involved competition and collaboration. The boom in alliance relationships illustrates the nature of the airline industry, where cooperation is needed in order to ensure survival. Air transportation is still highly regulated and restricted in terms of diplomatic and international trade. Deregulation and liberalisation have only affected certain regions and countries, such as the US, but has still been far-reaching in the international market. On other hand, airlines need to build extensive global networks to create economies of scale and density, and to meet customer demand. There are two ways for an airline to achieve this. The first is to expand globally; however, this can be restricted by regulations and financial considerations. The other method involves seeking partners, which is possible, even though most countries have ownership restrictions that do not allow for cross-country mergers, or take-overs. As the result, alliances have become an efficient solution for airlines in overcoming such restrictions. Forming an alliance partnership allows airlines to expand and strengthen their global service networks. Park and Zhang (1998) have suggested that partner airlines may improve competitiveness as they integrate with larger networks. Alliances involving network linkages and mutual traffic feeding will be much more beneficial to the participating airlines than would be the formation of an alliance on a few routes only (Park and Zhang, 1998). Alliances provide a way for carriers to overcome the limitations of bilateral agreements, ownership restrictions, and licensing and control regulations (Oum *et al.*, 2001).

Fan *et al.* (2001) identified three possible levels of cooperation strategy: ordinary, tactical and strategic. These three levels of cooperation strategy are also in line with the degrees of relationship in Lendrum (2003), mentioned above. The first level of cooperation strategy is ordinary cooperation, which includes business tactics such as outsourcing airport services in spoke cities or sharing maintenance services. Under ordinary cooperation, there are no deeper agreements between airlines and this cooperation can be seen as the most basic level. The next level of cooperation is tactical banding, which usually involves two airlines forming a cooperative relationship. This kind of cooperation is generally limited to specific routes or regions, and the carriers involved are still marketed as independent entities. For example, Air New Zealand proposed to code-share with Qantas on each other's trans-Tasman flights.

However, this kind of cooperation can easily be terminated for various reasons and is therefore considered to be an unstable and short-term cooperation relationship. The highest level of cooperation is the strategic level. Airlines form strategic alliances characterised by joint dedicated marketing entities for network-wide cooperation. This type of cooperation can really be called an alliance. The airlines involved usually share similar strategic views and long-term goals. Strategic-level cooperation is aimed at creating a shared vision so that every member airline in the alliance cooperation can receive benefits.

3.2.5 Importance of Alliance Partnership

From a theoretical perspective, the main reasons for an airline to choose an alliance partnership as a strategy are as follows. Firstly, through the alliance partnership, airlines can largely extend their networks. The nature of the airline industry causes airlines to continually expand and look for new opportunities brought on by passenger demand. Because of various regulations, financial deficiencies, national defence and diplomatic concerns, introducing a new route can become a big decision for an airline. An airline will introduce a new route because of increasing traffic demand. However, such demand will also attract other airlines. This usually results in increased competition on the chosen route, with an increase in flight schedules and possibly price cutting. This usually means that the airline needs a couple of years to break even on the new route. The airline industry is highly competitive; joining an alliance can increase competitive advantages and reduce the competitive pressure from other airlines, including large alliance groups.

Secondly, alliances, especially alliance groups, can create economies of scale. There are several ways to achieve economies of scale, as pointed out by Gsell (2005), such as through returns to scale, learning, specialisation and the distribution of fixed costs over a larger output. Kleymann and Seristö (2004) established three different economies of scale: technological, managerial and financial. Technological economies of scale are based on large-scale production, while managerial economies of scale are based on improving the division of labour; and financial economies of scale are based on reducing unit costs by pooling purchases, sales and financial transactions. For an airline, joining an alliance can

achieve technological economies of scale through efficiency gains by using larger aircraft, because these tend to be more efficient than smaller aircraft. However, airlines occasionally face insufficient demand for various reasons so that it is necessary to maintain a mixed fleet in order to meet the different demands of the network. By joining an alliance, the feeding agreement will ensure certain load factors between major hubs. An alliance will also ensure financial economies of scale through higher bargaining power in purchases, such as fuel, spare parts, aircraft, maintenance, catering and other services. As Iatrou and Oretti (2007) pointed out, financial economies of scale occur when an alliance, acting as a representative of its members, has greater negotiating clout with external suppliers.

Thirdly, airlines aim to join the larger alliance groups to try to position themselves better in the market competition. This generally involves two different dimensions. On one hand, airlines are facing fierce competition amongst themselves. Due to the nature of the industry, on a specific route between two countries or continents, there are at least two airlines (one from each destination) operating the flights. With open skies agreements and market liberalisation, there may be three or four airlines operating on the same route. Moreover, some airlines always have some initial disadvantage, such as poor location or a smaller scale of operations (Kleymann and Seristö, 2004). These airlines always perform worse financially compared with their larger counterparts in the market. Before the emergence of alliances, airlines competed with each other in areas ranging from operational to marketing. For example, in order to attract more passengers, airlines will increase the number of flights and apply price-cutting through promotions. This causes an over-capacity on particular routes, and the consistently lower airfares harm industry development.

On the other hand, airlines are facing more and more competitive pressures from different alliance groups. As Kleymann and Seristö (2004) point out that those independent carriers are facing ever-increasing competitive pressure from large airlines and even more from alliance groups. Currently, the three alliance groups account for more than 50% of passenger traffic and with two other major independent airlines, namely Emirates and Virgin, other airlines have faced huge competitive pressure.

As Sorenson (1990) suggested in his study, when an airline faces competitive pressure from others, there are three common strategic approaches it can adopt. Firstly, the airline could focus on its service differentiation, which sometimes is associated with the creation of large networks including numerous destinations, while at other times it means concentrating on particular niche markets. The second most common approach is area monopoly, which means that an airline assumes a dominant position, controlling various strategic airports. The third and least common strategic approach is that aimed at cost leadership, which means that as competition heightens, airlines start to cut costs as best they can, although it may not be able to attain a sustainable advantage through the mere low-cost approach. However, LCCs are specifically set up to operate under a low-cost model. For the transitional airline, it is almost impossible to transform into a low-cost airline. For the first two strategies, joining an alliance group would be the best choice for ensuring that those two strategies are achieved.

3.2.6 Benefits of Airline Alliance Partnerships

From a theoretical perspective, airline alliances bring a number of benefits to both airlines and passengers. From an airline's point of view, an alliance will bring potential economies of scale in many functions, economies of densities on routes, the benefit of a significant market presence, and the prestige of being part of a larger and perhaps geographically larger operation (Kleymann and Seristó, 2004). In fact, cooperative relationships among airlines have existed for a long time. The earliest instance of such cooperation was in 1919, with the formation of the International Air Traffic Association, now known as IATA.

Some factors have had a large influence on airline alliances and consolidations. Firstly, the increased globalisation in trade and air transportation has created more demand from international travellers (Fan *et al.*, 2001). Cooperation among airlines can provide a large degree of convenience for travellers and also assist airlines in gaining a significant competitive advantage. Airlines can effectively connect with other overseas carriers via cooperation agreements designed to extend the network but which require minimal capital investment.

Secondly, the economic incentives of airline consolidation are another key factor stimulating the development of strategic alliances (Fan *et al.*, 2001). Strong economic incentives for airlines, in terms of higher revenue potential and lower unit costs, are undoubtedly possible through operating large, dense networks. Moreover, the increased level of possible competition and the rapidly changing business environment has resulted in greater uncertainty for airlines. Creating an alliance relationship rather than competing in such an uncertain environment allows airlines to maintain more control over this uncertainty. Fan *et al.* (2001) also pointed out that airlines have strong incentives for operating within large networks in order to achieve step-changes in the network within a short timeframe. Alliances have extended the orientation of deregulation and open skies policies. The US deregulation and the open skies policy in the EU both aim to achieve perfect competition in the market, so airlines can benefit from optimal output, prices and efficient operations. In the rest of the world, however, an airline is still considered to be an oligopoly, facing a low number of competitors and having almost no significant individual market leverage (Kleymann and Seristö, 2004). The airline industry is also highly sensitive to variations in external factors such as fuel prices, wage levels and passenger demand. This sensitivity has increased in recent years and, with profit margins being small, competing in the airline industry is costly and risky.

Thirdly, the entry barriers to most markets are still highly regulated due to factors such as market power and regulations in some markets. The existence of national airlines, fifth freedom rights, flag carrier airlines and bilateral agreements greatly limit the number of airlines that can service routes between certain countries.

Fourthly, strategic alliances create economies of scale for the member airlines, which can bring large benefits to the individual airlines. Factors such as those discussed above (such as entry barriers and cost structures) have limited airline goals purely to the pursuit of becoming larger in size. Attempting to increase in size does not guarantee benefits for airlines. Kleymann and Seristö (2004) have suggested that the true scale of effects could only be observed in the growth of small airlines, where no significant long-term economies of scale have been found.

Iatrou and Oretti (2007) suggest that the following benefits and competitive advantages can be obtained from larger networks and better geographical spread:

- From the development of joint networks, alliances enable their members to stimulate new traffic and save on costs, to generating strategic advantages, and to secure long-term growth potential and market-oriented cost-efficient operations.
- Alliances secure additional traffic, as each partner feeds traffic to the other and more passengers fill the aircraft of these partner airlines, thereby increasing load factors and revenue through successfully linking the members' networks.
- Alliances allow partners to increase their efficiency by improving their capacity usage, or by reducing expenses by weeding out redundant operations and cutting back on fixed costs.
- Alliances enable carriers to enhance the marketability and quality of their services to passengers by offering more convenient flight schedules, greater flight frequency, a larger network and more online connections.
- Alliances help carriers to overcome regulator constraints that hinder the ability of individual airlines to enter and expand into foreign markets.
- Alliances have permitted airlines to enhance their ability to exercise market power and reduce the level of competition.
- Alliances have also been a way to temper the uncertainty of the operating environment, especially for smaller airlines.
- The flexible structure of alliances has allowed each member airline to monitor its growth within the grouping, while retaining the capacity to make adjustments to its contribution or level of commitment, and even to leave the alliance as a result of changes in the strategic environment.

From a passenger perspective, a key objective for airlines joining an alliance is to enhance the value of service offered in the eyes of the customer (Kleymann and Seristó, 2004). Passengers have come to demand a level of service that is impossible for a single airline to provide. For instance, they expect to be able to book through and deal with only one airline network when conducting global travel. To fulfil this kind of need, it is necessary to increase tight cooperation between carriers. An alliance also brings lower pricing for passengers due

to lower operational costs for a given route. Passengers can have a greater choice of departure times on a given route. With increased networks, passengers can reach more destinations through one alliance member airline. Passengers can expect shorter travel times as a result of optimised transfers.

By using a strategic alliance group of airlines, a passenger can choose from a wider range of airport lounges, shared by all the alliance members, and also receive faster mileage rewards by earning miles from several different airlines on a single rewards account. Goh and Uncles (2003) also pointed out that global airline alliances provide common benefits, such as greater network access, seamless travel, transferrable priority status, extended lounge access and enhanced FFP benefits. Morrish and Hamilton (2002) suggested that airlines that join an alliance appear to increase their load factors and experience a general rise in productivity levels, but these advantages are offset by increased flight frequencies and lower airfares. Moreover, market accessibility is usually a major motivation for individual airlines to seek strategic alliances. Nevertheless, the need for risk reduction to ensure long-term survival within the airline industry may be a more important factor behind strategic alliance membership.

3.2.7 Potential Risks of Alliance Partnerships

Alliance partnership cannot be considered to be a universal solution for the airline industry. Joining or forming an alliance partnership will also involve some risks. Airlines that join an alliance partnership will face the problem of losing independence and brand identities. Losing independence includes the loss of sovereignty and flexibility in terms of decision making. Loss of sovereignty would be relevant, particularly in making decisions concerning the routes to be served and capacity offered. After joining an alliance, an airline will largely be integrated into the alliance network and will have to offer certain routes and capacity to meet the requirements of the alliance. By joining an alliance, an airline will limit its future cooperation with other airlines or alliance groups on particular routes or projects. Currently, cooperation between two alliance groups does not exist. Additionally, by joining the alliance, an airline will reduce its costs in terms of alliance membership investment in areas such as

training, information technology systems and marketing. The cost of leaving or changing alliances will reduce an airline's flexibility in operation (Kleymann and Seristó, 2004).

Another risk is that because of aggressive alliance branding campaigns, individual member airlines may face a threat to their own brands. Airlines treat their own brand with high respect because it is an important non-price area in terms of competition. The brand concept will help an airline to create a positive impression for passengers in terms of service quality, cost and convenience. Without branding, an airline will only become a common service provider that is no different from others (Iatrou and Oretti, 2007). Before joining an alliance, airlines usually spend a lot on their brands, both through tangible and intangible investments. Tangible investments include things like airline brand design, and placing the livery on aircraft, crockery, cutlery and ticket covers. Intangible investments include things like the quality of in-flight service and ground handling, for instance, things that have created a particular brand with inherent characteristics.

Moreover, the airline brand, especially for legacy and flag carriers, is an important identity that is closely associated with national culture and symbolism. Nevertheless, after joining an alliance, member airlines have to promote the alliance's brand, which is the key to a cooperative relationship. This may cause two main problems. Firstly, the airline's brand will gradually lose its individual identity in return for the alliance brand as a whole. Despite prior investment, this may cause brand confusion because of code-sharing agreements and service quality differences (Kleymann and Seristó, 2004). Secondly, after the alliance's brand has become famous, the free rider problem may arise, whereby new members can enjoy the benefits from the well-known alliance brand without any effort.

A further risk in joining an alliance is the potential for conflict with regards to expectations and coordination. The purpose of alliance cooperation is to create a partnership between two (or more) airlines. However, the airlines all have individual needs (Kleymann, 2005). There are various reasons for an airline to join an alliance. Some airlines are looking for opportunities to expand their network, while others are looking for protection from competition. There are other reasons for joining an alliance, such as hoping for a quick fix if

an airline has problems, enjoying the status that comes with joining an alliance or free riding on the fame of an alliance's brand. These different expectations can bring new problems for the existing members in terms of cooperation. There are many examples of airlines exiting an alliance group because they have found better options. Even for the three global alliance groups that exist today, airlines have joined then exited or moved from one alliance group to another. As Iatrou and Oretti (2007) suggested, an alliance can be viewed as anything from a simple marketing tool to a means for true strategic long-term cooperation. However, some airlines aim to obtain a share or complete takeover of other members' traffic, for their own benefit and profit. The potential conflict between alliance members stems from the different motivations for joining an alliance.

Finally, it is not easy to enter an alliance group in the current market because of raised requirements; exiting an alliance is also not easy, because of high costs. Currently, to join an alliance group, airlines need a large amount of time and money. Airlines not only need to pay the alliance subscription fee to join and stay in the alliance, but they also face some one-off short-term operational costs and alliance-specific investments. These can include requirements such as the harmonisation of baggage-handling standards, the moving of airport facilities, and the creation of reservation system linkages, fuselage repainting, joint brand marketing, station operations and FFPs (Iatrou and Oretti, 2007). Additionally, airlines that wish to join an alliance have to meet certain membership requirements. For example, Turkish Airlines joined Star Alliance in April 2008 after an 18-month integration process, while Air India failed to meet their latest deadline of minimum standards for membership in July 2011, which resulted in Air India being suspended. With regards to financial investment, for example, airlines need to change their reservation and check-in systems to meet the requirements of an alliance group and also to upgrade their service standards to a certain level.

3.3 Review of Empirical Literature on Airline Alliances

3.3.1 Previous Research into Airline Alliances

There are many empirical studies that have examined the benefits of an airline alliance. It has been suggested that global strategic airline alliances not only dominate the market share in the industry (Fan *et al.*, 2001), but also demonstrate superiority and provide beneficial aspects in operational terms. A number of studies have assessed the various aspects of airline alliances. The empirical evidence shows that a failure to respond to ongoing alliance formations could harm an airline's market share and profitability (Park and Zhang, 1998). Goh and Uncles (2003) studied the benefits of global airline alliances from the customers' perspective and concluded that global strategic alliances provide: (a) greater network access, (b) seamless travel, (c) transferrable priority status, (d) extended lounge access and (e) enhanced FFP benefits.

From an operator's perspective, global alliances offer at least four main benefits: (a) cost reductions and economies of scale, scope, and density (Kleymann and Seristö, 2004); (b) coordinated scheduling and pricing in order to optimise the demand for flight capacity on each flight (Oum and Park, 1997); (c) market access to overcome restrictions over route access and airline ownership imposed by national governments (Weber and Dinwoodie, 2000); and (d) opportunities to reshape industry structures and raise new barriers to new entrants (Mak and Go, 1995). Oum and Zhang (2001) stated that strategic alliances enable partner airlines to achieve, on average, a 5% gain in total factor productivity and a 1.4% increase in profitability, while lowering their prices to customers by an average of 5.5%. Tactical alliances do not, however, have statistically significant effects on the partner airlines' productivity, pricing, or profitability. Park and Zhang (1998) suggested that most partners have greater traffic increases on their alliance routes than on their non-alliance routes. Alliances also increase passenger traffic, with a parallel increase in load factors and some reductions in cost, with a clear improvement in revenue levels being observed (Iatrou and Alamdari, 2005).

In terms of airline alliance survival, group alliances are more stable than bilateral agreement alliances. Li (2000) pointed out that alliances aimed at achieving customer loyalty, operation integration and bilateral code-sharing with serious financial tie-ups through pooling agreements on revenue/costs are likely to be long-lasting, while the leading cause of terminating an alliance is expansion into non-core and non-customer-oriented activities. He also suggested that an alliance that engages solely in code-sharing, joint operations or joint marketing without other substantial commitments by member airlines are likely to fail, or will exist only over the short-term.

The development of a strategic alliance ultimately leads to the emergence of a few strategic mega-alliance groups. Global alliance groupings have quickly come to dominate the airline market. Airlines have realised the benefits provided by these strategic mega-alliance groups, such as economies of scale, global networks and operational cost reductions, which may significantly increase profitability. As Oum *et al.* (2000) reported, emerging global alliance groupings collectively account for 63.6% of world passenger traffic (RPK), 55.8% of passenger numbers and 58.4% of group revenues. Airlines have various reasons for favouring membership in strategic mega-alliance groups. The benefits of this membership have all been summarised from existing empirical studies. It is necessary to explore the economic benefits that a strategic mega-alliance group brings for its members, as well as exploring the negative impacts of joining an alliance group.

An alliance group is a large entity which is not a simple arrangement, as has been outlined above. Because of the complexity of cooperation among the partners, it requires tight coordination. In examining the current airline industry, it can be observed that there are many global strategic alliances in existence, with most being cooperation agreements between two airlines. There is a strong trend for moving toward a few large global strategic alliance groups, which indicates that the number of groups may eventually reduce to one or two having dominance over the industry. There is another possibility that the global airline industry will move toward greater consolidation and merge into one or two global carriers. These two possibilities are, however, still far in the future.

3.3.2 Previous Research in Airline Performance Analysis

In the contemporary airline research literature, several identifiable scientific mathematical methods have been commonly adopted when analysing an airline's operational performance. There are three methods that are most appropriate for airlines because of their sophistication and preciseness. The first, DEA, models an airline's operational efficiency, and has been used in studies such as Schefzyk (1993), Distexhe and Perelman (1994), Good *et al.* (1995), Scheraga (2004), Barbot *et al.* (2008), Barros and Peypoch (2009) and Coli *et al.* (2011). The second analytical method is SFA, which also models an airline's operational efficiency, and has been used in studies such as Cornwell *et al.* (1990), Good *et al.* (1993), Good *et al.* (1995), Coelli *et al.* (1999), Inglada *et al.* (2006) and Coli *et al.* (2011). The third one is the panel regression approach on airline productivity and profitability as used by, for example, Oum and Zhang (2001), Oum *et al.* (2004) and Barbot *et al.* (2008).

3.3.2.1 Efficiency Analysis

The production efficiency of an airline is a critical element of its competitiveness in such a fierce market. Efficiency is one of the most important measurements in operation. It reveals the true relationship between what an organisation such as a producer, production unit, or other decision making unit (DMU) produces and what it could feasibly produce, under the assumption of full utilisation of the resources available (Garcia Del Hoyo *et al.*, 2004). Kumbhakar and Lovell (2000) explain that efficiency represents the degree of success that a firm has achieved in allocating the available inputs and the outputs they possess to achieve certain goals. Thus, efficiency is the ability of a DMU to obtain output from the inputs. There are two main categories of efficiency: output-oriented and input-oriented. Output-oriented efficiency focuses on maximising output from a set of inputs while the input-oriented efficiency tries to produce an output using the lowest possible amount of inputs (Kokkinou, 2009).

Productive efficiency is not a new concept. Farrell (1957) was the first to empirically measure productive efficiency in terms of deviations from an ideal frontier. He also proposed a decomposition of economic efficiency into: (a) technical efficiency (TE), which measures the ability of a firm to obtain the maximum output from given inputs, and (b) allocative efficiency, which measures the ability of a firm to use inputs in optimal proportions, given their prices (Farrell,1957):

$$\text{Economic Efficiency} = \text{TE} * \text{Allocative Efficiency.}$$

If there is no information for the input and output prices, but input and output quantities are available, then the type of efficiency that can be measured is TE. The allocative efficiency can be measured only where the quantity inputs and outputs are available, in addition to input and output prices. In order to achieve maximum profit, the firm needs to achieve both TE and allocative efficiency. To achieve these, the firm needs to produce the maximum output given the level of inputs employed, as well as using the right mix of inputs or producing the right mix of outputs (Pascoe *et al.*, 2003; Zagelmeyer, 2004). Nevertheless, in real economic situations, producers are unlikely to achieve full productive efficiency. The reasons for these unexpected differences can be explained in terms of technical and allocative inefficiencies, as well as a range of unforeseen exogenous shocks, which move the operation away from the full efficiency frontier. Thus, a related question has been raised here, which is whether inefficiency occurs randomly or whether some economic agents have predictably higher levels of inefficiency than others. By using the efficiency estimation, the corresponding production frontier can be drawn, which will indicate whether the percentage of potential output could be increased or if the potential cost could be decreased.

Here, a production frontier refers to the maximum output attainable from a given set of inputs with the existing production technologies. The production frontier defines TE in terms of a minimum set of inputs in order to produce a given output, or the maximum output produced by a given set of inputs. This approach involves selecting the mix of inputs that produce a given quantity of output at a minimum cost, namely the production frontier. If what a producer actually produces is less than what it could feasibly produce then it will lie below

the frontier. The distance at which a firm lies below its production frontier is a measure of the firm's inefficiency (Bera and Sharma, 1999). Because the production frontier cannot be observed directly, several techniques have been developed in order to estimate efficiency. The main methods of estimating production frontier and efficiency have been classified into two groups:

- Non-parametric models: the most common one is DEA, developed by and Charnes *et al* (1978);
- Parametric models, such as SFA, developed separately by Aigner *et al*, (1977), and Meeusen and van Den Broeck (1977).

SFA and DEA methods estimate the same underlying efficiency values but provide different efficiency estimations. This is mainly due to the differences between the underlying assumptions. There has been much discussion and argument as to which of the two approaches is the most appropriate technique; each has its own strengths and weaknesses.

DEA is a convenient method of analysing performance efficiency because it is a non-parametric method that does not require the specification of an explicit functional form for the production frontier. Lin and Tseng (2005) stated that DEA provides insights into adding up or reducing input resources to improve the efficiency score, while the SFA method focuses on economic justification and hypothesis testing. A combination of both DEA and SFA supports management to have a more comprehensive understanding of operating efficiency. Both methods are frontier functions to measure the efficiency of all firms with cross-section and panel data (Lin and Tseng, 2005). Moreover, DEA does not need a specification of the production process technology, is easily adapted to multi-product technology, and allows theoretical restrictions to be imposed (Garcia del Hoyo *et al.*, 2004). Nevertheless, the DEA method cannot separate statistical noise or the measurement errors from random errors. Thus the relative efficiency scores obtained from DEA may be vulnerable and confused with the effects of uncontrollable factors.

On the other hand, SFA has the advantage of allowing random noise to be incorporated into the model while DEA considers any statistical noise, measurement error, omitted variables and other misspecifications to be inefficiency. The SFA method can test hypotheses statistically and construct confidence intervals allowing for random errors, but may lose some flexibility in model specification (Hjalmarsson *et al.* 1996; Lee, 2005). If a model is incorrectly specified, it may cause multi-collinearity and some theoretical restrictions may also be violated. The effects of statistical noise or measurement errors can be distinguished from random errors when applying the SFA method to measure production inefficiency (Lee, 2005).

It is hard to say which of the two alternative approaches is better in terms of estimating production efficiency. Lee (2005) suggested that before any correctional improvement is applied, the stability of the TE, estimated from a parametric (or non-parametric) method, should be evaluated by comparing it against that found using the non-parametric (or parametric) method. Few studies have compared and contrasted the results of DEA and SFA. For example, Lin and Tseng (2005) used the DEA and SFA models to estimate and compare the efficiencies of 27 international container ports. Lee (2005) used the SFA and DEA methods to measure production efficiency for forest and paper companies. Within the airline industry, except for two articles – Good *et al.* (1995), which used both methods to measure the performance of 16 airlines during the period 1976–1986, and Coli *et al.* (2011), which evaluated the operational performance of an Italian airline for the year 2007 – there are few articles where both the DEA and SFA methods can be identified. Moreover, efficiency assessments by either DEA or SFA have not commonly been adopted in airline operation literature, compared to other industries such as agriculture. Hence, this study will use DEA and SFA separately to analyse airlines' efficiency.

3.3.2.2 Data Envelopment Analysis (DEA)

DEA is a mathematical programming approach for characterising the relationships among multiple inputs and multiple outputs. The initial DEA model, as originally presented in Charnes *et al.* (1978), built on the technical efficiency concept developed by Farrell (1957). It is a popular methodology for defining and analysing a firm's efficiency. It has been largely used to measure operational efficiency in transportation, banking and public services. Non-parametric DEA does not require the production process to be specified and only certain formal properties need to be defined that verify the points of the production set. These properties are related to returns to scale, the availability of inputs and outputs, or convexity. Data are enveloped by a frontier under these properties and efficiency can be obtained by comparing the actual values of the outputs with the production frontier (envelope). This technique uses linear programming methods to determine the frontier and inefficiency.

DEA has been used to measure the efficiency in various kinds of industries. Within the aviation field, the methodology has been mostly used to assess airport efficiency. For example, Gillen and Lall (1997) applied DEA to assess the performance of 21 US airports over the period 1989–1993. Parker (1999) used DEA to study the TE of the British Airport Authority, before and after privatisation, and found that privatisation had no noticeable impact on TE. Sarkis (2000) used DEA to evaluate the operational efficiencies of 44 major US airports over the period 1990–1994. Martin and Roman (2001) used DEA to evaluate the performance of 37 Spanish airports for 1997. Abbott and Wu (2002) used the DEA and the Malmquist Productivity Index (MPI) to investigate the efficiency and productivity of 12 Australian airports over the period 1990–2000; the result indicated that the airports experienced strong growth in TE and total factor productivity, but did not have good growth in scale efficiency (SE).

Fernandes and Pacheco (2002) employed DEA to evaluate the capacity efficiency of 35 Brazilian domestic airports for 1998. Pacheco and Fernandes (2003) used DEA to measure the distance from an airport's efficiency frontier to enable avenues to managerial improvement to be identified. Pels *et al.* (2003) used DEA to assess the technical efficiency

and SE coefficients of 33 European airports over 1995–1997. Sarkis and Talluri (2004) used DEA and clustering analysis to perform a benchmarking of airports as an extension of Sarkis (2000). Yoshida and Fujimoto (2004) employed DEA and endogenous-weight total factor productivity methods to measure the efficiency of 67 Japanese airports and compare the results. Yang (2009) adopted DEA and MPI to measure the efficiency and productivity growth of the Asia-Pacific region's international airports and suggested that technical efficiencies would improve with appropriate scale size and high utilisation of resources. They also found out that airport productivity started to decline after 2002–2003.

Concerning the airline industry, Schefczyk (1993) first adopted the DEA measurement model to measure airline efficiency. His study discussed the operational efficiency of 15 large international airlines for the year 1990. The sample contained 14 commercial carriers and Federal Express. Distexhe and Perelman (1994) aimed their study at evaluating the consequences of air transport deregulation by measuring the efficiency and productivity of 33 airlines operating in three market groups: Asia and Australasia, Europe and North America, covering the period 1977–1988. Good *et al.* (1995) analysed the efficiency and productivity differences observed between European and American companies covering the 1976–1986 period. The authors used two alternative methods: a parametric method using statistical estimates, and a non – parametric method using linear programming. The companies were classified according to specific productivities and efficiency differences observed at the time. Fethi *et al.* (1999) applied the DEA methodology to detect and model the efficiency of European airlines with the purpose of formulating air transport regulation policies in Europe. The analysis was based on data from 17 European airlines, covering the 1991–1995 period, and focused on the initial period of the air transport liberalising reforms in Europe.

Fethi *et al.* (2001) utilised Schefczyk's model to investigate the operational efficiency of European airlines. Their analysis utilised panel data for a set of 17 European carriers for the period 1991–1995. Soares de Mello *et al.* (2003) compared the relative efficiency of the Brazilian airlines during 1998–2000, where each company was considered to be a different DMU in each of the three years. An input-oriented DEA with a constant return to scale was adopted. The study done by Scheraga (2004) employed cross-sectional data for 38 airlines from 1995 to 2000 to determine the operational efficiency versus financial mobility of an

airline by using DEA and Tobit analysis. Araujo *et al.* (2007) assessed the relative efficiency of the Brazilian air transport industry during 1999–2001, also using the DEA method with variable returns to scale. Two scenarios were used in this study to analyse the national and regional airlines, which showed a great difference in performance between these airlines categories.

Scheraga (2006) used the DEA method to analyse the operational impact on a Chinese airline after consolidation into three groups. Araujo *et al.* (2007) used the DEA method to evaluate the relative efficiency of the main Brazilian carriers compared to other full service airlines, regional airlines and low-cost airlines in the period covering 2000–2005. Barbot *et al.* (2008) adopted the DEA and total factor productivity method, analysing airlines' efficiency and productivity in a new market context. The research suggested that LCCs are generally more efficient than FSCs and larger airlines, which suggests the existence of economies of scale. Barros and Peypoch (2009) used DEA to evaluate the operational performance of European airlines over 2000–2005. They adopted two stages, including semi-parametric models of productive efficiency that use truncated regression to evaluate the driver of efficiency.

3.3.2.3 The DEA-based Malmquist Productivity Index (MPI)

The results from the DEA can be used to analyse and measure the productivity change over time by adopting the DEA-based MPI. The MPI is a bilateral index that can be used to compare the productivity change over time of two or more economies. This quantity index was originally proposed by Malmquist (1953) for measuring the standard of living for the purpose of consumption analysis (Kortelainen, 2008). Later on, the MPI and its variations have mainly been adopted for use in the field of production analysis. Moreover, in recent years, it has been recognised that both technical change and efficiency change can contribute to productivity change (Mohammadi and Ranaei, 2011). Färe *et al.* (1992, 1994a) combined the ideas of efficiency measurement (Farrell, 1957) and productivity measurement (Caves *et al.*, 1982) to develop a DEA-based MPI by directly using the results from input and output analysis using DEA. This DEA-based MPI has proven to be a useful tool for measuring the

productivity change of a DMU. Moreover, the MPI index also can be used as the robustness test to confirm the choice of panel data for efficiency measurement.

There are quite a few researches that have adopted the MPI to measure the productivity change of DMUs in various area and industries.

- Mohammadi and Ranaei (2011) used the extended DEA-MPI methodology to reveal patterns of productivity change in Iranian cement companies listed in the Iranian stock exchange market in 2003 and 2004;
- Chen and Ali (2004) used the method in their study of Fortune Global 500 computer and office equipment companies over 1991–1997;
- Abbott and Wu (2002) employed DEA-MPI methodology to investigate the efficiency and productivity of 12 Australian airports over the period 1990–2000;
- Maudos *et al.* (1999) used MPI in studying the shifts in total factor productivity among the Organisation for Economic Cooperation and Development (OECD) countries;
- Madden and Savage (1999) used it to study telecommunications productivity, technology catch-up and innovation in 74 countries;
- Taskin and Zaim (1997) used it for an empirical investigation of the catch-up hypothesis for a group of high and low income countries;
- Fulghiniti and Perrin (1997) used to explore in agricultural productivity change in 18 developing countries;
- Grifell-Tatje and Lovell (1996) used it to look at the effect of deregulation on Spanish saving banks;
- Färe *et al.* (1994b) used it to study productivity developments in Swedish hospitals;

None of the available studies revealed that the extended DEA-MPI methodology has ever been applied to the airline industry, especially for productivity change over time in airline alliances.

3.3.2.4 The Stochastic Frontier Analysis (SFA)

SFA is a parametric method of economic modelling and is based on quantitative economic theory. It has been widely used for assessing efficiency in other industries. However, only a few articles that apply the SFA model on efficiency analysis can be identified within the airline industry. For example, Baten *et al.* (2009) used the stochastic frontier trans-log production function on the tea industry of Bangladesh and suggested that a 49% technical inefficiency existed in the tea yield. Garcia del Hoyo *et al.* (2004) estimated the TE of fishery operations in the Gulf of Cadiz. Demir *et al.* (2005) identified key factors determining the TE differentials among Turkish commercial banks in the pre-and post-liberalisation periods by using the technical inefficiency effects model.

Liu (1995) used SFA with a stochastic trans-log frontier production function to assess the TE of 28 UK ports with panel data for the years 1983–1990. Cullinane *et al.* (2002) adopted SFA with a Cobb–Douglas production function for the half-normal, exponential and truncated-normal distributions to assess the productive efficiency of 15 Asian container ports over 1989–1998. Estache *et al.* (2002) used SFA with the Cobb–Douglas and trans-log production functions for the half-normal and truncated normal distributions to analyse the TE of 11 Mexican ports over 1996–1999. Hazarika and Subramanian (1999) estimated the TE of the tea industry in Assam using the stochastic frontier production model and focusing on productivity and production factors only. Mahesh *et al.* (2002) analysed the TE of Indian tea production and concluded that there is plenty of scope for improving tea productivity with the proper allocation of existing resources. Ariyawardana (2003) examined the sources of competitive advantage and studied how it was related to growth in the performance of the tea industry in Sri Lanka with a deeper understanding from a management point of view.

With respect to the airline industry, Cornwell *et al.* (1990) used a frontier production function while considering a group of US airlines and the pattern of changes in efficiency across regulatory environments. Good *et al.* (1993) adopted the SFA model to analyse and compare TE and productivity growth among the four largest European carriers and their eight American counterparts over 1976–1986. Good *et al.* (1995) used the SFA model to analyse

the performance of the eight largest European and the eight largest American airlines during 1976–1986 and concluded that the European carriers under deregulation were as productively efficient as their American counterparts. Coelli *et al.* (1999) measured the efficiency of 32 international airlines by considering two alternative approaches to account for environmental influences in the SFA model. The two sets of results provide similar rankings of the airlines but suggest differing degrees of technical inefficiency. Coli *et al.* (2011) used the SFA method to measure the efficiency of an Italian airline in 2007.

3.3.2.5 Regression Model of Productivity and Profitability

Regression analysis can be used to identify the factors that account for differences in productivity and profitability. It can provide more solid evidence of whether joining an alliance can bring sound benefits. There are only a few studies that have been identified in the existing literature. Oum and Zhang (2001) used a regression model to analyse the effects of alliances on partners' productivity, price and profitability over 1986–1995. Oum *et al.* (2004) used a regression model to analyse the effect of horizontal alliances on the productivity and profitability of 22 international airlines over 1986–1995. Barbot *et al.* (2008) used the regression model to analyse the total factor productivity of 49 airlines in 2005. This study will also adopt a similar method to analyse whether alliance-related factors influence airline productivity and profitability.

3.4 Summary of Related Literature

In order to clarify the current level of knowledge, the following section provides a summary of the major alliance studies since 1990s and a critical analysis of three relevant studies. There are two main parts in this section. The first part provides a table (Table 3.1) that summarises current airline alliance research. It is organised by listing the author and date, research subjects, methods of analysis, sample contents, study period and major findings of the study. As Table 3.1 shows, no research has been done in terms of the performance change resulting from joining a global airline alliance group. Some research has provided similar

analysis; however, they all have some deficiencies when related to a study of airline alliance groups.

The second part mainly focuses on analysing some of the particular problems found in three relevant studies. The three most relevant studies have been gleaned from within airline alliance literature:

- Morrish and Hamilton (2002) for airline alliances;
- Oum *et al.* (2004) for horizontal alliances;
- Iatrou and Alamdari (2005) for airline grouping behaviour.

Firstly, Morrish and Hamilton (2002) have argued about who benefits from airline alliances. They have examined 15 years of airline alliance experience and have found no conclusive evidence that membership of an alliance has yielded monopoly profits to the airlines. They also suggest that the benefits of joining an airline alliance group, such as an improvement in load factors and general productivity levels, would result from fare reductions. An airline would only see modest gains from joining the alliance group. However, there are also some deficiencies in this research. The main deficiency is that the research drew its conclusions based on theoretical reviews without any qualitative or quantitative analysis. The whole research has low credibility because it generalises the results from airline alliance research in different backgrounds. Secondly, the authors did not specify what kind of alliance relationship they studied, but very broadly referred throughout the study to airline alliances. Nevertheless, the alliance group cooperation and bilateral alliance agreements between airlines certainly have two different means to airlines.

Table 3.1: Major Studies of Airline Alliances within the Timeline

Study	Subjects	Analyses methods	Sample	Study period	Findings
Oum <i>et al.</i> (1993)	Airline policy	Conceptual/theoretical review			A global continent
Debbage (1994)	Alliance networks	Conceptual/theoretical review	British Airways, US Air, Singapore Airlines, Iberia Airlines	1991	Strategic process.
Youssef and Hansen (1994)	Service quality, market concentration and fares	Case study/regression	SAS–Swissair strategic alliance	1989–1991	Alliance They inc but creat fare incr
Park (1997)	Airline outputs and profits, air fares and economic welfare.	Theoretical analysis/Panel regression	KLM– Northwest and Delta–Swissair–Sabena	1990–1994	A compl welfare,
Park and Cho (1997)	Airline market share	Frequency test and multivariate regression	Time series data of 56 airlines	1986–1993	Code-sh and will with few
Oum and Park (1997)	Airline alliance status, policy issues and future direction	Conceptual/theoretical review	A survey of 46 alliances among the 30 top airlines	1996	Strategic strength share in alliance
Park and Zhang (1998)	Airline outputs	Theoretical model and empirical analysis	Four major alliances in North Atlantic markets	1992–1994	Airlines routes th
Brueckner and Whalen (2000)	Effect of airline alliances on fares	Theoretical model and empirical analysis	US airlines with alliance partnerships	1991	Alliance interline carriers.
Park and Zhang (2000)	Passenger volume, air fares and consumer surplus	Structural model and regression	Four major alliances in the North Atlantic: British Airways, US Air, Delta, Sabena, Swissair, KLM, Northwest, Lufthansa, United	1990–1994	Allying increase were ger
Oum and Zhang (2001)	Alliance survival and duration	Panel regression	22 international airlines	1986–1995	Alliance enhancer improve

Gudmundsson and Rhoades (2001)	Effect of alliance membership on performance	Typology predicting	Alliances from <i>Airline Business</i> annual surveys	1994–1999	Alliance a low risk typologi
Morrish and Hamilton (2002)	Alliance strategy	Conceptual/theoretical review	Major carriers with alliance group membership	1986–2000	Alliance airlines. the allian reduction
Suen (2002)	Effect of horizontal alliance on productivity and profitability	Conceptual/case study	Swissair		The allia group's
Oum <i>et al.</i> (2004)	Airline traffic and performance in general	Panel regression	22 international airlines	1986–1995	Horizont producti positive are found producti
Iatrou and Alamdari (2005)		Qualitative survey	All the airlines in four global alliances	2002	Strategic and othe alliances

In the second study, Oum *et al.* (2004) studied the effect of horizontal alliances on firm productivity and profitability. They analysed airline firms as an example of horizontal alliances to illustrate the benefits of bilateral agreements between airlines. The study was based on panel data from 22 international airline companies which formed alliances during the 1986–1995 period. The study found that horizontal alliances make a significant contribution to productivity while there is no overall significant impact on profitability. The research adopted a quantitative research method to analyse the panel data about airline productivity and profitability. It is one of the few studies that have provided quantitative empirical evidence about the benefits of airline alliances. However, there are some deficiencies in terms of referring to strategic alliance analysis. Firstly, in the sample period, airlines only had bilateral agreements; the modern alliance group did not exist at that time. The study therefore cannot be used to generalise to airline alliance groups. The research provides an analysis of airline productivity and profitability, but missed one of the important indicators of airline operation, namely airline efficiency. Thirdly, the research also used relatively old data to analyse airline operations, which has less creditability and generalizability.

The third study (Iatrou and Alamdari, 2005) carried out an empirical analysis of the perceived impacts on participating airlines of the four alliances groups, which included Wings, Star Alliance, OneWorld and SkyTeam. The study employed a comprehensive survey of the alliance management departments of airlines participating in the alliances and gathered the opinions of all the airlines that belonged to the four global alliances in 2002 about the impact alliances have had on traffic and on performance in general. Based on the survey results, the research concluded that an alliance will increase passenger traffic with a parallel increase in load factors and some reduction in costs, and indeed an improvement of revenue. The greatest benefits from alliances are the more advanced and integrated forms of cooperation obtained by anti-trust immunity. They also mentioned that most alliances have been labelled strategic rather than a deeper form of integration. However, this research is out of date and alliance groups have been changed. Since Wings was dissolved, the results will have less generalizability for current airline alliance distributions. Moreover, the research adopted a qualitative method and conducted a survey to provide empirical evidence of the benefits of joining an alliance group. It lacks quantitative analysis and, for the economic data, quantitative analysis will provide a more comprehensive result. Additionally, the survey in

the study was carried out in 2002, when alliance groups were relatively new for the airlines and where four alliance groups existed. Thus the results may have some bias and lowed generalizability.

3.5 Conclusion

There is a wealth of knowledge with respect to the subject areas of strategies, alliances and their application to the airline industry. It is hard to estimate the details of change and growth within the airline industry, as it is an industry with a highly competitive nature and a lot of information remains unpublished. Actually, there is only one published work that examines the effects of an alliance on airlines' performance (Oum *et al.* 2004). However, it is limited by the early sample period, a focus on the bilateral agreements only and adopting the panel regression model only. For the DEA, MPI and SFA methodologies, most researchers have only focused on analysing airline performance, not the performance of the alliance as a whole. Finally, to date, there is no research that studies the three major global airline alliance groups. Thus the literature review has provided the fundamental structure for the whole research.

4. Data and Methodology

4.1 Data Collection and Construction of Variables

4.1.1 Data Collection

The research data were mainly obtained from a purchased ICAO database. This specialised database is run by the ICAO and asks airlines to report various operational and financial data in a standardised format on a voluntary basis. The standardised reporting format can minimise errors and difficulties resulting from differences in accounting practices across different countries. Due to the nature of the industry, some sensitive data still cannot be obtained. The database contains data for two main aviation groups: air carriers and airports. The air carrier data, which are of concern in this research, include financial, traffic by flight stage, personnel, fleet, and on-flight origin and destination data for 1973–2009 inclusive. Reporting these data to ICAO is, however, voluntary. Thus, data may be missing for particular airlines and years. The secondary data sources are the airlines' annual reports. Owing to the different reporting systems used, the data in those reports cannot strictly be matched with the ICAO database.

In this empirical analysis, an initial sample of the world's top 100 airlines in terms of revenue in 2007, as estimated and published by *Airline Business*, was selected. The sample included most of the major international airlines and large domestic airlines. Due to this ranking being made according to revenue, airlines that do not appear in the upper 100 rankings are those that are too small for comparison purposes in this study. The sample contained two main groups: airlines in one of three global strategic alliance groups, and airlines that are not members of any alliance group.

The study sought to compile a balanced panel dataset of the largest number of airlines for the longest period traversing the pre-strategic alliance years up to the latest date in the ICAO database which covered the 1973-2009 period. Since the first strategic alliance was formed in

1997, that year became pivotal. Owing to missing observations on some of the variables for some airlines in some years, the optimal panel dataset obtained was that for 20 airlines for the years 1995 to 2005 (i.e., 11 years). That the first year in the study period is two years before the first alliance was formed means that the analysis can identify the change in any airline's performance in the first and subsequent years of membership in an alliance. Because the study period ends in 2005 the findings from this study may be characterised as describing the relative performance of airlines during the first eight years of the presence of strategic alliances. Also, the fact that some airlines remained non-allied throughout the study period allows the research to distinguish between the performance of allied and non-allied airlines. The study period can further be rationalized by pointing out that it traverses the years when the airline industry experienced perhaps its biggest shock by way of the 9/11 attacks in New York in 2001 and the subsequent security changes made to air travel. At the start of this research the available ICAO database cost more than US\$5,000 to purchase. This research was not endowed enough to go beyond the data available to it. Any inquiry into airline performance beyond 2005 will have to be the subject of a different research.

4.1.2 Construction of Key Variables

In the study, the DEA and SFA methods will mainly use the original data for the analysis. For the panel regression, an overall input and output indices will be constructed for the analysis. As suggested in previous literature (Oum and Yu, 1998; Oum and Zhang, 2001; Oum *et al.*, 2004), the output index will be calculated by aggregating three categories of outputs using the trans-log multilateral index procedure based on a theory proposed by Caves *et al.* (1982). The airline outputs were classified into three categories: total passenger services (measured in revenue tonne-kilometers, or RTK), total freight services (measured in RTK) and incidental services (non-airline business). Incidental services include a wide range of non-airline business, such as catering services, group handling, aircraft maintenance and reservation services for other airlines, consulting businesses and hotels. Although these are non-core activities for the airlines, they account for an average of 9% of total operating revenue for the airlines included in this study. Oum and Yu (1998) and Oum *et al.* (2004) also suggested taking incidental revenue into account when measuring total output.

A similar quantity index for incidental outputs has been constructed following previous studies (Oum and Yu, 1998; Oum *et al.*, 2004). As incidental revenue includes a wide variety of activities and the sample airlines were based in different countries, the index for incidental revenue is approximated by deflating incidental revenues using the purchasing power parity index for GDP. The purchasing power parity index will equalise revenue amounts between changes in market exchange rates and changes in real price levels relative to the US dollar. In order to compare across years, the index was also adjusted by the US GDP deflator, using the year 2000 as the base year. The formula is as follows:

$$Y_k = \sum_i \frac{\bar{R}_{ik} + \bar{R}_i}{2} \ln \frac{Y_{ik}}{\tilde{y}_i}, \quad (4.1)$$

where Y_k is the aggregate output index for observation k , \bar{R}_{ik} is the revenue share of output i for observation k , \bar{R}_i is the arithmetic mean of the revenue share of output i over all observations in the sample, Y_{ik} is the output i for observation k and \tilde{y}_i is the geometric mean of adjusted output revenue i over all of the observations.

For the overall input index, two studies have been identified in the literature review as being of importance in this area. Oum and Yu (1998) classified airline inputs into five categories: labour, fuel, flight equipment, ground property and equipment (GPE), and materials. In that study, the price of labour input is measured by the average compensation per employee. The fuel price is obtained by dividing the total fuel cost by the gallons of fuel consumed. The flight equipment price is captured by total annualised aircraft costs, dividing the sum across all categories of aircraft. The ground properties and equipment price is estimated by aggregating all such costs into a single capital stock series and then dividing the total capital costs by the aggregate capital input quantity index. The material input cost consists of all other inputs not already included in any of the other input categories. The material price index uses a similar method to that of the incidental revenue, which is used to construct a materials price index. Finally, the five categories of input were aggregated to form an overall input index, using the trans-log multilateral index procedure (Oum and Yu, 1998).

Oum *et al.* (2004) classified airline inputs into four categories: labour, fuel, capital and materials. In their study, labour input was measured as the total number of employees. Fuel input was measured by gallons of fuel consumed. Capital input was measured by combining flight equipment costs, ground property costs and equipment costs. The material input category contains all other inputs not already included in the above categories. The material quantity index was constructed by dividing the material cost by the purchasing power parity index and the US GDP deflator. Finally, the four categories of input were formed into an overall input index based on the same trans-log multilateral index procedure as for the output index (Oum *et al.*, 2004). For this empirical study, a similar trans-log multilateral index method was adopted to calculate the input and output indices for the sample airlines. The output index was calculated by using the adjusted revenue share instead of the observed quantity measurement. Oum and Yu (1998) and Oum *et al.* (2004) used this method to calculate the incidental revenue index. Thus, the output index formula is as follows:

$$Y_k = \sum_i \frac{\bar{R}_{ik} + \bar{R}_i}{2} \ln \frac{R_{ik}}{\bar{R}_i}, \quad (4.2)$$

where Y_k is the aggregate output index for observation k , \bar{R}_{ik} is the revenue share of output i for observation k , \bar{R}_i is the arithmetic mean of the revenue share of output i over all observations in the sample, R_{ik} is the adjusted output revenue i for observation k and \bar{R}_i is the geometric mean of output revenue i over all of the observations.

For the input index, the labour inputs, fuel inputs and capital inputs could not directly be utilised due to insufficient data. However, there is an alternative method for the construction of a quantity index for all of the input categories. The alternative input index was calculated by aggregating four different airline input categories that included flight operation, group operation, general and administrative, and depreciation. Instead of dividing S_{ik} (the input i for observation k) by \tilde{S}_i (the geometric mean of input i over all of the observations), the multilateral index procedure was modified to:

$$E_k = \sum_i \frac{\bar{S}_{ik} + \bar{S}_i}{2} \ln \frac{S_{ik}}{\bar{S}_i}, \quad (4.3)$$

where E_k is the aggregate input index for observation k , \bar{S}_{ik} is the cost share of input i for observation k , \bar{S}_i is the arithmetic mean of the cost share of input i over all observations in the sample, S_{ik} is the adjusted input cost i for observation k , and \tilde{S}_i is the geometric mean of input cost i over all of the observations. This method has been used to calculate the incidental revenue index for output index and materials in previous literature (Oum and Yu, 1998; Oum and Zhang, 2001; Oum *et al.*, 2004).

Thus the airline productivity index is calculated by dividing the overall output index by the overall input index. The way to calculate the overall output and input indices has been explained above. The final productivity index will become one of the dependent variables of this study. Another dependent variable will be the airline profitability index, which is calculated by dividing the total revenues by total input costs.

4.1.3 Description of Other Variables

Joining an alliance is only a small part of an airline's operational decision making. As Oum *et al.* (2004) suggested, airline performance is affected not only by the formation of alliances, but also by a large number of other factors. As a result, it is necessary to introduce a number of control variables in this empirical study. Thus control variables such as company size, aircraft numbers, passenger numbers and special events will be included in this empirical study. These data are collected from the airlines' annual reports and from ICAO's traffic, fleet and personnel, and financial database.

4.1.3.1 Independent Variables

Alliance status

The variable *alliance status* (*Allied*) reflects whether an airline joined an airline strategic alliance group during the year under examination. This variable was coded 0 when the airline was not in any alliance group in a given year and 1 when the airline joined an alliance group in any given year.

Number of members

The alliance groups gradually expanded over the period of this study. The number of participants continually increased. This variable (*Alnumb*) simply reflects the number of members in a particular alliance group in a given year.

Membership duration

This variable (*Length*) is a measure of the number of years that each airline has participated in the alliance group in a given year. This variable took the value 0 when the airline was not in the alliance group, 1 when the airline had been a member of the alliance for one year, 2 when the airline had been a member of the alliance for two years and so on.

4.1.3.2 Control Variables

The empirical models controlled for the potential impact of *firm size* (*Size*), as performance may be affected by the size of the airline. A large airline may fly more aircraft and routes, but face accordingly high operational costs. Small airlines have limited resources, which result in

lower market domination and less competitive advantage. The study also controlled for the number of aircraft departures for each observation.

Aircraft departures (*Flights*) represent the total number of flights that the airline operated during a certain period. This measure is equal to the number of landings made. The more the number of flights, the more passenger and cargo revenue airlines can obtain. However, the aircraft departures also relate to airlines' operational costs, since fuel consumption and crew costs are highly dependent on this measurement.

The passenger load factor (*Plfac*) is an important indicator of airline operations so this has also been controlled for. The load factor will affect airline performance and was measured by dividing total seat kilometres available by passenger seat kilometres.

The study also controlled for the changes in business firm composition, the revenue share from freight operations (*Rsfrgt*) and the revenue share from incidental revenue (*Rsirev*). Total revenue has been divided into three different proportions, which are passenger business, freight business and other business; the last two variables were then included in the panel regression analysis (Oum *et al.* 2004). During the study period, two special events occurred that had a great impact on the airline industry: the September 11 2001 tragedy and the Severe Acute Respiratory Syndrome (SARS) outbreak in 2003. The effect of these two special events will be captured with dummy variables in the panel regression.

4.1.3.3 Dependent Variables

The dependent variables in this empirical study are the individual airlines' performances. Performance is defined for the purposes of this study as productivity and profitability. Firm productivity can be measured by the ratio of the firm's total outputs to its total inputs (Farrell, 1957). Usually, a firm will have multiple inputs to produce multiple outputs. This empirical study will therefore consider the firm's overall productivity, which is the ratio of multiple outputs to multiple inputs. Following similar research by Oum *et al.* (2004), the productivity

index in this study will be calculated by dividing the overall output index by the overall input index. The profitability of each airline's operation will be calculated by dividing total revenue by total input cost as difficulties have been identified in studies using the measure (total revenue – total input cost)/total revenue, with some negative results being found (Oum *et al.* 2004).

4.2 Methodology

4.2.1 Data Envelopment Analysis

4.2.1.1 Introduction to DEA

The application of the DEA model can be conducted in three steps:

- Definition of outputs or inputs;
- Choosing between constant returns to scale (CRS), also called the Charnes–Cooper–Rhodes (CCR) model by Charnes *et al.* (1978) or variable returns to scale (VRS), and also called the Banker–Charnes–Cooper (BCC) model by Banker *et al.* (1984);
- Deciding whether the model is input-oriented or output-oriented.

In various publications, the combinations of outputs and inputs have been different. Schefczyk (1993) has defined an input–output model characterised by two outputs and three inputs. Specifically, the outputs are RPK and non-passenger RTK. The inputs are: available ton-kilometres, operating costs and non-flight assets. With respect to the inputs, the available ton-kilometres reflect the available aircraft capacity. It is the sum of RPK for scheduled and charter (non-scheduled) services. Available ton-kilometres is the sum of the products obtained by multiplying the number of tons available for carrying revenue load passengers, freight and mail on each flight stage by the stage distance. The operating cost is computed as total operating expenses minus aircraft rent, depreciation and amortisation. Non-flight assets

are computed as total assets minus flight equipment at cost purchase deposit for flight equipment and the accumulated depreciation for flight equipment under capital leases. With respect to the output, RPK is the sum of RPK for scheduled and charter (non-scheduled) services. Non-passenger RTK includes ton-kilometres for freight and mail for both scheduled and non-scheduled service. RPK is the sum of the products obtained by multiplying the number of revenue passengers carried on each flight stage by the stage distance. Non-flight assets reflect all assets not included in available ton-kilometres such as facilities, reservation systems and current assets.

Distexhe and Perelman (1994) used DEA to measure airlines' TE and productivity growth over the period 1977–1988 with an input-oriented model. The output and input indicators are a measure of market performance; the average weight load factors were used as output indicators while the average number of aircraft departures per 100,000 km was used as input indicators. Good *et al.* (1995) used the DEA model to examine the performance of 16 airlines between 1976 and 1986. They used load factor, stage length and a measure of network size as output indicators and the percentage of the fleet that was wide-bodied as well as the percentage of the fleet that used turbo-prop propulsion.

Scheraga (2004) compared the operational efficiency versus the financial mobility of 38 airlines between 1995 and 2000 with an input-oriented DEA model. He suggested the reason for choosing an input-oriented model is that the primary objective of the airline under evaluation is to gain efficiency by reducing excess inputs while continuing to operate with its current technology mix. He adopted similar inputs and outputs to Schefczyk (1993). The outputs included RPK and non-passenger RTK. The inputs included available ton-kilometres, operating costs and non-flight assets. Barbot *et al.* (2008) used the DEA model to analysis 49 carriers' efficiency in 2005. They applied the input-oriented BCC model (Banker *et al.*, 1984), using VRS. The input indicators included labour (number of core business workers), fleet (number of operated aircraft) and fuel (in gallons consumed), and the output indicators included available seat kilometres, RPK and RTKs.

Barros and Peypoch (2009) used DEA to evaluate the operational performance of a sample of the Association of European Airlines during 2000–2005. They used an output-oriented DEA model because it can determine whether an airline is capable of producing the same level of output with less input. In their study, the outputs were measured by two indicators: RPK and earnings before interest and taxes. The inputs had three indicators: number of employees, operational costs and number of aircraft. Coli *et al.* (2011) defined an input-oriented DEA model under the assumption of CRS. For the definition of inputs and outputs, two inputs were chosen: total seats and total variable direct operating costs. For the output, they only used one, which was passenger-scheduled revenue. Moreover, they also considered undesirable outputs in their model, including number of delayed flights.

The literature review suggests that there are no restrictions on choosing the indicators of inputs and outputs. It will depend on the nature of the study. To choose between the CRS model and VRS model, Golany and Roll (1989) suggested that CRS identifies the overall inefficiency, whereas VRS differentiates between TE and SE. Investigating and comparing the SE of individual airlines will provide a deep insight into the benefits of an alliance. When choosing between an input-oriented or output-oriented model, many studies in the literature do not specifically explain the reason. According to Coli *et al.* (2011), the choice of model orientation is based on considerations of the factors that are more easily controlled by DMU, for example if an airline is required to meet market demand and can freely adjust input usage, then the input-oriented model is appropriate.

As a result, this study will choose an input-oriented VRS in order to examine whether, after joining the alliance group, the airlines have improved their operational efficiency by using limited inputs to obtain maximum outputs. The study uses one output and three inputs. According to Dyson *et al.* (2001) there are four key assumptions that need to be considered when selecting the input and output variables for DEA: (i) the selected indicators need to cover the full range of resource used; (ii) capture all activity levels and performance measure; (iii) the indicators have to be common to all units; and (iv) capture environmental variation if necessary. The output for this study is total revenue, which refers to the financial value of all the services that an airline produces. The inputs for this study are total aircraft hours, total operational costs and total assets. Additionally, the DEA method requires that the minimum

number of DMU observations to be greater than three times the number of inputs plus outputs (Vassiloglou and Giokas, 1990; Dyson *et al.*, 2001; Raab and Lichty, 2002; Barros and Peypoch, 2009). In this case, there are 20 DMUs with data for 11 years, which totals 220 observations, and $220 \geq 3 \times (1 + 4)$, which satisfies the DEA requirement that the minimum number of units should be equal to or larger than three times the sum of outputs and inputs (Boussofiane and Dyson, 1991).

4.2.1.2 DEA Modelling

DEA is a mathematical model that measures the relative efficiency amongst a set of DMUs with multiple inputs and outputs. It does not need an *a priori* production function to specify how to aggregate the data observed. One of the strong points of DEA is its non-parametric character, which means that only the consumption values of the observed inputs and output production amounts are needed in order to assess the relative efficiencies of the DMU properly. By using inputs and outputs for all DMUs, it is possible to develop a production possibility set using certain assumptions, including the assumption that interpolated input–output combinations are feasible, that inefficiency input–output combinations can exist, and that output cannot be produced without any input. In DEA models, the relative efficiency of a DMU is equal to a weighted sum of outputs divided by the weighted sum of inputs.

The main purpose of DEA analysis is to project the inefficiency of DMUs onto the production frontiers. There are usually two ways to achieve that: the input-oriented model and the output-oriented model. The input-oriented model aims to reduce the amount of input by as much as possible while keeping at least the present level of output. In other words, with certain outputs, the TE of input will depend on the ratio of actual inputs and minimum inputs (Min θ). The output-oriented model maximises output levels from the present consumption of inputs. In other words, with certain inputs, the TE of output will depend on the ratio of actual output and maximum outputs.

Consider a set of n DMUs. For DMU k , let $y_{rk}(r = 1, \dots, s)$ denote the level of the r^{th} output, and let $x_{ik}(i = 1, \dots, m)$ be the level of the i^{th} input. To measure the efficiency of DMU k , one

finds the best weights for u_r , and v_i to maximise a ratio E_k , subject to a set of constraints. The model is formulated as follows:

$$\begin{aligned}
 \text{Max} \quad & E_k = \frac{\sum_{r=1}^s u_r y_{rk}}{\sum_{i=1}^m v_i x_{rk}}, & (4.4) \\
 \text{subject to} \quad & \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{rj}} \leq 1, \quad j = 1, \dots, n, \\
 & u_r, v_i \geq 0, \quad r = 1, \dots, s, i = 1, \dots, m.
 \end{aligned}$$

The set of constraints requires that the same weights, when applied to all DMUs, do not produce any unit with an efficiency score greater than 1. The value of E_k ranges from 0 to 1. A DMU with an E_k of 1 is considered relatively efficient, otherwise, it is relatively inefficient. As in the following equation:

$$\frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{rj}} \leq 1, \quad j = 1, \dots, n, \quad (4.4.1)$$

The efficiency ratio ranges from zero to one, with DMU k being considered relatively efficiency if it receives a score of one. Thus, each unit will choose weights so as to maximize self-efficiency, given the constraints.

There are two classic DEA models: (i) The CCR model, also known as CRS, which considers constant returns to scale, as proposed by Charnes *et al.* (1978), which uses proportionality between inputs and outputs. In detail, the CCR model uses the CRS concept to assess the relative productive efficiencies of DMUs with multiple inputs and outputs. The input-oriented CCR model seeks a minimum θ :

$$\begin{aligned}
& \text{Min } \theta, & (4.5) \\
\text{subject to } & \theta x_{ik} - \sum_{j=1}^n \lambda_j x_{ij} \geq 0, & i = 1, \dots, m, \\
& \sum_{j=1}^n \lambda_j y_{rj} \geq y_0, & r = 1, \dots, s, \\
& \lambda_j \geq 0, & j = 1, \dots, n.
\end{aligned}$$

where

The optimal θ , denoted by θ^* , satisfies $0 < \theta^* \leq 1$. If $\theta < \theta^* \leq 1$. If θ is equal to 1, the DMU under measurement is said to be technically efficient and lies on the efficiency frontier, which is composed of the set of efficient units. The observed data of inefficient units are said to be enveloped by the frontier.

The output-oriented CCR model seeks a maximum z :

$$\begin{aligned}
& \text{Max } z, & (4.6) \\
\text{subject to } & zx_{ik} - \sum_{j=1}^n \lambda_j x_{ij} \geq 0 \\
& \sum_{j=1}^n \lambda_j y_{rj} \geq zy_0 & r = 1, \dots, s, \\
& \lambda_j \geq 0, & j = 1, \dots, n.
\end{aligned}$$

The BCC model was developed from the CCR model. Originally, the CCR model assumed that DMUs have CRS to restrict the possible production set. Banker *et al.* (1984) extended the original CCR model to allow for a VRS model, so as to evaluate the TE and SE of DMUs.

The BCC model adds the convexity restriction ($\sum_{j=1}^n \lambda_j = 1$). The dual linear programming for of the BCC model is represented by:

$$\begin{aligned}
 & \text{Min } \theta, & (4.7) \\
 \text{subject to } & \theta x_{ik} - \sum_{j=1}^n \lambda_j x_{ij} \geq 0, \quad i = 1, \dots, m, \\
 & \sum_{j=1}^n \lambda_j y_{rj} \geq y_{rk}, \quad r = 1, \dots, s, \\
 & \sum_{j=1}^n \lambda_j = 1, \\
 & \lambda_j \geq 0, \quad j = 1, \dots, n.
 \end{aligned}$$

Similar to the TE in the CCR model, the objective value of the BCC model aims at pure technical efficiency (PTE). Compared to the CCR, imposing the additional constraint $\sum_{j=1}^n \lambda_j = 1$ causes the feasible region of the BCC to be a subset of the CCR, which means that the PTE is not less than the original TE. The PTE measures how a DMU utilises the resources under exogenous environments, and a low PTE implies that the DMU manages its resources ineffectively.

4.2.1.3 Scale Efficiencies and the MPI

After constructing the VRS model, the study also aims to obtain the SE and the nature of the returns to scale of individual airlines. Golany and Roll (1989) stated that VRS differentiates between TE and SE. VRS allows us to decompose TE into PTE and SE, where $SE = TE/PTE$. SE measures how the scale size affects the efficiency. Scale inefficiency is due to either increasing or decreasing returns to scale, which can be determined by using the input-oriented CRS model and checking the sum of $\sum_{j=1}^n \lambda_j$. If this sum is equal to 1, CRS prevails, while increasing or decreasing returns to scale prevail when the sum is smaller or larger than 1. Here, the scale inefficiency score only indicates whether VRS are present or not, but does not necessarily tell the direction of the returns.

Coelli (1996) demonstrated how to calculate the SE: decompose the TE scores obtained from a CRS DEA into two components to obtain scale inefficiency and pure technical inefficiency, which is the VRS result. If there is a difference between the two TE scores for a particular DMU, then it indicates that the DMU has scale inefficiency, and the scale inefficiency can be calculated from the ratio of the CRS TE score to the VRS TE score. Figure 4.1 illustrates the CRS and VRS frontiers for DMUs using one input and producing one output. The technical inefficiency for the point P is the distance PP_c under CRS while the measure is the distance PP_v under VRS. The difference between these two, $PcPv$, is put down to scale inefficiency. The efficiency measures can be expressed as the following ratios:

$$TE_{I, CRS} = AP_c/AP,$$

$$TE_{I, VRS} = AP_v/AP, \text{ and}$$

$$SE_I = APC/AP_v,$$

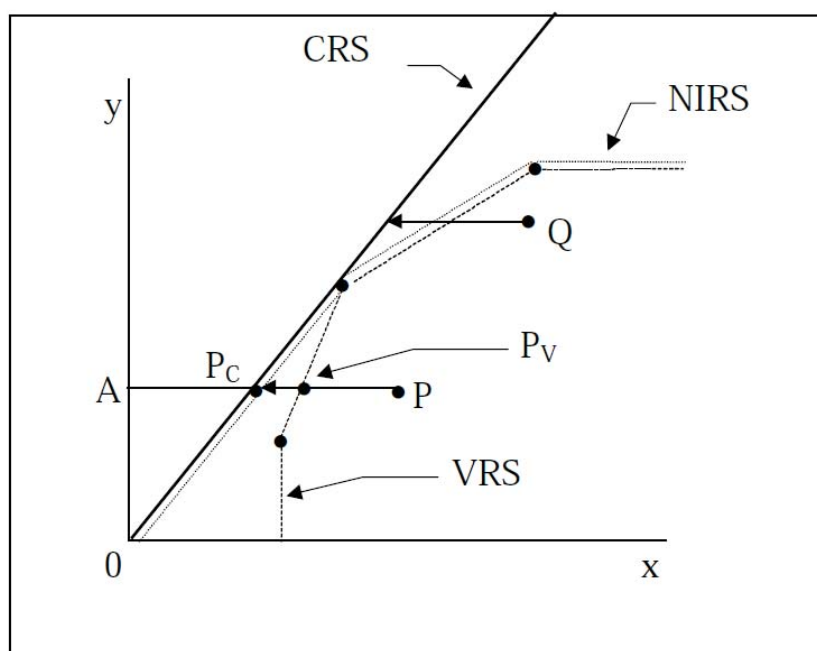
where all these measures are between 0 and 1. We also obtain the following model:

$$TE_{I, CRS} = TE_{I, VRS} * SE_I.$$

The CRS TE measure can therefore be decomposed into PTE and SE. However, there is a shortcoming in this SE measurement because the value cannot indicate whether the DMU is operating in an area of increasing or decreasing returns to scale. In order to do so, the non-increasing returns to scale restriction is imposed. This can be done by altering the DEA model:

$$\begin{aligned} & \text{Min } \theta, & (4.8) \\ \text{subject to } & \theta x_{ik} - \sum_{j=1}^n \lambda_j x_{ij} \geq 0, \quad i = 1, \dots, m, \\ & \sum_{j=1}^n \lambda_j y_{rj} \geq y_{rk}, \quad r = 1, \dots, s, \\ & \sum_{j=1}^n \lambda_j \leq 1, \\ & \lambda_j \geq 0, \quad j = 1, \dots, n. \end{aligned}$$

Figure 4.1: Calculations of Scale Economies in DEA by using CRS and VRS frontiers



Note: Sourced from Coelli (1996). NIRS, non-increasing returns to scale

Figure 4.1 also shows the non-increasing returns to scale DEA frontier. The nature of the scale inefficiencies caused by either increasing or decreasing returns to scale for a particular DMU can be determined by checking whether the non-increasing returns to scale TE score is equal to the VRS TE score. If the two scores are not equal, such as for the point P in Figure 4.1, then increasing returns to scale exists for that DMU. If they are equal, for example, for point Q , then decreasing returns to scale apply. If there is no difference between the two TE scores (CRS and VRS) for a particular DMU, it means this particular DMU operates at the most productive scale size (Coelli, 1996).

4.2.1.4 The Malmquist Productivity Index (MPI)

Färe *et al.* (1992) constructed the DEA-based MPI as the geometric mean of two MPIs as used by Cave *et al.* (1982). According to Chen and Ali (2004), assuming there is a production function in period t as well as in period $t+1$, the MPI calculation requires two single-period

and two mixed-period measures. The two single-period measures can be obtained by using the CCR DEA model (Charnes *et al.* 1978) as follows:

$$\begin{aligned}
 D_o^t(x_o^t, y_o^t) &= \min \theta, & (4.9) \\
 \text{s.t. } \sum_{j=1}^n \lambda_j x_{ij}^t &\leq \theta x_{io}^t, & i = 1, 2, \dots, m, \\
 \sum_{j=1}^n \lambda_j y_{rj}^t &\geq y_{ro}^t, & r = 1, 2, \dots, s, \\
 \lambda_j &\geq 0, & j = 1, 2, \dots, n,
 \end{aligned}$$

where x_{io}^t is the i^{th} input and y_{ro}^t is the r^{th} output for DMU_o in time period t . The efficiency measure ($D_o^t(x_o^t, y_o^t) = \theta_o^*$) determines the amount by which observed inputs can be proportionally reduced while still producing the given output level. Using $t + 1$ instead of t for the model, the equation obtained is $D_o^{t+1}(x_o^{t+1}, y_o^{t+1})$, the TE score for DMU_o in period $t + 1$. For the two mixed-period measures, which are defined as $D_o^t(x_o^{t+1}, y_o^{t+1})$ and $D_o^{t+1}(x_o^t, y_o^t)$ for each DMU_o, the measure is computed as the optimal value for the following linear programming problem:

$$\begin{aligned}
 \min \theta & & (4.10) \\
 \text{s.t. } \sum_{j=1}^n \lambda_j x_{ij}^t &\leq \theta x_{io}^t, & i = 1, 2, \dots, m, \\
 \sum_{j=1}^n \lambda_j y_{rj}^t &\geq y_{ro}^t, & r = 1, 2, \dots, s, \\
 \lambda_j &\geq 0, & j = 1, 2, \dots, n.
 \end{aligned}$$

The input-oriented MPI of Färe *et al.* (1992), which measures the productivity change of a particular DMU_o $o \in Q = \{1, 2, \dots, n\}$ in time $t + 1$ and t is given as:

$$Mo = \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^t, y_o^t)} \right]^{1/2} \quad (4.11)$$

It can be seen that the above measure actually is the geometric mean of two MPIs as used by Caves *et al.* (1982). Thus, following Caves *et al.* (1982), Färe *et al.* (1992) stated that $Mo > 1$ indicates a productivity gain while $Mo < 1$ indicates a productivity loss; $Mo = 1$ means no change in productivity from time t to $t + 1$.

The MPI can be decomposed into two components, one measuring the change in efficiency and the other measuring the change in the frontier technology (Färe *et al.*, 1992). This is set out in the following equation:

$$\begin{aligned} Mo &= \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^t, y_o^t)} \right]^{1/2} \\ &= \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} \frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} \right]^{1/2} \end{aligned} \quad (4.12)$$

where the first component, $\frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)}$, measures the change in TE and the second component, $\left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} \frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} \right]^{1/2}$, measures the technology frontier shift between time t and $t + 1$. If the value of the technology frontier is greater than 1, this indicates a positive shift or technical progress. If the value of the technology frontier is less than 1, this indicates a negative shift or technical regression. If the value of the technology frontier is equal to 1, this means no shift in the technology frontier has taken place.

Based on the calculations above, the total productivity changes in a period of time can be expressed as the following equation:

$$\text{Productivity change (MPI)} = \text{TE change} \times \text{Technological Changes.} \quad (4.13)$$

Färe *et al.* (1994a, b) further decompose productivity changes to include SE and other congestion components. Therefore, productivity changes (MPI) can be decomposed as shown in the following equation:

$$\text{Productivity change (MPI)} = \text{SE change} \times \text{management efficiency change} \times \text{technological changes.} \quad (4.14)$$

By evaluating the productivity elements, one can find out the main reason for a drop in a firm's productivity: production activities of an inappropriate size and a limited productivity scale, the inefficiency of managerial decisions, or lack of technological advancements and the nonexistence of necessary investments (Mohammadi and Ranaei, 2011).

4.2.2 Stochastic Frontier Analysis (SFA)

4.2.2.1 Introduction to SFA

SFA originally comes from the deterministic production frontier models proposed by Aigner and Chu (1968). They used the Cobb–Douglas production function and argued that, within a given industry, firms might differ from each other in their production processes, because of certain technical parameters in the industry, differences in their scale of operation or because of organisational structures. Under this assumption, they considered a Cobb–Douglas production function, with an empirical frontier production model as follows:

$$q_{it} \leq f(x_{it}) \quad (4.15)$$

where i denotes the subject, and t denotes the time.

Equation 4.15 defines a production relationship between inputs (x) and output (q_{it}), where for a given x , the observed value of q_{it} must be less than or equal to $f(x_{it})$. Since the theoretical production function is an ideal (the frontier of efficient production), any non-zero disturbance is considered to be the result of inefficiency, which must have a negative effect on the production function:

$$q_{it} = f(x_{it}) - u_{it}, i = 1, 2, 3, 4 \dots, I, t = 1, \dots, N. \quad (4.16)$$

Taking natural logarithms, the model becomes:

$$\ln q_{it} = \beta_0 + \ln x_{it}\beta - u_{it}, \quad (4.17)$$

where:

- $\ln q_{it}$ is the natural logarithm of the output of the i^{th} firm;
- $\ln x_{it}$ is the natural logarithm of inputs;
- β is a column vector of the unknown parameters to be estimated;
- u_{it} is a non-negative random variable associated with technical inefficiency, representing the shortfall of actual output from its maximum possible value;

TE for the i^{th} firm is defined as the ratio of the observed output for the i^{th} firm relative to the potential output (frontier function):

$$\begin{aligned} TE_{it} &= \frac{\text{observed output}}{\text{potential maximum output}} = \frac{q_{it}}{\exp(x_{it}\beta)} \\ &= \frac{\exp(x_{it}\beta - u_{it})}{\exp(x_{it}\beta)} = \exp(-u_{it}), 0 \leq TE_{it} \leq 1. \end{aligned} \quad (4.18a)$$

and:

$$u_{it} = \ln (TE_{it}). \quad (4.18b)$$

TE values are always between zero and one. $TE_{it} = 1$ shows that production is fully efficient and, correspondingly, the observed output q_{it} is maximum.

$TE_{it} < 1$ provides a measure of the shortfall of the observed output from maximum feasible output, where the following hold:

$$TE_{it} = \exp (-u_{it}), 0 \leq TE_{it} \leq 1, \quad (4.19)$$

which will ensure that the observed output lies below the frontier. In short:

$$q_{it} \leq f (x_{it}\beta) \quad (4.20)$$

Nevertheless, in this case, the model is deterministic and all deviations from the frontier are assumed to be the result of technical inefficiency and no account is taken of any measurement errors (such as errors associated with the choice of functional form) or any statistical noise (such as the omission of relevant variables from the vector x_{it}). Because of these problems, the deterministic production frontier model has been extended later on.

Building on Farrell's (1957) theory of efficiency measurement, Aigner *et al.* (1977) and Meusen and van Den Broeck (1977) independently constructed an error structure for SFA to measure the productivity efficiency of a firm. They proposed a model to account not only for technical inefficiency, but also for any measurement errors or any statistical noise. They developed a statistically and theoretically sound method for measuring efficiency. The main difference of the new model is that it allows random events to contribute to variations in producer output. Under the new theoretical frame, efficiency deviations from the production

function could arise from two sources: (a) productive inefficiency, which would necessarily be negative, and (b) effects specific to a firm, which could be of either sign. Thus, the new model introduced another random variable representing any statistical noise or measurement errors. In order to capture this, the stochastic model includes a composite error term including: (a) a two-sided error term, measuring all effects outside the firm's control, and (b) a one-sided non-negative error term, measuring technical inefficiency. The resulting frontier is presented in terms of a general production function, known as a "stochastic production frontier". The composite error structure is:

$$\epsilon_{it} = v_{it} - u_{it} \quad (4.21)$$

where the observed response ϵ_{it} is the composite error, v_{it} is the statistical noise and $-u_{it}$ is the technical inefficiency. A normal production frontier model without random components can be written as:

$$y_i = f(x_{it}; \beta) \cdot TE_{it}, \quad (4.22)$$

where y_{it} is the observed scalar output of the producer i , $i = 1, \dots, I$, in period t , $t = 1, \dots, T$; x_{it} is a vector of N inputs used by producer i in period t ; $f(x_i, \beta)$ is the production frontier and β is a vector of the technology parameters to be estimated.

TE_{it} denotes the TE defined as the ratio of observed output to maximum feasible output. $TE_{it} = 1$ shows that the i^{th} firm in production year t obtains the maximum feasible output, while $TE_{it} < 1$ provides a measure of the shortfall of the observed output from the maximum feasible output.

A stochastic component that describes random shocks affecting the production process is added. These shocks are not directly attributable to the producer or the underlying technology. These shocks could be anything from weather changes, economic adversity or

plain luck. We denote these effects by using $\exp \{v_{it}\}$. Each producer faces a different shock, but we assume that the shocks are random and they are described by a common distribution.

The stochastic production frontier will become:

$$y_{it} = f(x_{it}; \beta) \cdot TE_{it} \cdot \exp \{v_{it}\} \quad (4.23)$$

We assume that TE_{it} is also a stochastic variable, with a specific distribution function, common to all producers.

We can also write it as an exponential $TE_i = \exp \{-u_{it}\}$, where $u_{it} \geq 0$, since we require $TE_{it} \leq 1$. Thus, we obtain the following equation:

$$y_{it} = f(x_{it}; \beta) \cdot \exp \{-u_{it}\} \cdot \exp \{v_{it}\} \quad (4.24)$$

Thus, if we consider $f(x_{it}; \beta)$ in the normal regression function form, the model can be written as:

$$y_{it} = x_{it}\beta + (v_{it} - u_{it}), \quad i = 1, \dots, N; \quad t = 1, \dots, T. \quad (4.25)$$

Coelli *et al.* (2005) used the Cobb–Douglas function to explain the stochastic frontier model further. The Cobb–Douglas function production can be written as:

$$\ln q_{it} = \beta_0 + \beta_1 \ln x_{it} - u_{it} \quad (4.26)$$

For the stochastic frontier model, the equation takes the following form:

$$\ln q_{it} = \beta_0 + \beta_1 \ln x_{it} + v_{it} - u_{it}, \quad (4.27a)$$

or:

$$q_{it} = \exp(\beta_0 + \beta_1 \ln x_{it} + v_{it} - u_{it}), \quad (4.27b)$$

or:

$$q_{it} = \exp(\beta_0 + \beta_1 \ln x_{it}) \times \exp(v_{it}) \times \exp(-u_{it}) \quad (4.27c)$$

where $\exp(\beta_0 + \beta_1 \ln x_{it})$ is the deterministic component, $\exp(v_{it})$ is the statistical noise and $\exp(-u_{it})$ is the technical inefficiency.

The model equation can be rewritten as:

$$q_{it} = f(x_{it} \beta) \times \exp(v_{it} - u_{it}), u_{it} \geq 0. \quad (4.28)$$

As stated above, u_{it} represents the shortfall of the output from the frontier. The composite error structure is:

$$\epsilon_{it} = v_{it} - u_{it}. \quad (4.29)$$

The stochastic econometric approach enables us to attempt to distinguish the effects of noise and inefficiency, thereby providing the basis for statistical inference. The noise component v_{it} is assumed to be independently and identically distributed, symmetric and distributed independently of u_{it} . For the stochastic frontier model, the composite error term of the

function is made up of two independent components: (a) a two-sided random term v_{it} , and (b) a one-sided positive error term u_{it} . The component v_{it} represents measurement errors, and left out explanatory variables that cannot be controlled by production units. On the other hand, the component u_{it} represents the shortfall from the production frontier due to inefficiency, which may be a result of cultural factors, such as attitudes towards work; climatic factors such as different seasons; or traditions such as religious holidays. In this case, it will particularly refer to alliance-related factors.

4.2.2.2 Problems in Stochastic Frontier Modelling

With regards to SFA modelling, the first problem is choosing an appropriate functional form to represent the production effort. In the literature, there are two main models that have been applied, which are the Cobb–Douglas and the trans-log production function. For example, Cornwell *et al.* (1990) assumes Cobb–Douglas technology for their frontier model. Battese and Coelli (1995) used a linearized version of the logarithm of the Cobb–Douglas production of function. Good *et al.* (1995) also adopted the Cobb–Douglas functional form in their approach. Coli *et al.* (2011) specified the stochastic frontier production function as a Cobb–Douglas function for analysing the efficiency of Italian airlines domestic routes. On the other hand, Lin and Tseng (2005) applied SFA models of both the Cobb–Douglas and trans-log production functions with truncated normal distribution. Garcia del Hoyo *et al.* (2004) chose a flexible trans-log functional form in their study and stated the reason for this was because it represents a second-order approximation of any arbitrarily chosen function as well as being theoretically possible (Berndt and Christensen, 1973). Baten *et al.* (2009) tested both the trans-log production function and the Cobb–Douglas production function in SFA modelling and preferred the trans-log production function. Baten *et al.* (2010) confirmed the result that the trans-log production function in the stochastic frontier approach is preferred compared to the Cobb–Douglas production function. In this study, the SFA modelling will adopt both the Cobb–Douglas and the trans-log production functions for measuring airlines’ operational efficiency and will compare the results of these two functions.

The second problem the SFA method faces is the choice of the appropriate inputs and outputs. Similar to the DEA approach, the SFA method requires the selection of different inputs and outputs, as well as a way of accounting for different environmental variables. In previous studies, different outputs and inputs were chosen to analyse airline efficiency. Good *et al.* (1995) used aggregated revenue outputs including passenger service, cargo service and incidental services, while inputs included labour, energy and other materials, and aircraft fleet. They took into account the stage length, load factor, network size, percentage of wide-body aircraft and percentage of turbo-prop aircraft as the environmental variables. In their SFA model, Coelli *et al.* (1999) used one output measure and two input measures, which are labour and capital. The labour input is an aggregate of two separate categories of employment used in the production of air travel, while capital input is the sum of the maximum takeoff weights of all aircraft multiplied by the number of days the aircraft have been able to operate during a year. Coli *et al.* (2011) chose three inputs for producing one output. The inputs included total seats, total variable direct operating costs and number of delayed flights. The output was passenger-scheduled revenue. They considered three alternative model formulations by employing three different distributional assumptions for the one-sided inefficiency term: the original half-normal formulation, the exponential distribution and the truncated normal distribution. Since there is no mandatory provision about which inputs and outputs should be used for measuring efficiency, this research will choose three inputs and one output for SFA. The inputs are aircraft hours, total operational cost and total assets while the output is the total revenue.

4.2.2.3 Stochastic Frontier and Technical Inefficiency Effects Model

The following subsection specifies the stochastic frontier production function using the Cobb–Douglas function and trans-log production function with three inputs producing one output. The data were collected from the ICAO database and supplemented with airline annual reports. The study concerned 20 airlines covering the period 1995–2005. The input variables, output variable and alliance factors are described below:

Total Revenue

Total Revenue is the measurement of an airline's operational results. It represents the revenue (sold) capacity of passengers and cargo. In this analysis, Total Revenue (output, (Y_{it})) is a dependent variable.

Aircraft Hour

Aircraft hour (*Aircraft*) is the accumulated time from the moment the aircraft is pushed back from the gate to the moment it comes to a final stop at the destination gate. The longer the aircraft flights, the more passenger and cargo revenue airlines can obtain. However, aircraft hours also relate to airlines' operational costs, since fuel consumption and crew costs are highly dependent on this measurement.

Total operational costs

Total operational cost (*Cost*) is the gross expenditure of an airline in a complete financial year. It will represent one of the inputs of that airline.

Total assets

Total assets (*Assets*) are the gross assets including the fixed and current assets of an airline.

The SFA model also includes the explanatory variables for technical inefficiency. In this case, the explanatory variables include airline stage length, load factors, proportion of passenger revenue and alliance-related variables.

Stage length

Stage length (*SL*) is defined as the ratio of total aircraft kilometres flown to the total number of aircraft departures, which measures the airline's network size.

Load factors (LF)

Load factors (*LF*) are defined as the ratio of performed tonne-kilometres to available tonne-kilometres, and is considered to be a measure of market demand.

Proportion of passenger business

Proportion of passenger business (*PP*) is the ratio of revenue from passenger service to the total revenue. Airlines focus either on passenger service or freight service. The more an airline invests in one part, the more the other part of operation will be affected.

Number of members

The number of members in an alliance (*Member*) is used as an influencing variable in this study.

Membership duration

Duration of membership in an alliance (*Duration*) is also used as an influencing variable in this study. It is a measure of the number of years that each airline has participated in the alliance group in a given year. This variable was coded 0 when the airline was not in the

alliance group, 1 when the airline had been a member of the alliance for one year, 2 when the airline had been a member of the alliance for two years and so on.

4.2.2.4 The Functional Form of the Stochastic Frontier Cobb–Douglas Production Model

In particular, the deterministic core of the Cobb–Douglas production frontiers is specified as follows:

$$\ln (Y_{it}) = \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + V_{it} - U_{it}, \quad (4.30)$$

where the subscripts i and t represent the i^{th} airline and the t^{th} year of observation, respectively; $i = 1, 2, \dots, 20$; $t = 1, 2, \dots, 11$; Y_{it} denotes the output variable of the i^{th} airline in the t^{th} period; X_{1it} , X_{2it} and X_{3it} are the input variables; “ \ln ” refers to the natural logarithm; β_i is the unknown parameter to be estimated; V_{it} is assumed to be $N(0, \sigma_v^2)$ random errors, independently distributed from U_{it} ; U_{it} represents the non-positive random variables associated with the technical inefficiency of production, which are assumed to be independently distributed and follows a truncation at zero of the distribution of $N(\mu, \sigma_u^2)$.

The estimated inefficiency of the airline industry is considered as a function of some explanatory variables and inefficiency effects. The model is defined as:

$$U_{it} = \delta_0 + \sum_{j=1}^n \delta_j Z_{jit} + W_{it}, \quad (4.31)$$

where δ_0 is the intercept term and δ_j ($j = 1, 2, \dots, n$) is the parameter for the j^{th} explanatory variable. Z_j is the explanatory variable for airline inefficiency and W_{it} represents the random errors of the equation.

Thus, in detail, the empirical frontier Cobb–Douglas production function is specified as follows:

$$\begin{aligned} \ln(Y_{it}) = & \beta_0 + \beta_1 \ln(\text{Aircraft})_{it} + \beta_2 \ln(\text{Cost})_{it} \\ & + \beta_3 \ln(\text{Assets})_{it} + V_{it} - U_{it} \end{aligned} \quad (4.32)$$

The technical inefficiency effects are assumed to be defined by:

$$\begin{aligned} U_{it} = & \delta_0 + \delta_1(SL_{it}) + \delta_2(LF_{it}) + \delta_3(PP_{it}) + \delta_4(\text{Duration}_{it}) \\ & + \delta_5(\text{Numbers}_{it}) + \delta_6(\text{Duration}_{it})^2 + \delta_7(\text{Numbers}_{it})^2 + W_{it} \end{aligned} \quad (4.33)$$

where SL_{it} represents the stage length of the airline i in year t ; LF_{it} represents the total load factors for airline i in year t ; PP_{it} represents the proportion of passenger services, which is the ratio of revenue from passenger service to the total revenue for airline i in year t ; Duration_{it} is airline i 's alliance membership duration in year t and Numbers_{it} is the number of airlines in the alliance group for airline i in year t .

4.2.2.5 The Functional Form of the Stochastic Frontier Trans-log Production Function Model

The stochastic frontier production function is specified as a trans-log production model with three inputs producing one output. The functional form of the stochastic frontier trans-log production model is defined as:

$$\begin{aligned}
\ln(Y_{it}) = & \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_{12} \ln X_{1it} \ln X_{2it} + \beta_{13} \ln X_{3it} \ln X_{1it} \\
& + \beta_3 \ln X_{3it} + \frac{1}{2} (\beta_{11} \ln X_{1it}^2 + \beta_{22} \ln X_{2it}^2 + \beta_{33} \ln X_{3it}^2) \\
& + \beta_{23} \ln X_{3it} \ln X_{2it} + V_{it} - U_{it},
\end{aligned} \tag{4.34}$$

where the subscripts i and t represent the i^{th} airline and the t^{th} year of observation, respectively; $i = 1, 2, \dots, 21$; $t = 1, 2, \dots, 11$; Y_{it} denotes the output variable of the i^{th} airline in the t^{th} period; X_{1it} , X_{2it} and X_{3it} are the input variables; \ln refers to the natural logarithm; β_i is the unknown parameter to be estimated; V_{it} s represents $N(0, \sigma_v^2)$ random errors, independently distributed from U_{it} s; U_{it} s represents the non-positive random variables, associated with technical inefficiency of production, which are assumed to be independently distributed and to follow a truncation at zero of the distribution of $N(\mu, \sigma_u^2)$.

Thus, in detail, the empirical frontier model of the trans-log production function is as follows:

$$\begin{aligned}
\ln(Y_{it}) = & \beta_0 + \beta_1 \ln(\text{Aircraft})_{it} + \beta_2 \ln(\text{Cost})_{it} + \beta_{12} \ln(\text{Aircraft})_{it} \ln(\text{Cost})_{it} \\
& + \beta_{13} \ln(\text{Aircraft})_{it} \ln(\text{Assets})_{it} + \beta_3 \ln(\text{Assets})_{it} \\
& + \frac{1}{2} (\beta_{11} \ln(\text{Aircraft})_{it}^2 + \beta_{22} \ln(\text{Cost})_{it}^2 + \beta_{33} \ln(\text{Assets})_{it}^2) \\
& + \beta_{23} \ln(\text{Assets})_{it} \ln(\text{Cost})_{it} + V_{it} - U_{it}
\end{aligned} \tag{4.35}$$

where *Aircraft* is the number of flights an airline operates in a year, *Cost* represents the total operational cost and *Assets* represents the total assets of an airline.

The inefficiency function will be the same as that for the Cobb–Douglas function:

$$U_{it} = \delta_0 + \sum_{j=1}^n \delta_j Z_{jit} + W_{it}, \tag{4.36}$$

where δ_0 is the intercept term and δ_j ($j = 1, 2, \dots, n$) is the parameter for the j^{th} explanatory variable (Z_j) for airline inefficiency and W_{it} represents the random errors of the equation.

Thus, the technical inefficiency effects are assumed to be defined as:

$$U_{it} = \delta_0 + \delta_1(SL_{it}) + \delta_2(LF_{it}) + \delta_3(PP_{it}) + \delta_4(\text{Duration}_{it}) + \delta_5(\text{Numbers}_{it}) + \delta_6(\text{Duration}_{it})^2 + \delta_7(\text{Numbers}_{it})^2 + W_{it} \quad (4.37)$$

where SL_{it} represents the stage length of airline i in year t ; LF_{it} represents the total load factors for airline i in year t ; PP_{it} represents the proportion of passenger service, which is the ratio of revenue from passenger service to the total revenue for airline i in year t ; Duration_{it} is the airline i 's alliance membership duration in year t and Numbers_{it} is the number of airlines in the alliance group for airline i in year t .

4.2.3 Panel Regression Analysis (PRA)

4.2.3.1 Introduction to PRA

Panel regression analysis (PRA) is a statistical method that deals with two-dimensional panel data, which are collated over time and with the same individuals, and it runs a regression over these two dimensions (Maddala, 2001). Panel data refer to the pooling of observations on a cross-section of sites, countries or individuals over several periods (Baltagi, 1995). The panel data regression models are becoming increasingly popular in applications because each individual cross-sectional unit is observed over time and, consequently, individual heterogeneity can be accounted for (Aquaro and Čížek, 2013). PRA possesses several advantages over either cross-sectional or time-series analysis. For instance, a study adopting the panel data technique can control individual heterogeneity, giving more data points, increasing degrees of freedom and reducing problems created by data multicollinearity. It

also makes it easier to identify economic models and discriminate between competing economic hypotheses. Panel data analysis can reduce estimation bias and provide micro-foundations for aggregated data analysis (Baltagi, 1995; Hsiao, 2003). It provides a more precise analysis than multiple regressions because it resolves the problem of omitted variables.

A basic panel data regression model can be expressed as follows:

$$y_{it} = \beta_0 + \beta_{it}x_{it} + \epsilon_i \quad i = 1, \dots, N; t = 1, \dots, T, \quad (4.38)$$

where y is the dependent variable, x is the independent variable, β_0 and β_{it} are the coefficients, i denotes the cross-sectional dimension, and t denotes the time-series dimension. ϵ_i is the error term for individual-specific time-invariant effects. The interpretation of this equation causally implies that an increase or decrease in x_{it} , y_{it} will accordingly increase or decrease by an amount represented by the coefficient β . The error term ϵ_i represents the unobserved factors that affect the dependent variables.

The error term ϵ_i will determine whether the model will be a fixed effects model or a random effects model. In a fixed effects model, ϵ_i is assumed to vary non-stochastically over i or t , making the fixed effects model analogous to a dummy variable model, and ϵ_{it} becomes two error terms, α_i and u_{it} , as follows:

$$\epsilon_{it} = \alpha_i + u_{it}. \quad (4.39)$$

Thus, a fixed effects model can be presented as the following:

$$y_{it} = \beta_0 + \beta_{it}x_{it} + \alpha_i + u_{it} \quad i = 1, \dots, N; t = 1, \dots, T, \quad (4.40)$$

where α_i captures all unobserved time-constant factors that affect y_{it} , and the error term u_{it} is the idiosyncratic error or time-varying error which represents unobserved factors that change over time and affect y_{it} .

For a random effects model, it is assumed that α_i is uncorrelated with each explanatory variable in all periods. Thus, the unobserved effects can be redefined as the composite error term:

$$v_{it} = \alpha_i + u_{it}, \quad (4.41)$$

where v_{it} is the composite error, α_i is the unobserved effects that are uncorrelated with all explanatory variables and u_{it} is the idiosyncratic error.

Thus, the random effects model could be written as:

$$y_{it} = \beta_0 + \beta_{it}x_{it} + v_{it}, \quad i = 1, \dots, N; t = 1, \dots, T, \quad (4.42)$$

where $v_{it} = \alpha_i + u_{it}$ represents a composite error term.

To choose between random effects and fixed effects, Wooldridge (2009) stated that fixed effects allow an arbitrary correlation between unobserved effects and explanatory variables, while random effects does not. Fixed effects are widely thought to be a more convincing tool for estimating effects *ceteris paribus*. This study has chosen a fixed effects model for PRA for the following reasons. Firstly, by using a fixed effects model, there will be a variable to capture all unobserved effects and the time-constant factors that affect the dependent variable, and this variable will be found over time. In this case, the variable represents all factors affecting airline performance that do not change over time. For instance, the geographical features of an airline main hub and the local demographic features of the population will be

included in this variable. Secondly, the alternative regression model is a random effects model that requires the assumption that the unobserved effect is uncorrelated with each explanatory variable. But in this study it is believed the unobserved effects have some correlation with the explanatory variables. More objectively, the research ran a Hausman test to help to choose between random effect and fixed effect. The null of random effect was rejected and satisfies the fixed effect at the 5% significance level

4.2.3.2 The Regression Model

In this PRA, the purpose is to find determinates from the alliance group effects that contribute to airline productivity and profitability. As stated before, this analysis concentrates on 20 airlines from the selected sample during the period of 1995–2005. Thus the dependent variable is the airline's productivity or profitability. Airline productivity is constructed by dividing the aggregated outputs by the aggregated inputs to form productivity indices (see Equations 4.1 and 4.2) and airline profitability is constructed by dividing total revenue by total input costs to form profitability indices. The study has chosen three independent variables to establish the relation between alliance effects and airline productivity/profitability. They are explained briefly below.

First, the analysis has the alliance group status variable, *Allied*, which reflects whether an airline has joined an airline strategic alliance group during the year under examination. Second, the study has two alliance-related variables, which are *Alnmb* and *Length*. *Alnmb* reflects the number of members in a particular alliance group in a given year. As the alliance groups gradually expanded over the period of this study, the number of members continually increased. *Length* reflects the duration that each airline has participated in the alliance group in a given year. Beside these independent variables, the study also introduced some control variables in order to explain the variations in how the productivity/profitability has changed. These include firm size (*Size*), which controls the potential impact of an airline's size, as airline performance may be affected by the size of the airline. The study controls for the number of aircraft departures of each airline, *Flights*, which represents the total number of flights that the airline operated during a certain period. The passenger load factor (*Plfac*) is an important indicator of airline performance that is also controlled for in this study. The study

controlled for the changes in business firm composition, the revenue share from freight operation (RS_{frgt}) and the revenue share from incidental revenue (RS_{irev}). This panel regression also will introduce dummy variables to refer to year effects to capture the unexpected factors that may have an impact on airline operations during the sample period.

There are only a few studies relating to changes in airline productivity and profitability based on whether airlines have joined an alliance. In order to investigate the cause-effects relationship, the estimation of the effects an alliance group has on airline productivity and profitability has been established as follows:

$$PI_{i,t} = f(Allied_{it}; Alnmb_{it}; Length_{i,t}; X_{it}) \quad (4.43)$$

where $PI_{i,t}$ represents the productivity or profitability indices of airline i ; $Allied_{it}$ is the airline alliance group status, which shows whether airline i has joined an airline alliance group, $Alnmb_{i,t}$ is the number of airlines in the alliance group and $Length_{i,t}$ is the duration of airline i 's alliance membership. X_{it} is a set of control variables containing additional information on the factors that affect airline productivity and profitability.

The panel regression model generally follows Oum *et al.* (2004), but it is applied to analyse the effects of joining an airline alliance group rather than individual bilateral agreements. The final form of the estimation model is:

$$PI_{it} = \alpha_0 + \gamma Allied_{it} + \delta Alnmb_{it} + \rho Length_{it} + \beta_1 Size + \beta_2 Flights \\ + \beta_3 Plfac + \beta_4 Rspax + \beta_4 RSirev + \sum_{j=2}^T \partial_j DV_{it} + a_i + u_{it}, \quad (4.44)$$

where PI_{it} represent the dependent variable of airline i and year t ; α_0 is the constant variable of the equation; γ , δ and ρ are the coefficient of three independent variables; $Size$ represents the size of the airline, which is measured by total assets through the year; $Flights$ represents

the total number of flights the airline operated during a certain period; $Plfac$ refers to passenger load factors; $RSpax$ and $RSirev$ refer to the percentage share of passenger and incidental revenue of the total revenue, respectively; $\sum_{j=2}^T \theta_j DV_{it}$ refers to the dummy variables for the year effects; a_i is the unobserved effect term and u_{it} is an idiosyncratic error term.

5 Results and Analysis

5.1 Data Envelopment Analysis (DEA) Results

5.1.1 General DEA Results

The DEA results and interpretations consist of three main parts and are presented in the following section. The first part presents the constant returns to scale (CRS) technical efficiency (TE) scores and an interpretation of individual airlines across the sample period. The second part includes the SE and the nature of the returns to scale of individual airlines within the sample period. The third part mainly concerns the Malmquist productivity index (MPI), which indicates the change in productivity compared to the previous year, and also the subdivisions of productivity change, indicating the reasons for this change. When interpreting the results, it should be noted that the DEA model provides results that only describe the relative efficiency of airlines in the pool. This efficiency index only indicates airline efficiency relative to other airlines rather than absolute values. Therefore, conclusions can only be drawn with regards to changes in maximum efficiency rather than the actual changes in efficiency for individual airlines. Moreover, it is very important to understand that the DEA model does not provide any evidence as to why an airline becomes efficient or not. However, it can provide a general overview of the efficiency of a particular group of airlines, e.g. the airlines that have joined an alliance group.

The first part of the results presents the efficiency scores of individual airlines. The DEA analysis has adopted the CRS input-oriented model, using the DEA software DEAP. The estimated TE indices of individual airlines for each year are reported in Table 5.1. The TE results are very straightforward. There are 20 airlines with 11 consecutive years of data (1995–2005) in this study. In Table 5.1, the year an airline joined an alliance is indicated in parentheses after its name; non-allied airlines do not have dates beside their names. The scores appearing in shaded cells in the table are for years when the airlines were members of

Table 5.1: Airline Constant Returns to Scale Technical Efficiency (CRS-TE) Scores d

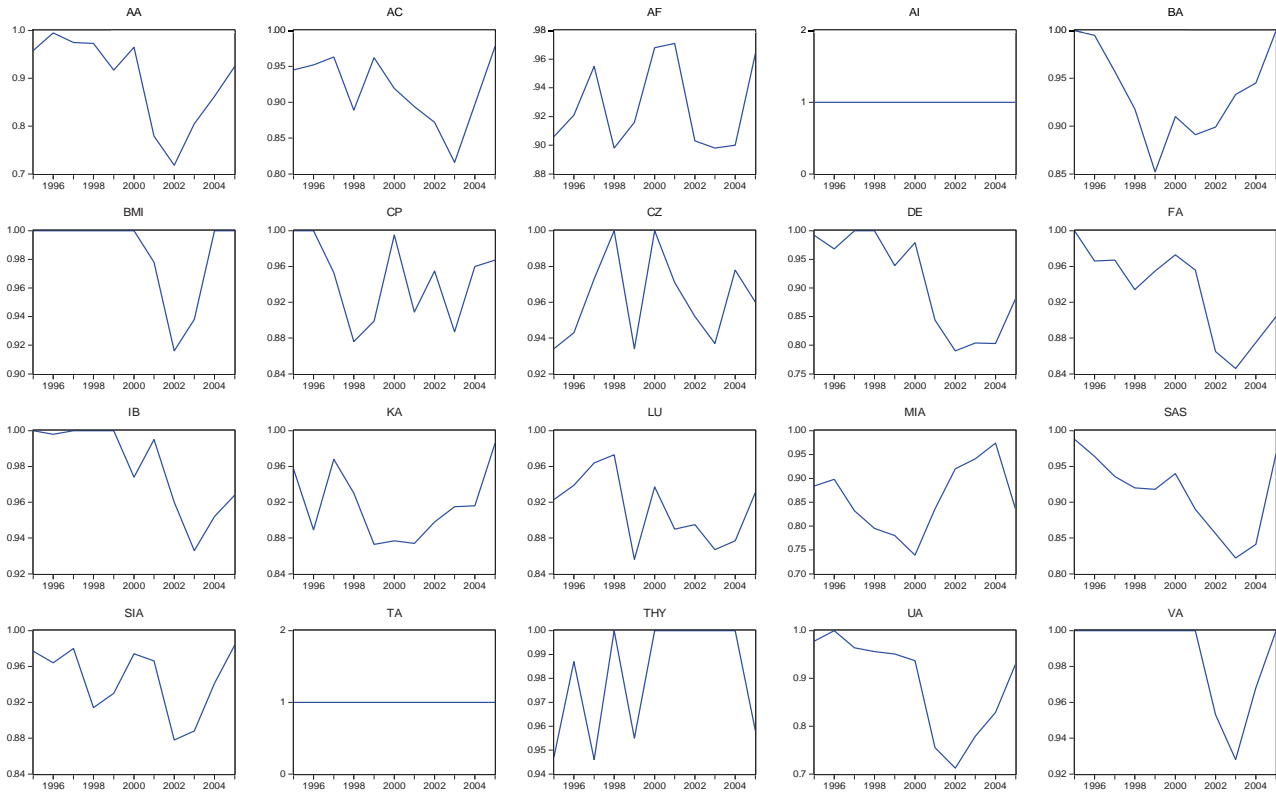
Airline/ Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
AC (1997)	0.945	0.952	0.963	0.889	0.962	0.919	0.894	0.872	0.816
LU (1997)	0.923	0.939	0.964	0.973	0.856	0.937	0.890	0.895	0.867
SAS (1997)	0.988	0.964	0.936	0.920	0.918	0.940	0.890	0.856	0.822
TA (1997)	1	1	1	1	1	1	1	1	1
UA (1997)	0.978	1	0.964	0.956	0.951	0.937	0.755	0.712	0.779
AA (1999)	0.958	0.995	0.975	0.973	0.917	0.965	0.779	0.718	0.805
BA(1999)	1	0.995	0.957	0.918	0.852	0.910	0.891	0.899	0.933
CP (1999)	1	1.000	0.953	0.876	0.899	0.995	0.909	0.955	0.887
IB (1999)	1	0.998	1	1	1	0.974	0.995	0.960	0.933
FA (1999)	1	0.966	0.967	0.934	0.955	0.973	0.956	0.865	0.846
SIA (2000)	0.977	0.964	0.980	0.914	0.930	0.974	0.966	0.878	0.888
BMI (2000)	1	1	1	1	1	1	0.978	0.916	0.938
AF (2000)	0.906	0.921	0.955	0.898	0.916	0.968	0.971	0.903	0.898
DE (2000)	0.992	0.968	1	1	0.939	0.979	0.844	0.790	0.804
KA (2000)	0.957	0.889	0.968	0.930	0.873	0.877	0.874	0.898	0.915
CZ (2001)	0.934	0.943	0.973	1	0.934	1	0.971	0.952	0.937
THY	0.947	0.987	0.946	1	0.955	1	1	1	1
MA	0.884	0.898	0.832	0.795	0.780	0.739	0.836	0.920	0.941
VA	1	1	1	1	1	1	1	0.953	0.928
AI	1	1	1	1	1	1	1	1	1
Average	0.969	0.969	0.967	0.949	0.932	0.954	0.920	0.897	0.897

Note: A score of 1 = 1.000. AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

an alliance. For example, in 1995, the relatively efficient airlines were Thai Airways, United Airlines, British Airways, Cathay Pacific, Finnair, British Midland International, Virgin Atlantic Airways and Air India, because they all had a TE score of 1.00. The rest of the airlines were deemed to be technically inefficient. The lower the score, the more inefficient the airline is deemed to be.

From the airline TE scores, it can be seen that there were two airlines that achieved maximum efficiency every year of the research period (1995–2005): Thai Airways and Air India. Among the airlines that did not achieve consistent maximum efficiency, Virgin Atlantic Airways and British Midland International came close, achieving maximum efficiency for 8 out of 11 years. Turkish Airlines achieved maximum efficiency for 6 out of 11 years. The other airlines (British Airways, Iberia Lineas and Czech Airlines) achieved 2–4 years of maximum efficiency. There are some airlines within the group that achieved only one year of maximum efficiency or never achieved maximum efficiency at all. United Airlines, Cathay Pacific and Finnair had only one year of maximum efficiency, while Air Canada, Scandinavian Airlines, Lufthansa, American Airlines, Singapore Airlines, Air France, Korean Airlines and Malaysia Airlines never achieved maximum efficiency during the sample period. Figure 5.1 shows graphs of the time series of individual airlines' TE estimations, providing a more direct view of the changes in airline TE across the sample period.

Figure 5.1: Time Series Graphs of TE Estimates using DEA CRS



Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

Further, by reviewing the TE scores, the research suggests that the airlines can be categorised into three groups according to their average efficiency scores for the period: perfect scores, above average and below average. The categorisation of the airlines is presented in Table 5.2. Ten percent of the airlines had perfect scores; 35% had above average scores and 55% scored below average. It will be noted that all three American airlines in the sample and the three consecutive years of 2001, 2002 and 2003 all scored below average. No doubt the events of 9/11 and their consequences were contributory factors.

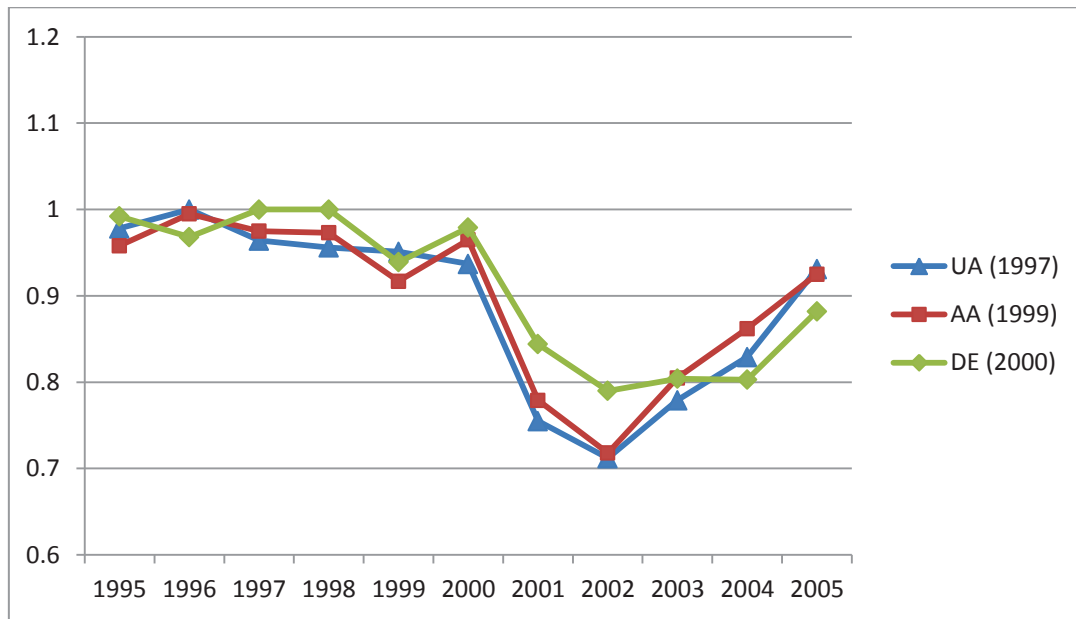
Table 5.2: Categorisation of Airlines and Years with Respect to Technical Efficiency Performance

Efficiency score	Airlines	Years
Perfect score	AI, TA	N/A
Above sample average	BMI, CP, CZ, IB, SIA, THY, VA	1995, 1996, 1997, 1998, 2000
Below sample average	AA, AC, AF, BA, DE, FA, KA, LU, MA, SAS, UA	1999, 2001, 2002, 2003, 2004, 2005

Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

The results also show that some airlines had a significant drop in TE after the year 2000. This phenomenon can be found among the North American airlines in particular. For example, United Airlines scored 0.937 in 2000 and dropped to 0.755 in 2001, which equates to a ~18% loss of efficiency. It fell further to 0.712 in 2002. American Airlines dropped from 0.965 in 2000 to 0.779 in 2001 and to 0.718 in 2002, which equates to 18.6% and 24.7% losses of efficiency, respectively. Delta Air Lines also dropped from 0.979 in 2000 to 0.844 in 2001 and further down to 0.790 in 2002. Those American airlines all recovered their efficiency in 2003 (as seen in Figure 5.2). Although the results show that most airlines had a drop in efficiency between 2000 and 2001, three airlines still achieved maximum efficiency in 2001: Thai Airways, Turkish Airlines and Virgin Atlantic Airways. Moreover, three airlines showed efficiency increases during the period: Iberia Lineas, Air France and Malaysia Airlines.

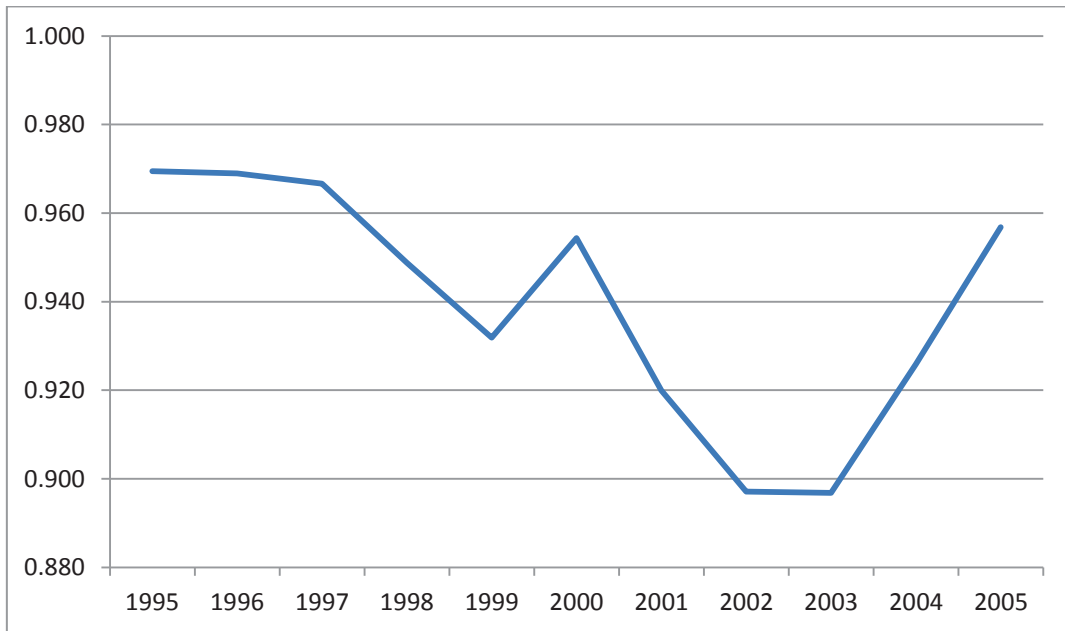
Figure 5.2: TE Scores of American Airlines



Note: UA = United Airlines; AA = American Airlines; DE = Delta Air Lines.

To illustrate trends in efficiency, Figure 5.3 shows the time series graph of the annual average TE scores of the sample airlines. The overall trend for the average airlines' TE appears to be a U-shape. In 2002, the average TE score reached the lowest point, which was 0.897. The average TE then started to improve by 2004. It is obvious that before 2001/2002, the average TE was already trending downwards. The decline after 1996 was briefly reversed in 2000, but the 2001 shock continued to depress performance in the following year. The decline was halted in 2003, after which the average TE score steeply passed the 11-year average of 0.926 in 2004. By 2005, the efficiency scores had recovered and exceeded the 'long-term' average of 0.940.

Figure 5.3: Average Annual TE Scores of the Sample Airlines.



The second part of the DEA results shows the airlines' SE scores and the nature of the returns to scale underneath the SE scores. The presentation format is similar to that of the TE scores. As shown in Table 5.3, the year an airline joined an alliance is listed in parentheses after its name; non-allied airlines do not have dates beside their names. The scores appearing in shaded cells in the table are for the years when the airlines became members in an alliance. The nature of the return-to-scale results obtained from DEAP software is shown underneath the SE score. The cells with 'irs' indicate that the airline's operation experienced increasing returns to scale and could consider an increase in its operational size. The cells with 'drs' (decreasing returns to scale) suggest that an airline in a particular year grew larger than its most productive scale size and could consider downsizing. 'MPSS' shows that the airlines operated at their most productive scale size. For example, in 1995, Air Canada had a SE score of 0.998 and was only 0.002 away from maximum efficiency. The nature of the return to scale (irs) indicates the airline could consider increasing its operational size, albeit by a small amount, to reach the most productive scale size.

Table 5.3: Airlines' Scale Efficiency (SE) Scores during 1995–2005

Airline	1995	1996	1997	1998	1999	2000	2001	2002
AC (1997)	0.998 drs	0.999 irs	0.995 irs	0.996 drs	0.969 drs	0.983 drs	0.970 drs	0.901 drs
LU (1997)	0.923 drs	0.939 drs	0.964 drs	0.973 drs	0.856 drs	0.937 drs	0.890 drs	0.895 drs
SAS (1997)	0.994 drs	0.998 irs	0.992 irs	0.998 drs	0.930 drs	0.982 drs	0.999 drs	0.996 irs
TA (1997)	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS
UA (1997)	0.978 drs	1 MPSS	0.964 drs	0.956 drs	0.951 drs	0.937 drs	0.755 drs	0.807 drs
AA (1999)	0.958 drs	0.995 drs	0.975 drs	0.977 drs	0.936 drs	0.965 drs	0.859 drs	0.718 drs
BA (1999)	1 drs	0.995 drs	0.969 drs	0.969 drs	0.909 drs	0.958 drs	0.953 drs	0.961 drs
CP (1999)	1 MPSS	1 MPSS	0.996 irs	0.975 drs	0.991 irs	0.995 drs	0.995 irs	0.994 irs
IB (1999)	1 MPSS	0.998 drs	1 MPSS	1 MPSS	1 MPSS	0.974 drs	0.995 drs	0.960 drs
FA (1999)	1 MPSS	0.976 irs	0.967 irs	0.998 irs	0.995 irs	0.997 irs	0.977 irs	0.922 irs
SIA (2000)	1 MPSS	0.997 drs	0.999 irs	0.987 drs	0.989 drs	0.991 drs	0.999 irs	0.999 irs
BMI (2000)	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	0.978 irs	0.916 irs
AF (2000)	0.998 drs	1 MPSS	0.999 irs	0.991 drs	0.957 drs	0.968 drs	0.921 drs	0.903 drs
DE (2000)	0.992 drs	1 MPSS	1 MPSS	1 MPSS	0.940 drs	0.979 drs	1 MPSS	0.921 drs
KA (2000)	0.999 drs	1 MPSS	0.996 irs	0.991 drs	1 MPSS	0.995 drs	0.999 drs	1 MPSS
CZ (2001)	0.934 irs	0.943 irs	0.973 irs	1 MPSS	0.934 irs	1 MPSS	0.971 irs	0.952 irs
THY	0.998 drs	0.987 drs	0.946 drs	1 MPSS	0.955 drs	1 MPSS	1 MPSS	1 MPSS
MA	1 MPSS	0.999 irs	0.997 irs	0.990 drs	0.996 irs	0.998 irs	0.997 irs	0.956 drs
VA	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	0.953 irs
AI	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS	1 MPSS

Note: Score 1 = 1.000. AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; M = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

The SE results show that out of 20 airlines, there were two – namely Thai Airways and Air India – which achieved the most productive scale size (MPSS) through the entire sample period of 11 years. Two airlines, British Midland International and Virgin Atlantic Airways achieved MPSS in 8 out of 11 years, while Turkish Airlines achieved MPSS in 6 out of 11 years. Six airlines only achieved MPSS for 1 out of 11 years: United Airlines, Singapore Airlines, Air France, British Airways, Finnair and Malaysia Airlines. Four airlines did not achieve MPSS at all during the sample period; these included Air Canada, Lufthansa, Scandinavian Airlines and American Airlines. The rest of the airlines achieved MPSS in 2–5 years out of 11 years. Similar to TE scores, the airlines and years have been categorised into different groups according to their scores compared to the sample mean in Table 5.4.

Table 5.4: Categorisation of Airlines and Years with Respect to Scale Efficiency (SE) Scores

Efficiency score	Airlines	Years
Perfect score	TA, AI	N/A
Above sample average	AC, BMI, CP, IB, KA, MA, SAS, SIA, THY, VA	1995, 1996, 1997, 1998, 2000
Below sample average	AA, AF, BA, CZ, DE, FA, LU, UA,	1999, 2001, 2002, 2003, 2004, 2005

Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

Table 5.5 shows the number of airlines characterised by the different categories of returns to scale in each of the sample years. No consistent pattern seems to emerge but for most of the time, most airlines either operated at the right size or above the optimal size.

Table 5.5: Number of Airlines Achieving Different Levels of Return to Scale in Each Year

Nature of return to scale	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
MPSS	9	9	6	8	6	6	5	4	3	4	5
Decreasing returns to scale	10	6	5	11	10	12	9	9	9	9	10
Increasing returns to scale	1	5	9	1	4	2	6	7	8	7	5

The results in Table 5.5 also show some interesting phenomena. First, there were several airlines that almost continually operated at ‘drs’ (i.e. they were bigger than their optimal size) during the sample period. These included Air Canada in 9 out of 11 years, Lufthansa in all 11 years, United Airlines in 10 out of 11 years, Air France in 9 out of 11 years, American Airlines in all 11 years and British Airways in 10 out of 11 years. This suggests that they have grown larger than their MPSS and could consider downsizing. These airlines are all legacy carriers. Secondly, these seven most relatively scale-inefficient airlines were also the relatively most inefficient in TE terms. Those airlines included Lufthansa, United Airlines, American Airlines, British Airways, Finnair, Air France and Delta Air Lines. It should be noted that it is relatively easier to reduce technical inefficiency than to reduce scale inefficiency. An airline should consider achieving TE first and then deal with scale inefficiency. Additionally, there are three airlines that never achieved decreasing returns to scale: included British Midland International, Czech Airlines and Virgin Atlantic Airways. Considering the nature of the airline business, it is easier for airlines to increase the scale of their operation. British Midland International and Virgin Atlantic Airways achieved MPSS in 8 out of 11 years.

The third part of the DEA results includes reporting on the MPI. The details of the MPI or productivity change and its components are reported in Appendix Table A. With reference to Färe *et al.* (1994 a, b), productivity change is the product of SE change, management efficiency change and technological change, i.e.:

$$\begin{aligned} \text{Productivity change} &= \text{Scale efficiency change} \times \text{Management efficiency change} \\ &\times \text{Technological change.} \end{aligned}$$

Using the formula above, it is possible to identify the reasons for a change in productivity. An increase or decrease in airline productivity could be the result of technological advancements and investments. It could also be the result of the size of an activity, the scale of productivity or general business efficiency. Using the data presented in Appendix Table A, Table 5.6 reports the airlines' MPI scores in the various years. The value for any particular year indicates the change in productivity from the previous year. A value less than, equal to or greater than 1 indicates a decrease, no change or increase in productivity, respectively. The year an airline joined an alliance is indicated in parentheses after its name; non-allied airlines do not have dates beside their names. The scores appearing in shaded cells in the table are for years when the airlines had membership in an alliance. For instance, in the first cell (for Air Canada), the score of 0.995 suggests that, compared to the previous year, Air Canada lost 0.5% productivity in 1996. The first shaded cell (for Air Canada in 1998) represents the productivity change of Air Canada after it joined an alliance group. The rest of the table can be read similarly. Overall, the table suggests that, on average, the sampled airlines experienced productivity gains of 0.5% from 1996 to 1997, 2.7% from 1999 to 2000, 3% from 2001 to 2002 and 3% from 2003 to 2004. In contrast, the sampled airlines experienced a loss in productivity of 1% from 1995 to 1996, 0.5% from 1997 to 1998, 3.1% from 1998 to 1999, 7.6% from 2000 to 2001, 1% from 2002 to 2003 and 0.7% from 2004 to 2005. The MPI only indicates airline productivity change relative to other airlines in previous years rather than absolute values.

It will be noted in Table 5.6 that no airlines achieved continuous growth in productivity; furthermore, no airlines experienced a consistent drop in productivity. Airlines within the sample period experienced erratic and irregular change in productivity. The largest drop in productivity occurred in 2001, where the sampled airlines scored an average of 0.924 on the MPI. Between 2000 and 2001, there was only one airline that experienced productivity growth, namely Malaysia Airlines, with a score of 1.095, indicating that the airline had 9.5% growth in productivity. For other airlines, productivity dropped compared to the previous year. Two American airlines had the largest drop, with United Airlines scored 0.785 and American Airlines scored 0.786. These numbers indicate that in 2001, these two airlines achieved about only 78% of the productivity achieved in the previous year. From the decomposed MPI scores in Appendix Table A, the productivity gain of Malaysia Airlines in 2001 is attributed mainly to management efficiency gains, and the precipitous productivity loss of the two American airlines (AA and UA) is attributed to scale inefficiency. The latter observation stands to reason because following the 9/11 event in 2001, many people must have been put off flying by fear of a repeat of the hijacks and the inconvenience of the rigorous flight safety checks put in place at airports and in airplanes. The third American airline, Delta, also suffered losses but to a lesser extent.

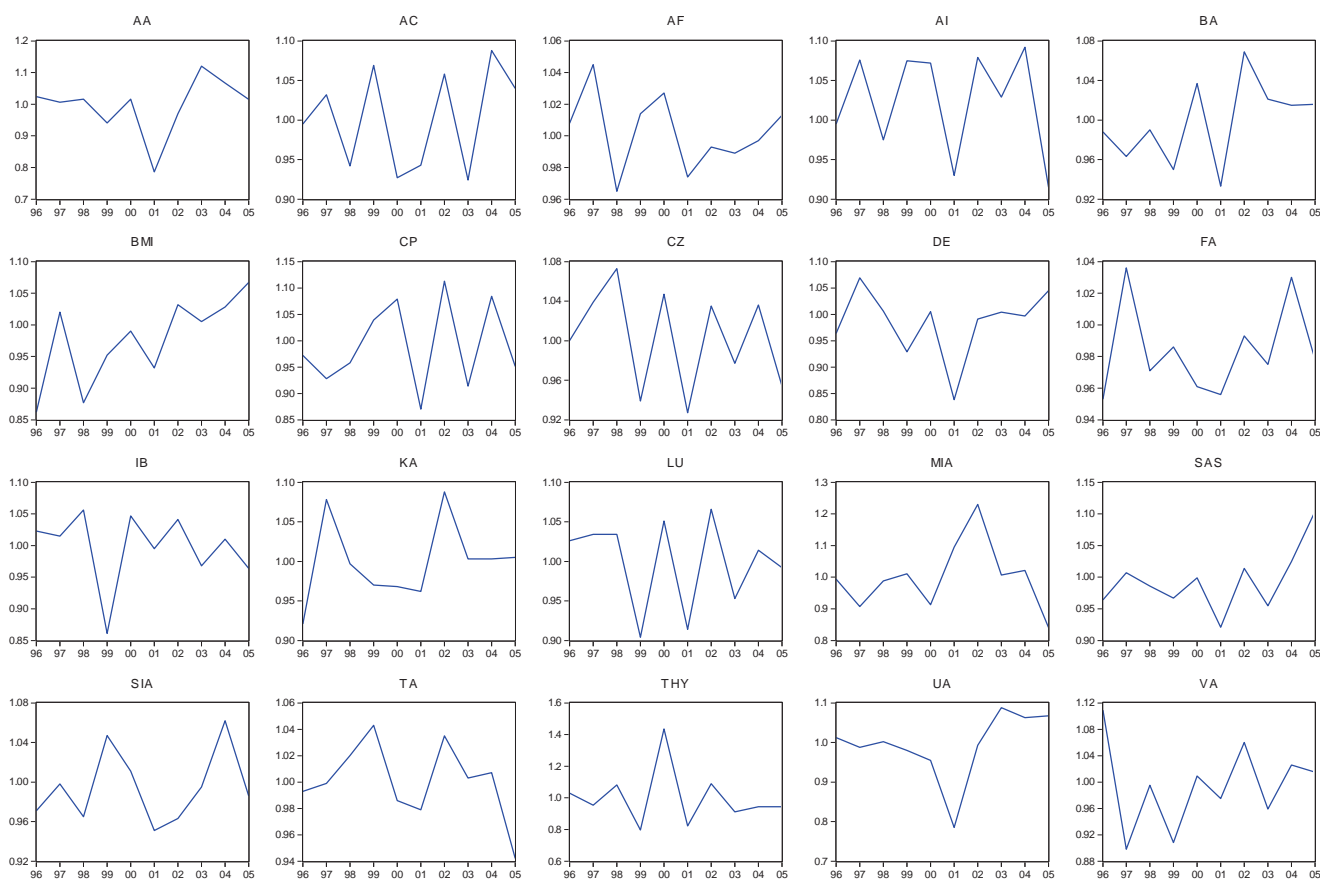
The highest single estimated positive productivity change occurred in 2000 for Turkish Airlines, which scored 1.436, implying a productivity increase of 43.6% compared to 1999. The decomposed MPI scores in Appendix Table A suggest that technology change was the main driver of this outstanding productivity performance. This outcome could possibly be the result of the airline adopting the correct technological advancements, and making safe and profitable investments. Moreover, the airline also achieved an improvement in SE of nearly 5%, which undoubtedly contributed to the increase in productivity. The year 2002 was the best year for productivity change during the sample period. In that year, the sampled airlines achieved an average of 1.046, which represents an increase in productivity of about 5%. In 2002, only 6 out of the 20 airlines experienced a negative change in productivity. This indicates that airlines soon found a way to cope with the effects of the 9/11 event in 2001. Figure 5.4 provides the graphs of the MPI for individual airlines during the sample period.

Table 5.6: DEA-based Malmquist Productivity Index (MPI) (Productivity Ch

Airline/ Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
AC (1997)	0.995	1.032	0.942	1.069	0.927	0.943	1.058	0.924	1.000
LU (1997)	1.026	1.034	1.034	0.904	1.051	0.914	1.066	0.953	1.000
SAS (1997)	0.964	1.007	0.986	0.967	0.999	0.921	1.014	0.955	1.000
TA (1997)	0.993	0.999	1.020	1.043	0.986	0.979	1.035	1.003	1.000
UA (1997)	1.012	0.988	1.002	0.980	0.955	0.785	0.993	1.088	1.000
AA (1999)	1.024	1.006	1.016	0.941	1.016	0.786	0.970	1.120	1.000
BA(1999)	0.988	0.963	0.990	0.950	1.037	0.933	1.069	1.021	1.000
CP (1999)	0.972	0.928	0.958	1.039	1.079	0.870	1.113	0.914	1.000
IB (1999)	1.023	1.015	1.056	0.861	1.047	0.995	1.041	0.968	1.000
FA (1999)	0.953	1.036	0.971	0.986	0.961	0.956	0.993	0.975	1.000
SIA (2000)	0.971	0.998	0.965	1.047	1.011	0.951	0.963	0.995	1.000
BMI (2000)	0.862	1.020	0.877	0.952	0.990	0.932	1.032	1.005	1.000
AF (2000)	1.008	1.045	0.965	1.014	1.027	0.974	0.993	0.989	1.000
DE (2000)	0.964	1.069	1.006	0.929	1.005	0.838	0.991	1.004	1.000
KA (2000)	0.921	1.078	0.997	0.970	0.968	0.962	1.088	1.003	1.000
CZ (2001)	1.000	1.039	1.073	0.939	1.047	0.927	1.035	0.977	1.000
THY	1.030	0.954	1.081	0.797	1.436	0.823	1.089	0.912	1.000
MA	0.994	0.907	0.988	1.011	0.913	1.095	1.230	1.007	1.000
VA	1.109	0.898	0.995	0.908	1.009	0.975	1.060	0.959	1.000
AI	0.995	1.076	0.975	1.075	1.072	0.930	1.079	1.029	1.000
Average	0.990	1.005	0.995	0.969	1.027	0.924	1.046	0.990	1.000

Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

Figure 5.4: Time Series Graphs for the Malmquist Productivity Index (MPI)



Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

As indicated in Section 3.3.2.3, the MPI can be used as a robustness test to measure the frontier shifts of nonparametric frontiers and confirm the choice of panel data for efficiency measurement. Tulkens and Vanden Eeckaut (1995) suggest that a frontier shift is captured by the technological change component of the MPI. From the airlines' average yearly productivity changes and the components reported in Table 5.7, it will be seen that technology change averaged 0.994 per annum. This shows that the best-practice technology barely changed during the study period, thus justifying the pooling of the data and estimating a single grand frontier (Fried *et al.*, 2008, p. 54).

Table 5.7: Annual Average of MPI Productivity Changes and its Components

MPI and Component	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Productivity change	0.990	1.001	0.992	0.97	1.015	0.932	1.028	0.99	1.028	0.969	0.992
Technology change	0.985	1.004	1.01	0.992	0.997	0.956	1.054	0.993	0.950	0.999	0.994
Technical change	1	0.997	0.981	0.999	0.997	0.978	0.991	1.014	1.038	0.983	0.998
Scale efficiency change	1.006	1	1.001	0.979	1.021	0.997	0.984	0.983	1.043	0.987	1

5.1.2 Airline Efficiency and Alliance Membership

The DEA results provide an overview of the individual airlines' efficiency during the study period. By linking these results with alliance group status, the DEA results provide a vivid relationship between airline efficiency and alliance group status. The results suggest that airlines that are in an alliance group do not always have better efficiency than the non-allied airlines. For some of the airlines, their efficiency was related to year effects. However, after 1999, the number of airlines belonging to an alliance group greatly surpassed the number of non-allied airlines. Moreover, as a non-parametric analytic method, the DEA method cannot determine the cause-effect relationships between maximising efficiency and joining an alliance group.

In the DEA results, it is not obvious that allied airlines have systematically higher efficiency scores than non-allied airlines. However, performance for both groups varied from year to year. As seen in Table 5.8, in 2000 and 2005, the average efficiency scores of airlines in an allied group were better than those of non-allied airlines. In the year 2000, the allied group had the better efficiency, with an average of 0.957 compared with an average of 0.954 for the non-allied group. In 2005, the allied group had an average TE score of 0.959 compared to the non-allied group's average of 0.957. After 2001, the non-allied group had better efficiency scores than the allied group. The low performance of the allied airlines after 2001 may be attributed to the impact of the September 11 terrorist attack in the US. The American airlines in the sample, American Airlines, Delta Air Lines and United Airlines are all part of an alliance, and they experienced dramatic drops in their TE scores following the 9/11 incident.

The average TE scores of allied and non-allied airlines in the various years are presented in Table 5.8. In 1997, when the alliances were formed, there were five allied airlines in the sample. The number increased thereafter, reaching a maximum of 16 in 2001. If we compare the efficiencies of allied and non-allied airlines, the average efficiency score of the allied group in 1997 was 0.965, while the non-allied group achieved an average of 0.967. In 1998, there were still only five allied airlines within the sample group. They achieved 0.944 efficiency on average, while the non-allied group achieved a score of 0.949. Although the average efficiency began dropping after the year 1997, 2000 was the first year that the average TE of the allied airlines was higher than that of the non-allied airlines.

Table 5.8: Time Series of the Average TE Scores of Allied and Non-Allied Airlines

Year	Allied airlines		Non-Allied airlines		Average TE score of all airlines
	Number of airlines	Average TE score	Number of airlines	Average TE score	
1995	0	0	20	0.969	0.969
1996	0	0	20	0.969	0.969
1997	5	0.965	15	0.967	0.967
1998	5	0.944	15	0.954	0.949
1999	10	0.931	10	0.933	0.932
2000	15	0.957	5	0.948	0.954
2001	16	0.910	4	0.959	0.920
2002	16	0.879	4	0.968	0.897
2003	16	0.879	4	0.967	0.897
2004	16	0.911	4	0.986	0.926
2005	16	0.959	4	0.948	0.957
Average	–	0.926	–	0.961	0.940

The figures in Table 5.8 also show that the allied group only had better efficiency than the non-allied group for 2 out of 11 years. Comparing the DEA TE scores between two groups, the Mann-Whitney U-test ($Z = 3.026$, $P = 0.0025$) and the rank sum for non-allied airlines (172.5, 80.5) for allied airlines suggests that the non-allied airlines attained significantly higher TE scores than the allied airlines. From 2001, the allied group always achieved lower efficiency than the non-allied airlines. There are three possible reasons for this. Firstly, after 2001, more airlines have joined an alliance group, causing the average efficiency to drop. Secondly, it is possible that the longer an airline stays in an alliance group, the more its efficiency drops.

Thirdly, the years covering the sample period had a great effect on the efficiency of airlines' operations. Since the allied group outnumbered the non-allied group in 2000, the September 11 event in 2001 had more negative effects on the allied group than on the non-allied group. Nevertheless, as stated before, the DEA results cannot provide causality for the variables. However, the evidence shows that the year effects have a great impact on an airline's efficiency, regardless of whether or not it is in an alliance.

With regards to airline SE and alliance status, there is no significant evidence indicating that airlines that joined an alliance group improved their operational SE as a result, even though the literature suggests that by joining an alliance group, an airline can improve its operational SE. The results show that there is no obvious trend of improving SE. SE depends on the nature of an airline and the strategic intentions of its management. Again, the airline SE scores only relate to the efficiency index of the best airline of the year, not the absolute value.

For a slightly more rigorous analysis of the alliance membership and year effects on the DEA TE and SE scores, Tobit regression models were estimated. In the empirical literature, there is no agreement on the correct approach to take in such second-stage regressions. For instance, Grosskopf (1996) suggested that because the observed values of the DEA efficiency scores lie above zero and cannot exceed unity, OLS is not appropriate. In that case, the Tobit model seems more appropriate for the second-stage analysis. Simar and Wilson (2007) have also argued that DEA efficiency estimates are somehow censored, since, typically, numerous estimated values are equal to unity, although no coherent account of how the censoring arises has been offered for using the OLS. They object to the use of the Tobit model and instead recommend bootstrapping to generate efficiency scores that are then suitable for further analysis. Hoff (2007) advocated using both the Tobit model and OLS in second-stage regressions and suggested that OLS performed at least as well as the Tobit model and actually may in many cases replace Tobit as an adequate second-stage DEA model. McDonald (2009) drew a similar conclusion about OLS but did not advocate using the Tobit model. However, in this study, because the use of OLS in limited dependent variable models yields biased and inconsistent estimates (Gujarati, 2011, pp. 182–185; Wooldridge, 2013, chapter 17), the Tobit model has been used to examine the alliance membership and year effects on the DEA TE and SE scores.

Table 5.9 presents the Tobit regression results for the TE and SE scores. There are two models for each dependent variable. Model 1 regressed the dependent variable on just the alliance dummy and year dummies. Model 2 expanded Model 1 by adding the interaction terms of the year dummies and the alliance dummy. In Model 1, the alliance dummy allows us to test for the efficiency differentials between allied and non-allied airlines. In Model 2, the interaction terms allow us to test whether or not the efficiency differentials between allied and non-allied airlines depend on the year. For all the regressions, the base group is non-allied airlines in 1995. It also needs to be noted that the explanatory power of the models is low because efficiency and performance are affected by other variables, rather than just the year and alliance status. Moreover, since the study's focus is mostly on the effect of alliances on efficiency, the models were deemed to be adequate.

For the TE Tobit regressions, the results in Table 5.9 suggest that alliance membership has a negative impact on airline efficiency: in Model 1, membership in an alliance (ALLIED) led to a 0.026 decrease in TE, which is significant at the 1% level. Model 2's results show that the alliance differential depended on the years, although the year did not make a significant difference, except in 2002, 2003 and 2004. The results also show that the interaction terms of year and alliance status had positive coefficients in 1998, 1999 and 2000, but the estimates were not statistically significant. The rest of the period interaction terms had negative insignificant coefficients. Thus the results suggest that allied airlines suffered more from the TE dropping in 2002, 2003 and 2004. For SE, Model 1's results also show that the alliance dummy has a negative coefficient and the result is significant. Other significant variables in the Model 1 are the year dummies for 2002 and 2003, which indicate that the downturns in SE for those particular years were significant. In Model 2, although the alliance dummy takes a negative coefficient, which suggests that alliance membership reduces SE, the result is statistically insignificant. Moreover, none of the year dummies and interaction variables in Model 2 is significant. Therefore, the impact of alliance status on SE does not depend on the year and vice versa.

Table 5.9: Tobit Regression Results of Technical Efficiency (TE) and Scale Efficiency (SE)

Independent dummy variables	Dependent variable (TE)		Dependent variable (SE)	
	Model 1	Model 2	Model 1	Model 2
Constant	0.969*** (0.013)	0.969*** (0.12)	0.989*** (0.009)	0.989*** (0.009)
ALLIED	-0.026*** (0.010)	-0.002 (0.028)	-0.025*** (0.007)	-0.005 (0.021)
YR96	-0.0005 (0.018)	-0.0005 (0.017)	0.003 (0.012)	0.003 (0.013)
YR97	0.004 (0.018)	-0.002 (0.018)	0.004 (0.012)	0.001 (0.014)
YR98	-0.014 (0.018)	-0.020 (0.018)	0.007 (0.013)	0.003 (0.014)
YR99	-0.024 (0.019)	-0.041 (0.021)	-0.011 (0.014)	-0.012 (0.015)
YR00	0.005 (0.019)	-0.027 (0.027)	0.013 (0.014)	0.011 (0.020)
YR01	-0.028 (0.019)	-0.010 (0.030)	-0.05 (0.014)	0.011 (0.022)
YR02	-0.051*** (0.019)	-0.0012 (0.030)	-0.031** (0.014)	-0.011 (0.022)
YR03	-0.052*** (0.019)	-0.002 (0.030)	-0.025** (0.014)	-0.006 (0.022)
YR04	-0.022 (0.019)	0.016 (0.030)	-0.012 (0.014)	0.0002 (0.022)
YR05	0.008 (0.019)	-0.021 (0.030)	-0.003 (0.014)	-0.028 (0.022)
ALLIEDYR98	–	0.00007 (0.040)	–	-0.002 (0.029)
ALLIEDYR99	–	0.008 (0.037)	–	-0.019 (0.027)
ALLIEDYR00	–	0.017 (0.039)	–	-0.017 (0.029)
ALLIEDYR01	–	-0.047 (0.041)	–	-0.041 (0.030)
ALLIEDYR02	–	-0.087** (0.041)	–	-0.045 (0.030)
ALLIEDYR03	–	-0.086** (0.041)	–	-0.044 (0.030)
ALLIEDYR04	–	-0.073* (0.041)	–	-0.035 (0.030)
ALLIEDYR05	–	0.013 (0.041)	–	0.011 (0.030)
Statistics				
LR χ^2	48.42	66.61	50.85	58.04
Sigma	0.562	0.538	0.041	0.040
Log Likelihood	318.168	327.262	388.81	392.41
Observations	220	220	220	220

Notes: Standard errors are given in parentheses. The asterisks ***, ** and * indicate, respectively, significance at the 1%, 5% and 10% levels, respectively. ALLIED means that an airline joined an alliance group and YR means the year.

In a bid to explore the extent to which the scores of the MPI and its components may have been impacted by the alliance and year effects, the study duplicated the second-stage regressions for the respective dependent variables. This time, however, OLS was used because the dependent variables (productivity change and its components) were not restricted in value.³ Table 5.10 reports the results of the regression models, fitting productivity change and its components to the year and alliance dummies. The explanatory power of each of the models is low (on the basis of the R^2 values) and the models probably suffer from omitted variable bias. Nonetheless, the regressions provide an added insight into the alliance and year effects on the dependent variables. The technological change model had the best relative fit, followed by the productivity change model. For productivity change, the results of Model 1 show that alliance membership *per se* was inconsequential, but the gains in 2002 and 2004 and the loss in 2001 for all airlines were significant. The presence of the interaction terms in Model 2 reveals that allied airlines lost out significantly in 2000 and 2002 and gained significantly in 2005 *vis-à-vis* non-allied airlines' performance in 1995. With slight variations, the results for the components are qualitatively similar to those for productivity change. The management efficiency change model had the poorest fit, followed by the SE change model.

³ Note: We are aware, however, that the truncation of the response variable is not the only area of concern with use of OLS.

Table 5.10: OLS Regression Results of Productivity Change and its Components

Independent variable	Dependent variable (Scale Efficiency Change)							
	Productivity change		Technological change		Management efficiency change		SE change	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Constant	0.990*** (0.014)	0.990*** (0.013)	0.990*** (0.010)	0.990*** (0.010)	0.996*** (0.009)	0.996*** (0.009)	1.004*** (0.008)	1.004*** (0.008)
ALLIED	-0.009 (0.011)	0.006 (0.022)	-0.007 (0.007)	0.016 (0.016)	-0.0002 (0.007)	0.008 (0.013)	0.0008 (0.006)	0.001 (0.013)
YR97	0.017 (0.020)	0.013 (0.020)	0.018 (0.014)	0.012 (0.014)	0.006 (0.013)	0.008 (0.013)	-0.008 (0.011)	-0.008 (0.012)
YR98	0.007 (0.020)	-0.003 (0.020)	0.018 (0.014)	0.012 (0.014)	0.006 (0.013)	0.008 (0.013)	-0.008 (0.011)	-0.008 (0.012)
YR99	-0.016 (0.021)	-0.026 (0.023)	-0.0005 (0.015)	-0.005 (0.017)	0.012 (0.013)	0.001 (0.015)	-0.029** (0.02)	-0.022 (0.014)
YR00	0.044 (0.022)	0.105*** (0.031)	0.019 (0.015)	0.088*** (0.021)	0.007 (0.014)	-0.007 (0.020)	0.015* (0.012)	0.020 (0.018)
YR01	-0.058** (0.023)	-0.034 (0.034)	-0.026* (0.016)	- 0.066*** (0.023)	-0.008 (0.014)	0.037* (0.022)	-0.027** (0.012)	-0.004 (0.019)
YR02	0.062** (0.022)	0.124*** (0.033)	0.086*** (0.016)	0.110*** (0.023)	0.007 (0.014)	0.040* (0.021)	-0.029** (0.012)	-0.026 (0.019)
YR03	0.007 (0.022)	-0.013 (0.034)	0.036 (0.016)	-0.013 (0.023)	-0.002 (0.014)	-0.003 (0.022)	0.004 (0.012)	0.002 (0.019)
YR04	0.048** (0.022)	0.031 (0.034)	0.013 (0.016)	0.011 (0.023)	0.023* (0.014)	0.017 (0.022)	0.010 (0.012)	0.003 (0.019)
YR05	-0.01 (0.022)	-0.061* (0.034)	-0.026* (0.016)	-0.023 (0.023)	0.03** (0.014)	-0.007 (0.022)	-0.006 (0.012)	-0.032 (0.019)
ALLIEDYR99	-	0.004 (0.04)	-	-0.014 (0.025)	-	-0.028 (0.023)	-	-0.014 (0.020)
ALLIEDYR00	-	-0.098** (0.038)	-	- 0.116*** (0.027)	-	0.025 (0.025)	-	-0.007 (0.022)
ALLIEDYR01	-	-0.045 (0.041)	-	0.026 (0.028)	-	-0.051* (0.026)	-	-0.029 (0.024)
ALLIEDYR02	-	-0.092** (0.041)	-	-0.053* (0.028)	-	-0.036 (0.026)	-	-0.004 (0.024)
ALLIEDYR03	-	0.010 (0.041)	-	-0.003 (0.028)	-	0.007 (0.026)	-	0.002 (0.024)
ALLIEDYR04	-	0.006 (0.041)	-	-0.021 (0.028)	-	0.013 (0.026)	-	0.087 (0.024)
ALLIEDYR05	-	0.074* (0.041)	-	-0.026 (0.028)	-	0.052** (0.026)	-	0.048 (0.024)
Statistics								
R^2	0.219	0.301	0.320	0.407	0.069	0.151	0.174	0.214
Adj R^2	0.177	0.235	0.284	0.351	0.020	0.072	0.130	0.141
Observations	200	200	200	200	200	200	200	200

Notes: Standard errors are given in parentheses. The asterisks ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. ALLIED means that the airline had joined the alliance group and YR means the year. Prod is the airline's productivity change; Techgl is the airline's TE change; Mgteff is the airline's management efficiency change and Scaleff is the airline's SE change.

5.2 Stochastic Frontier Analysis (SFA) results

SFA employs two different production functions: the Cobb–Douglas production frontier function, and the trans-log production frontier function. The results have been presented in the following four subsections. The first section presents the frontier estimation for the Cobb–Douglas and trans-log frontier functions. The second section presents the results of the technical inefficiency estimations for both frontier functions and explains the effects of the alliance-related variables on the airlines' TE change. The third section presents the estimated TE scores from Cobb–Douglas and trans-log functions. The last section provides an analysis of the effects of alliance group membership on an airline's efficiency change.

5.2.1 Stochastic Frontier Model Estimations

The first section presents the estimation results of the Cobb–Douglas production frontier and the trans-log production function frontier. In Table 5.11, the estimated ordinary least squares (OLS) coefficients and the estimated maximum likelihood (MLE) coefficients of each variable are presented in the columns under the frontier function name, Cobb–Douglas or trans-log. The values of the log-likelihood functions for the OLS and MLE coefficients allow us to test whether technical inefficiency exists or not. If technical inefficiency does not exist, the OLS and MLE results will be the same. The OLS and MLE results reported in Table 5.11 are not the same, which means technical inefficiency exists. Because of the existence of this inefficiency, the results interpreted in the frontier model mainly focus on the MLE coefficients.

Table 5.11: The Cobb–Douglas and Trans-log Estimates of the Stochastic Frontier Model

Variable/statistic	Cobb–Douglas		Trans-log	
	OLS	MLE	OLS	MLE
Frontier component				
Constant	0.592*** (0.181)	0.600*** (0.155)	-2.056 (5.720)	-1.191 (5.232)
<i>Aircraft</i>	-0.009 (0.010)	-0.006 (0.011)	-1.081** (0.532)	-1.024*** (0.330)
<i>Cost</i>	0.945*** (0.017)	0.941*** (0.016)	2.008* (1.028)	2.021*** (0.916)
<i>Assets</i>	0.050*** (0.011)	0.047*** (0.009)	-0.261 (0.520)	-0.429 (0.314)
<i>Aircraft</i> ²	–	–	-0.092*** (0.035)	-0.040 (0.031)
<i>Cost</i> ²	–	–	-0.175* (0.100)	-0.175*** (0.047)
<i>Assets</i> ²	–	–	-0.048 (0.037)	-0.044* (0.025)
<i>Aircraft</i> × <i>Cost</i>	–	–	0.134*** (0.051)	0.114*** (0.044)
<i>Aircraft</i> × <i>Assets</i>	–	–	-0.048 (0.034)	-0.065*** (0.024)
<i>Cost</i> × <i>Assets</i>	–	–	0.074 (0.053)	0.089*** (0.034)
Inefficiency component				
Constant	–	0.753** (0.345)	–	-0.860** (0.433)
<i>SL</i>	–	0.005 (0.030)	–	-0.005 (0.082)
<i>LF</i>	–	-1.178** (0.515)	–	-1.269** (0.657)
<i>PP</i>	–	-0.217 (0.148)	–	-0.228 (0.186)
<i>Allied</i>	–	-0.074 (0.097)	–	-0.060 (0.116)
<i>Duration</i>	–	0.089* (0.046)	–	0.092** (0.055)
<i>Number</i>	–	-0.002 (0.015)	–	-0.004 (0.018)
<i>Duration</i> ²	–	-0.008* (0.005)	–	-0.008 (0.004)
<i>Number</i> ²	–	0.0001 (0.001)	–	0.0002 (0.001)
Sigma-squared (Σ^2)	0.0045	0.010** (0.004)	0.0044	0.012** (0.006)
Gamma (γ)	–	0.873*** (0.006)	–	0.908*** (0.05)
Log-likelihood function	283.735	316.744	189.248	323.761

Notes: Standard errors are given in parentheses. The asterisks ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

For the Cobb–Douglas function, the OLS and MLE estimation results have been presented in the second and third columns in Table 5.11. The MLE results show that the variables *Costs* and *Assets* are positively related to airline production yields, whereas the variable representing total aircraft hours becomes negative but insignificant. The coefficients of operation costs and total assets are statistically significant at the 1% level. This implies that, as operational cost and total assets increase, the airline’s output (total revenue) will increase. Thus, for the airlines, increasing operational costs and total assets means that the production yields will increase accordingly.

Similar to the Cobb–Douglas function, the trans-log function estimation results have been presented in the fourth and fifth columns in Table 5.11. The MLE estimation results show that seven coefficients out of nine were statistically significant. Among those variables, three variables have positive effects on airline revenue production, which included *Cost* at the 1% level, and the interaction terms of *Aircraft* \times *Cost* and *Cost* \times *Assets* at the 1% level. Four variables that are negatively related to airline revenue production (*Aircraft*, *Cost*², *Assets*² and the interaction terms of *Aircraft* \times *Assets*) are statistically significant.

5.2.2 Estimating the Inefficiency Effects Model

As noted earlier, because of the difference between the OLS and MLE results, technical inefficiency exists. This study follows the practice of other empirical studies of modelling inefficiency (the theoretical model was outlined in Section 4.2.2 in Chapter 4). The empirical technical inefficiency results are also reported in Table 5.11. The technical inefficiency results are presented in the MLE columns of each function after the frontier model estimation.

In the Cobb–Douglas inefficiency model, variables taking negative signs are *LF* (load factor), the proportion of passenger business (*PP*), the alliance dummy, alliance membership numbers and the quadratic term of alliance membership duration (*Duration*²). The negative sign indicates that these variables are inversely related to inefficiency. Thus, an increase in load factors, the proportion of passenger business, the number of members in the alliance and longer membership duration will increase airline efficiency. The variable *LF* is statistically significant

at the 1% level and *Duration*² is statistically significant at the 10% level. The sign of *SL*, *Duration* and *Number*² are positively related to airline inefficiency. This implies that an increase in those variables would result in an increase in airline inefficiency. Among these variables, membership duration is statistically significant at the 5% level. The implications of the inefficiency effects model results are that an increase in load factors and the proportion of passenger business will reduce airline inefficiency, but an increase in the stage length will increase an airline's inefficiency.

The most important variables in the inefficiency model results are *Allied*, *Duration*, *Number* and their quadratic terms. The signs of *Duration* and *Number*, as well as their squared values, imply that airline efficiency changes upon joining an airline alliance group. The dummy variable *Allied*, which represents membership in an alliance group has a negative sign. This suggests that membership in an alliance group has a negative impact on airline inefficiency – in other words, a positive impact on airline efficiency. However, the result is statistically insignificant.

From the signs taken by *Duration* and its quadratic term in Table 5.11, the relationship between inefficiency and *Duration* has an inverted U-shape. Thus the airline membership duration has a decreasing marginal effect on inefficiency. By definition, the partial effect of membership duration on the TE of production has a U-shape. This implies that alliance membership duration has increasing marginal effects on efficiency and the longer that an airline remains in an alliance group, the more its efficiency rises. Thus, by using the formula⁴ (for the turning point in a quadratic relationship), the turning point for the variable *Duration* can be calculated as 5. This suggests that an airline has to remain in the alliance for at least 5 years to start experiencing increases in efficiency.

The partial effect of the variable *Number* is opposite to the variable *Duration*, where the relationship of *Number* with inefficiency has a U-shape so that its effects on the TE of production have an inverted U-shape. This implies that the number of members in an alliance group has a decreasing marginal effect on the TE of production. However, the result is statistically insignificant.

⁴ Note: For any quadratic function, $y = \beta_0 + \beta_1x + \beta_2x^2 + u$, the turning point of the function will be $x^* = | \beta_1 / (2\beta_2) |$ (Wooldridge, 2013).

For the trans-log inefficiency model, the results show that the variables *SL*, *LF*, *PP* and *Alliance* all negatively affect airline inefficiency. In other words, they positively influence airline efficiency. However the impact of *LF* is significant but that of *PP* is not. Airline operation inefficiency decreases by 1.269% with a 1% increase in airline load factors, which is significant at the 10% level. Furthermore, an increase in stage length increases efficiency, but this is not significant. For the alliance-related variables, *Allied*, *Duration*, *Number* and their quadratic terms, the trans-log production frontier model had similar results to the Cobb–Douglas production frontier model. The dummy variable *Allied*, which represented membership in an alliance group, had a negative impact on an airline’s operation inefficiency. Membership in an alliance therefore had a positive impact on production efficiency. However, this impact is not significant, as in the case of the Cobb-Douglas model. The relationship between *Duration* and inefficiency has an inverted U-shape and, by definition, a U-shape with production efficiency. This implies that the length of time for which an airline has been part of an alliance will negatively impact on efficiency at first, but if the airline stays in the alliance group until a certain period, efficiency will start to rise. However, the trans-log results show that the drop in efficiency in the early years of joining the alliance is significant but the recovery in later years is not. The coefficient of the variable *Number* and its squared counterpart suggest a U-shaped relationship within inefficiency and inverted U-shape relationship with production efficiency. Again, this result is not statistically significant.

5.2.3 Estimates of the TE Scores

Frontier analysis also provides the individual airline TE scores. Table 5.12 presents the airline efficiency scores from 1995 to 2005 using the Cobb–Douglas production frontier model. In Table 5.12, the first column shows the names of the sample airlines with the years they joined an alliance group in parentheses. The scores appearing in shaded cells in the table are for the years when the airlines were members in an alliance. The airlines with no year specified are those that never joined an alliance group. For example, for Air Canada in 1995 (AC (1995)), the TE estimate is 0.960. It is observed that with regards to an airline’s TE, the overall mean efficiency of the sample airlines during the period 1995–2005 is 0.942. This implies that, on average, the airlines realised only about 94% of their TE. None of the airlines had a TE of 100%. The TEs for individual airlines range from a minimum of 0.770 to a maximum of 0.989.

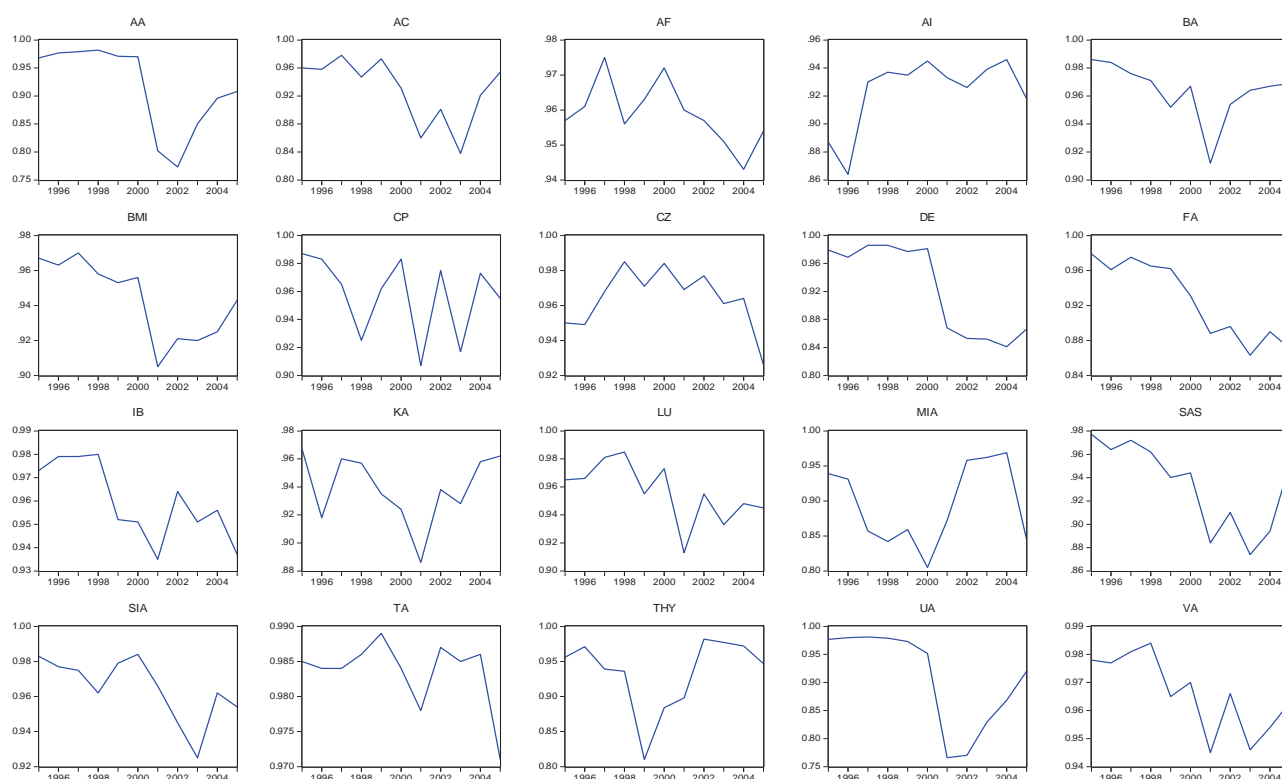
The findings also suggest that an inefficiency of about 6% existed in the sample airline operations. The best performing airline was Thai Airways, which had an average efficiency of 0.983, while the worst performing airline in the sample was Malaysia Airlines, which had an average efficiency of 0.895. It is worth mentioning here that Malaysia Airlines had poor performance in 2005 after two years of growth. In 2005, the airline reported a loss of RM.1.3 billion (about US\$ 340 million) and a 28.8% increase in costs. This poor performance has been attributed to escalating fuel prices, increased maintenance and repair costs, staff costs, low yield per available seat kilometre via poor yield management, and an inefficient route network. The efficiency score in Table 5.12 also reflects this drop, where Malaysia Airlines only scored 0.845 in 2005 compared to 0.969 in 2004. The time series graphs of individual airlines' TE scores are presented in Figure 5.5, which provides a more graphical view of individual TE change during the sample period.

Table 5.12: Estimated TE Scores from the Cobb–Douglas Production Frontier Mod

Airline (Year)	1995	1996	1997	1998	1999	2000	2001	2002	2003
AC (1997)	0.960	0.958	0.978	0.947	0.973	0.931	0.860	0.901	0.838
LU (1997)	0.965	0.966	0.981	0.985	0.955	0.973	0.913	0.955	0.933
SAS (1997)	0.977	0.964	0.972	0.962	0.940	0.944	0.884	0.910	0.874
TA (1997)	0.985	0.984	0.984	0.986	0.989	0.984	0.978	0.987	0.985
UA (1997)	0.977	0.980	0.981	0.979	0.973	0.952	0.766	0.770	0.829
AA (1999)	0.968	0.977	0.979	0.982	0.971	0.970	0.802	0.773	0.850
BA(1999)	0.986	0.984	0.976	0.971	0.952	0.967	0.912	0.954	0.964
CP (1999)	0.987	0.983	0.965	0.925	0.962	0.983	0.907	0.975	0.917
IB (1999)	0.973	0.979	0.979	0.980	0.952	0.951	0.935	0.964	0.951
FA (1999)	0.979	0.961	0.975	0.965	0.962	0.931	0.888	0.896	0.863
SIA (2000)	0.983	0.977	0.975	0.962	0.979	0.984	0.966	0.945	0.925
BMI (2000)	0.967	0.963	0.970	0.958	0.953	0.956	0.905	0.921	0.920
AF (2000)	0.957	0.961	0.975	0.956	0.963	0.972	0.960	0.957	0.951
DE (2000)	0.979	0.969	0.986	0.986	0.977	0.981	0.868	0.853	0.852
KA (2000)	0.967	0.918	0.960	0.957	0.935	0.924	0.886	0.938	0.928
CZ (2001)	0.950	0.949	0.968	0.985	0.971	0.984	0.969	0.977	0.961
THY	0.956	0.971	0.939	0.936	0.810	0.884	0.898	0.982	0.977
MA	0.939	0.931	0.857	0.842	0.859	0.805	0.872	0.958	0.962
VA	0.978	0.977	0.981	0.984	0.965	0.970	0.945	0.966	0.946
AI	0.887	0.864	0.930	0.937	0.935	0.945	0.933	0.926	0.939
Average	0.966	0.961	0.966	0.959	0.949	0.950	0.902	0.925	0.918

Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; S = SAS; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

Figure 5.5: Individual Time Series Graphs of the TE Scores from the Cobb–Douglas Production Frontier Model: 1995–2005



Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lines; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

There is wide variation in the TE scores among the different airlines. Table 5.13 categorises the airlines and years into two main groups according to their average scores. The table shows that eight airlines achieved above average efficiency scores: Lufthansa, Thai Airways, British Airlines, Cathy Pacific, Singapore Airlines, Iberia Lines, Air France, Czech Airlines and Virgin Atlantic Airways. Apart from Virgin Atlantic Airways, these airlines were members of an alliance group.

Table 5.13: Categories of Average TE Scores by Airline and Year under the Cobb–Douglas Production Frontier Model

Efficiency score	Airlines	Years
Above the sample average	AF, BA, BMI, CP, CZ, IB, LU, SIA, TA, VA	1995, 1996, 1997, 1998, 1999, 2000
Below the sample average	AA, AC, AI, DE, FA, KA, MA, SAS, THY, UA	2001, 2002, 2003, 2004, 2005

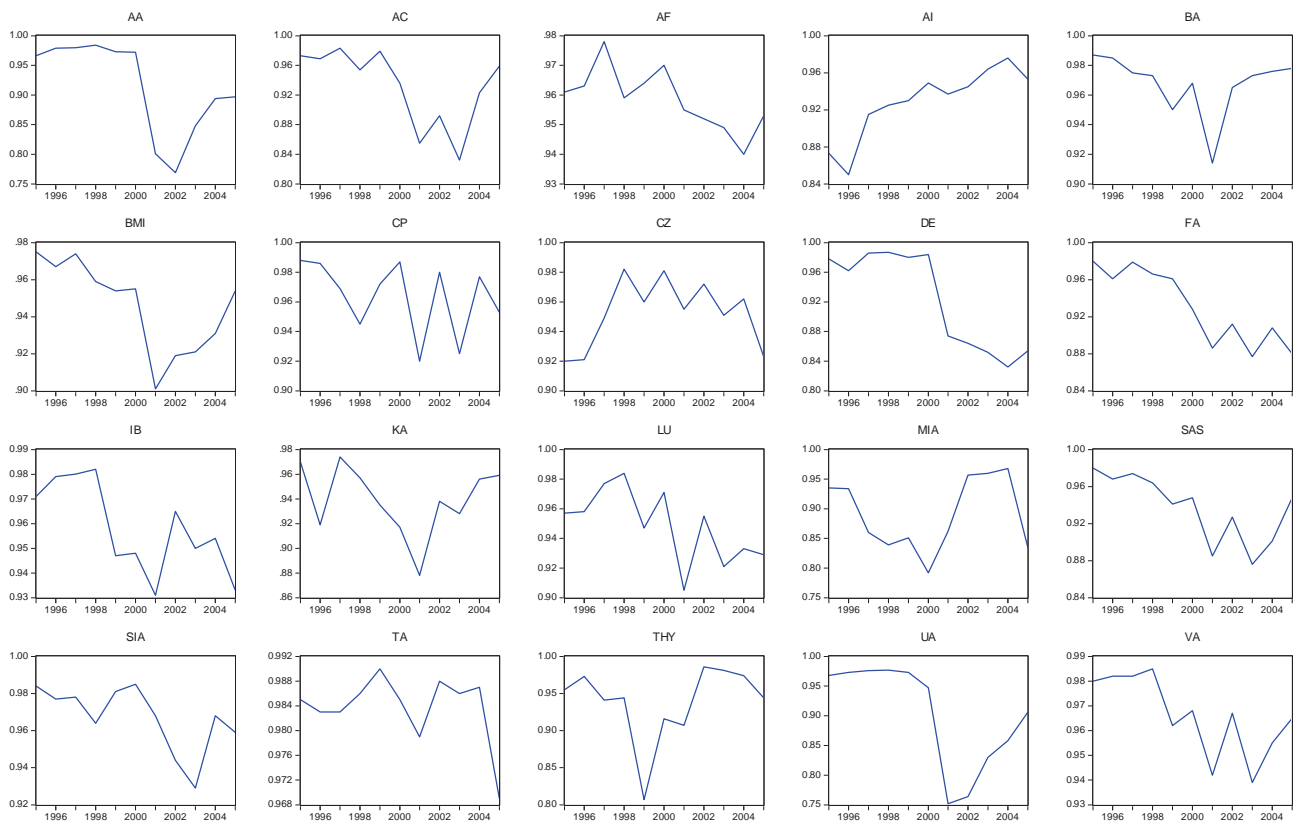
Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lines; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

Table 5.12 also shows that, on average, airlines performed unfavourably from 2001 onward. Some of the airlines had a large drop in TE during 2001, 2002 and 2003. For example, a large drop in efficiency occurred for United Airlines in 2001, which was a drop from 0.952 in 2000 to 0.766 in 2001. A similar situation also happened to Air Canada, Scandinavian Airlines, American Airlines, Finnair, British Midland International and Delta Air Lines. This was mainly because of the September 11 event, which had a huge impact on the airline industry. The effects also spread to the European and Asian airlines, though the impacts were not as serious as they were on American airlines. The American airlines had significant drops during 2001, 2002 and 2003. The Asian airlines suffered from the impact of the September 11 events and they were also seriously affected by the outbreak of SARS in the Asian region in 2003. For instance, most Asian airlines had a sudden drop in efficiency in 2001; however, these airlines made a significant recovery in 2002 but dropped again in 2003. Three Asian airlines, Singapore Airlines, Cathay Pacific and Korean Airlines, all experienced significant drops in 2003.

From the trans-log production function frontier analysis, an airline efficiency table can also be constructed to represent the airlines' efficiency scores for 1995–2005. Table 5.14 presents the operation TE scores for the frontier estimation. The scores appearing in shaded cells in the table are for the years the airlines were members in an alliance. The average TE of the airline industry during the period 1995–2005 was found to be 0.942. This implies that technical inefficiency of about 5.8% existed in the airline industry. According to the trans-log model, none of the airlines achieved 100% efficiency and airline efficiency ranged from a

minimum of 0.752 to a maximum of 0.990. The best performing airline was Thai Airways, which had an average efficiency of 0.984, while the worst performing airline in the sample was Malaysia Airlines, which had an average efficiency of 0.890. The time series graphs of individual airlines' TE scores are presented in Figure 5.6.

Figure 5.6: Individual Time Series Graphs of the TE scores from the Trans-log Production Frontier Model: 1995–2005



Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

Table 5.14: Estimated TE Scores under the Trans-log Production Frontier Model:

Airline (year)	1995	1996	1997	1998	1999	2000	2001	2002	2003
AC (1997)	0.973	0.969	0.983	0.954	0.979	0.936	0.855	0.892	0.832
LU (1997)	0.957	0.958	0.977	0.984	0.947	0.971	0.905	0.955	0.921
SAS (1997)	0.980	0.968	0.974	0.964	0.941	0.948	0.885	0.927	0.876
TA (1997)	0.985	0.983	0.983	0.986	0.990	0.985	0.979	0.988	0.986
UA (1997)	0.968	0.973	0.976	0.977	0.973	0.947	0.752	0.764	0.830
AA (1999)	0.966	0.979	0.980	0.984	0.973	0.972	0.801	0.769	0.848
BA(1999)	0.987	0.985	0.975	0.973	0.950	0.968	0.914	0.965	0.973
CP (1999)	0.988	0.986	0.969	0.945	0.972	0.987	0.920	0.980	0.925
IB (1999)	0.971	0.979	0.980	0.982	0.947	0.948	0.931	0.965	0.950
FA (1999)	0.980	0.961	0.979	0.966	0.961	0.928	0.886	0.912	0.877
SIA (2000)	0.984	0.977	0.978	0.964	0.981	0.985	0.968	0.944	0.929
BMI (2000)	0.975	0.967	0.974	0.959	0.954	0.955	0.901	0.919	0.921
AF (2000)	0.961	0.963	0.978	0.959	0.964	0.970	0.955	0.952	0.949
DE (2000)	0.978	0.962	0.986	0.987	0.980	0.984	0.874	0.864	0.852
KA (2000)	0.970	0.919	0.974	0.957	0.935	0.917	0.878	0.938	0.928
CZ (2001)	0.920	0.921	0.949	0.982	0.960	0.981	0.955	0.972	0.951
THY	0.955	0.973	0.941	0.944	0.807	0.916	0.907	0.986	0.981
MA	0.935	0.934	0.860	0.839	0.851	0.792	0.862	0.957	0.960
VA	0.980	0.982	0.982	0.985	0.962	0.968	0.942	0.967	0.939
AI	0.873	0.850	0.915	0.925	0.930	0.949	0.937	0.945	0.964
Average	0.964	0.959	0.966	0.961	0.948	0.950	0.900	0.928	0.920

Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CZ = Czech Airlines; DE = Delta Air Lines; FA= Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

The trans-log efficiency scores also show that the airline industry had a significant efficiency drop after 2001, presumably because of the September 11 event of 2001 and the SARS outbreak in 2003. For example, the North American airlines showed a big drop in efficiency in 2001 and recovered slowly in the following years, while three East Asian airlines, Cathay Pacific, Singapore Airlines and Korean Airlines, showed a big drop in 2003 after recovering slightly in 2002. The airline efficiency categories have been summarised in Table 5.15.

Table 5.15: Categories of Average TE Scores by Airline and Year under the Trans-log Production Frontier Model

Efficiency score	Airlines	Years
Above the sample average	AF, BA, BMI, CP, CZ, IB, LU, SIA, TA, VA	1995, 1996, 1997, 1998, 1999, 2000
Below the sample average	AA, AC, AI, DE, FA, IB, KA, MA, SAS, THY, UA,	2001, 2002, 2003, 2004, 2005

Note: AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lines; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

5.2.4 Airline Efficiency and Alliance Membership

In the SFA results, the relationship between an airline's efficiency and its alliance membership can be analysed from two main angles: the efficiency scores from the two different frontier functions and the impact of joining an alliance in the inefficiency model. For airline efficiency, this study expected that airlines that joined an alliance group would have better TE than those that are not in any alliance group. The mean efficiency scores of the allied group, the non-allied airlines and the whole sample from the two models have been summarised and are presented in Table 5.15. Comparing the TE scores from Cobb-Douglas and trans-log frontier functions, the Mann-Whitney U-test ($Z = -0.221$, $P = 0.825$; $Z = 0.221$, $P = 0.825$) suggested that there is no significant TE difference between allied and non-allied airlines.

Table 5.16: Average Annual TE Scores from the Cobb–Douglas and Trans-log Frontier Functions

Year	Allied airlines		Non-Allied airlines		All airlines	
	Cobb–Douglas	Trans-log	Cobb–Douglas	Trans-log	Cobb–Douglas	Trans-log
1995					0.966	0.964
1996					0.961	0.959
1997	0.979	0.978	0.961	0.961	0.966	0.966
1998	0.972	0.973	0.955	0.957	0.959	0.961
1999	0.963	0.963	0.935	0.932	0.949	0.948
2000	0.960	0.960	0.917	0.921	0.950	0.950
2001	0.900	0.897	0.912	0.912	0.902	0.900
2002	0.917	0.919	0.958	0.964	0.925	0.928
2003	0.909	0.909	0.956	0.961	0.918	0.920
2004	0.931	0.931	0.960	0.968	0.937	0.939
2005	0.937	0.935	0.918	0.924	0.933	0.932

The results from the Cobb–Douglas and trans-log production functions in Table 5.16 show that the allied group achieved better TE than the non-allied airlines before the year 2000. From 2001 onward, the non-allied group had higher average TE. This is mainly because after 2001, most airlines in the sample had joined an alliance group and many airlines suffered seriously from the September 11 event in 2001, which resulted in a significant efficiency drop in that year, especially for the American airlines, which were all members of alliance groups. Similarly, the outbreak of SARS in 2003 mostly affected Asian airlines that belonged to alliance groups. These results are consistent with the findings from Ito and Lee (2005a, 2005b), Liu and Zeng (2007), and Brauer and Dunne (2012).

The results from the two inefficiency effect estimations reveal how an airline’s alliance membership duration and alliance membership numbers affect TE. The results from the Cobb–Douglas model suggest that airlines should remain in the alliance group for 5 years and would then experience an increase in production TE. The trans-log model has similar results, but the results are statistically insignificant. The results from the Cobb–Douglas model are statistically significant, suggesting that airlines joining an alliance group will not start to experience an increase in efficiency immediately, as production TE only starts to rise about 5

years after the airline joins the alliance group. These results are in line with the theoretical literature, which states that joining an airline alliance group is not the ultimate problem-solving solution for airlines to get out of difficult situations (Iatrou and Oretti, 2007; Kleymann, 2005; Kleymann and Seristö, 2004).

The results regarding to the size for an alliance group in both the Cobb–Douglas and trans-log models are all statistically insignificant. This therefore suggests that the size of an alliance group generally will not have any effect on airline performance. However, an alliance group creates the economies of scale for its members so that the individuals can obtain benefits from membership. Many studies have suggested that an alliance can create economies of scale to increase the performance of its members (Clark, 2007; Kleymann and Seristö, 2004; Oum *et al.*, 2004; Seristö, 2004). During the study period, Star Alliance had 15 members in 2003, and SkyTeam had nine members and OneWorld had eight members at the end of 2005. According to the results, this suggests that SkyTeam and OneWorld should continue to expand their membership numbers, while Star Alliance needs to consider its size. What we found out is that at the end of 2012, Star Alliance had 27 full members, OneWorld had 12 and Skyteam had 17. The airline alliance groups all tried to increase their membership numbers in order to achieve economies of scale. Many studies also confirmed that economies of scale would bring many benefits and more advantages in many aspects for participating firms (Ulijn *et al.*, 2010; Garten, 2000; Gomes-Casseres, 1996; Farrell and Scotchmer, 1988). In fact, the three alliance groups are all trying to increase their membership numbers.

Moreover, although the results from both models are statistically insignificant, there could possibly be an optimal level of membership numbers. The airlines' production TE will start to drop when the number of memberships exceeds the optimal number. Too many members in the group will reduce the members' TE. As Gangopadhyay (2009) proposed, as the size of the group increases, the marginal production cost of firms in the group declines due to economies of scale up to a point; beyond that point, diseconomies of scale set in because of supervision constraints. This also implies that when an airline chooses to join an alliance group, the current alliance membership numbers should be considered. If the airline joins an alliance group with too many members without taking other factors into account, according to this study, this will have a negative impact on the airline's operational TE.

5.3 Comparison of the DEA and SFA Results

There are many studies that have adopted both DEA and SFA for comparison purposes. This study has presented the results of one DEA model and two SFA models for 20 airlines' efficiency scores during 1995–2005. The average efficiency scores for the period and the rank of each airline under the three different models have been presented in Table 5.17.

Table 5.17: Airline Period Average Efficiency Scores and Ranks

Airline	DEA-CRS	SFA-CD	SFA-TL	DEA-CRS Rank	SFA-CD Rank	SFA-TL Rank
AA	0.897	0.916	0.915	18	18	18
AC	0.917	0.929	0.932	13	14	14
AF	0.927	0.959	0.958	12	7	6
AI	1.000	0.924	0.929	1	16	16
BA	0.936	0.964	0.968	10	5	2
BMI	0.985	0.944	0.946	4	10	10
CP	0.946	0.957	0.964	8	8	5
CZ	0.962	0.964	0.952	7	4	8
DE	0.909	0.923	0.923	17	17	17
FA	0.931	0.926	0.931	11	15	15
IB	0.980	0.960	0.958	6	6	7
KA	0.917	0.939	0.939	14	11	11
LU	0.914	0.956	0.949	15	9	9
MA	0.858	0.895	0.890	20	20	20
SAS	0.913	0.934	0.937	16	12	13
SIA	0.945	0.965	0.967	9	3	3
TA	1.000	0.983	0.984	1	1	1
THY	0.981	0.934	0.939	5	13	12
UA	0.890	0.909	0.902	19	19	19
VA	0.986	0.966	0.966	3	2	4
Average	0.940	0.942	0.942	N/A	N/A	N/A

Note: CD = Cobb–Douglas production frontier model; TL = trans-log production frontier model; CRS = constant returns to scale model; AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.

Among the 20 airlines, Thai Airways was ranked the best performing airline by all the models. This could be a result of the geographic location of the airline and the tourism industry of Thailand. Air India also achieved a good result in DEA and MPI analysis. This

could be a result of the strong internal/domestic demand within India. Delta Air Lines, American Airlines, United Airlines and Malaysia Airlines were ranked consistently as 17th, 18th, 19th and 20th, respectively, by all models. This could be due to the 9/11 events. The remaining airlines showed variation in ranking by the different models. The DEA model yielded the lowest average efficiency score compared to the SFA models, but the results are very close. For 6 out of 20 airlines, the DEA scores are higher than the respective SFA scores. Figure 5.7 shows that the time series of the average annual efficiency scores from all three models have U-shapes. All the models show a big drop from 2000 to 2001, but whereas the SFA models indicate a quick recovery in 2002, the DEA model indicates that recovery was delayed until 2004.

Figure 5.7: Time Series of Average Annual Efficiency Scores in Each Model



The Spearman rank correlation method has been adopted to examine the TE rankings obtained from the DEA approach and the different SFA approaches. The estimates show that the rank correlation between DEA-CRS and SFA-CD is 0.647, that between DEA-CRS and SFA-TL is 0.624, and that between SFA-CD and SFA-TL is 0.968. The high rank correlation between the two SFA models is understandable and is to be expected. The estimated rank correlations between the DEA and SFA models of 0.647 and 0.642 are comparable to the findings from other studies. For instance, the previous studies of Coli *et al.* (2011) have

0.9982, 0.9987 and 0.9997 between SFA models, and 0.6739, 0.6665 and 0.6696 between the SFA and DEA models; Cullinane *et al.* (2006) had 0.9989, 0.9772 and 0.9768 between SFA models, and 0.7993, 0.7957 and 0.8002 between the SFA and DEA models; and Lin and Tseng (2005) had 0.6526 between SFA models and 0.6371, 0.6335, 0.8118 and 0.6866 between SFA (Cobb–Douglas) and DEA models; and 0.4459, 0.4966, 0.6310 and 0.6451 between SFA (TL) and DEA models.

5.4 Panel Regression Analysis Results

The results from the panel regression analysis (PRA) of airline productivity and profitability are presented in this section. The regression model for airline productivity and profitability was outlined in Chapter 3. Two variants of the models for productivity and profitability have been estimated and the results are reported in Table 5.18. In this table, Model 1 regresses productivity on the alliance dummy, the size of the airline and its quadratic form, the number of flights, the passenger load factor, the revenue share of freight, the share of incidental revenue and the year dummies. Model 2 expands Model 1 by adding the number of members in an alliance, the number of years of membership in an alliance and their quadratic terms. Models 3 and 4 repeat what was done for productivity, except that the dependent variable is ‘profitability’.

5.4.1 Airline Productivity Analysis

Model 1 and Model 2 established the relationship between airline productivity and other related variables. Compared with Model 1, Model 2 adds alliance membership numbers, membership duration and their quadratic terms into the model. It provides more insight into productivity change and the effects of joining an airline alliance. Most variables retained the same signs as in Model 1; however, firm size and its quadratic term took signs that were opposite to those they took in Model 1. Since Model 2’s adjusted R^2 is slightly higher than that of Model 1 and the additional variables ($Number^2$ and $Duration^2$) are significant, the preferred model is Model 2.

Table 5.18: Panel Regression Result for Alliance Group Effects on Airline Productivity and Profitability

Variable	Productivity (in log)		Profitability (in log)	
	Model 1	Model 2	Model 3	Model 4
Constant	1.118 (1.839)	0.337 (0.994)	-1.821*** (0.532)	-1.413*** (0.547)
<i>Allied</i>	0.003 (0.010)	0.004 (0.019)	-0.004 (0.006)	0.005 (0.010)
<i>Number</i>	–	0.003 (0.004)	–	-0.002 (0.002)
<i>Number</i> ²	–	-0.0004** (0.0002)	–	0.000 (0.000)
<i>Duration</i>	–	-0.007 (0.006)	–	-0.006* (0.003)
<i>Duration</i> ²	–	0.002** (0.001)	–	0.000 (0.000)
<i>Size</i>	-0.144 (0.298)	0.162 (0.316)	0.504*** (0.165)	0.364** (0.174)
<i>Size</i> ²	0.008 (0.023)	-0.015 (0.025)	-0.042*** (0.013)	-0.0299** (0.014)
<i>Flights</i>	-0.140*** (0.041)	-0.164*** (0.044)	0.045*** (0.023)	0.033 (0.024)
<i>PLF</i>	0.395*** (0.129)	0.274* (0.141)	0.189** (0.07)	0.284*** (0.078)
<i>RSfrght</i>	0.180* (0.105)	0.073 (0.115)	-0.053 (0.058)	-0.069 (0.063)
<i>RSireve</i>	0.612*** (0.075)	0.636*** (0.08)	-0.083** (0.041)	-0.117*** (0.042)
<i>DV1996</i>	-0.023* (0.012)	-0.022* (0.012)	-0.009 (0.007)	-0.011* (0.007)
<i>DV1997</i>	-0.009 (0.013)	-0.009 (0.013)	-0.007 (0.007)	-0.009 (0.007)
<i>DV1998</i>	0.0108 (0.013)	0.012 (0.013)	-0.007 (0.007)	-0.007 (0.007)
<i>DV1999</i>	-0.019 (0.014)	-0.017 (0.014)	-0.017** (0.008)	-0.017** (0.008)
<i>DV2000</i>	-0.056*** (0.015)	-0.044*** (0.017)	-0.021** (0.009)	-0.022** (0.009)
<i>DV2001</i>	-0.082*** (0.015)	-0.078*** (0.016)	-0.046*** (0.008)	-0.040*** (0.009)
<i>DV2002</i>	-0.080*** (0.016)	-0.076*** (0.017)	-0.034*** (0.009)	-0.025*** (0.009)
<i>DV2003</i>	-0.081*** (0.015)	-0.079*** (0.017)	-0.032*** (0.009)	-0.019** (0.009)
<i>DV2004</i>	-0.082*** (0.016)	-0.082*** (0.019)	-0.025*** (0.009)	-0.009 (0.010)
<i>DV2005</i>	-0.108*** (0.017)	-0.117*** (0.020)	-0.032*** (0.009)	-0.013 (0.011)
Statistics				
<i>R</i> ²	0.911	0.915	0.621	0.646
Adj <i>R</i> ²	0.894	0.897	0.546	0.567
F-statistic	52.13	48.45	8.323	8.162
Observations	220	220	220	220

Notes: Standard errors are given in parentheses. The asterisks ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. *Allied* represents the airline alliance status; *Number* represents the number of members in the alliance group; *Duration* represents the time that an airline has been in the alliance group; *Size* represents the airline size; *Flights* represents the number of aircraft the airline operates, *PLF* represents the passenger load factors, *RSfrght* is the revenue share from passenger business, *RSireve* is the revenue share from incidental revenue and *DV* is the dummy variable for the year.

In Model 2, the variables for passenger load factors, revenue share from freight, the revenue share of incidental revenue and the year dummy for 2000 have a positive impact on productivity, while the number of flights and the year dummies for 1996, 2001, 2002, 2003, 2004 and 2005 have significant negative impacts. Since the research focuses on airline alliances, the alliance-related variables are more interesting here. Firstly, regarding airline alliance status, in Model 2, the alliance dummy is insignificant. This suggests that joining an alliance group does not contribute to airline productivity. Moreover, for both alliance group membership number and duration, the results are statistically insignificant, which suggests that alliance group membership numbers and duration will also not affect airline productivity.

However, because of the statistical significance of two variables, *Number*² and *Duration*², the results suggest that as the number of members in the alliance group increases, individual productivity will increase accordingly until a certain point but will then fall thereafter. According to the formula in Section 5.2.2, the optimal number of members in an alliance group is 3.75, which is about 4. This implies that after the number of members reaches 5, individual productivity will decrease as the alliance group expands. Membership duration has an increasing marginal effect on airline productivity. Thus an airline's productivity will decrease for a certain time after the airline joins an alliance group, but productivity will then start to increase. The results show that the decrease in productivity is not significant in the beginning, but the increase in productivity in the later years of membership is significant. The turning point of membership duration is 1.75 years after an airline joins an alliance group. This result implies that an airline's productivity will not benefit from remaining in the alliance group until after about 21 months; afterwards, productivity starts to increase along with the length of time it remains in the alliance group. The increase is statistically significant, suggesting that an airline will enjoy the productivity benefits of the alliance group 21 months after joining.

5.4.2 Airline Profitability Analysis

The results for airline profitability are presented in Table 5.18 as Model 3 and Model 4. Because Model 4 has added alliance-related variables and the adjusted R^2 is slightly higher than that of Model 3, the discussion will focus on the results from Model 4 only. Among the significant variables in Model 4, passenger load factors had a positive impact, while the revenue share from incidental revenue and the year dummies for 1996, 1999, 2000, 2001, 2002 and 2003 had negative impacts. The quadratic of the variable *Size* appears to have a parabolic shape and therefore has a decreasing marginal effect on profitability, which is the same as its effects on productivity. Thus, as the size increases, airline profitability will also increase until a certain point; after this, an increase in size will have negative effects on the airline's profitability. Both results are statistically significant.

The alliance status dummy in Model 3 took a negative coefficient and the result was not significant. In Model 4, after adding extra variables (including alliance membership numbers and membership duration), the alliance dummy changed its sign from negative to positive. Because the results from two models are all statistically insignificant, joining an alliance group will have no effects on airline profitability. The quadratic terms of *Number* and *Duration* took zero coefficients, suggesting that they were not necessary in the profitability model. *Numbers* took a negative and insignificant coefficient, meaning the number of members will not affect airline profitability, while the negative and significant coefficient of *Duration* suggests that longevity in a group does not aid profitability.

5.5 Airline Performance and Airline Alliance Groups

The results from the PRA have revealed how airline alliance groups affect an airline's performance. In the productivity and profitability models that the study estimated, the results show that joining an alliance group will not have any effects on airline productivity and profitability. This result is different from the study of Oum *et al.* (2004), which suggested that horizontal strategic alliances make significant contributions to the parent firms' overall productivity gains but there will be no significant overall impact on profitability gains. The PRA results show strong year effects on both productivity and profitability. The results show that since 2000, the year dummies have had significant negative impacts on both airline productivity and profitability. Moreover, the PRA model also suggests that the alliance-related variables *Numbers* and *Duration* have no effect on airline productivity and profitability, but there will be a possible optimal level of membership and an optimal membership duration.

6. Discussion

6.1 Introduction

The study provides some results related to airline alliance groups and airline performance. In the following section, it reviews, compares and discusses the findings from the three analytical techniques used. First, the effects of joining an airline alliance group will be addressed. Secondly, the effects of alliance group membership numbers and membership duration on airline performance will be discussed. These two findings are related to the hypotheses stated in Chapter 1. The third section will focus on explaining the year effects and their impact on airline performance. The last section compares and discusses the results from the DEA and SFA analyses because these two models are usually compared in the literature. The research limitations and possible future studies also will be addressed in this section.

6.2 Discussion

6.2.1 Airline Alliance Groups and Airline Performance

The research found that joining an airline strategic alliance group will have no effect on an airline's performance. The alliance dummy *Allied*, which indicates whether an airline had joined an alliance group (as required by Hypothesis 1), was tested in the SFA and PRA models. The results from both models are statistically insignificant. The DEA and SFA efficiency scores also show that the allied airlines do not have better efficiency than the non-allied airlines. Thus, this study suggests that during the premature stage of an alliance group, membership will not affect airline performance. However, in the SFA study, the alliance dummy in the Cobb–Douglas production frontier and the trans-log production frontier inefficiency models had a negative sign. This implies that joining an airline alliance group will result in positive impacts on an airline's production yield efficiency. In the PRA study, the results suggest that the alliance dummy has a positive effect on both productivity and profitability, but it is statistically insignificant. These results also reveal possible economic

evidence that joining an airline alliance group will contribute positively to airlines' productivity and profitability gains.

The economic evidence is generally in line with the study of Oum *et al.* (2004), which suggested that a horizontal bilateral alliance between/among airlines will have a significant impact on productivity but will not have a significant overall influence on profitability. This study suggested that joining an alliance group will have economic meaning for improving an airline's productivity but will have no overall influence on profitability. The economic evidence also confirmed other previous studies which suggested that airline alliance groups can have benefits for their members (Morschett *et al.*, 2010; Iatrou and Oretti, 2007; Kleymann, 2005; Kleymann and Seristö, 2004; Stern and Hutchinson, 2004). Moreover, this study has provided an empirical quantitative analysis which has not been used before for analysing airline alliance group effects. No studies have been identified so far that have adopted DEA, SFA and PRA together to analyse alliance group effects. For example, Oum *et al.* (2004) only adopted the PRA method and provided an analysis on bilateral airline alliances.

Additionally, joining an alliance group has an important meaning for airlines today. For a mature industry, reducing operational costs or increasing the passenger load factor is not easy for an airline. There will be many obstacles for airlines in reducing operational costs. For example, fuel and labour are the major costs for airline companies (Kleymann and Seristö, 2004; O'Connell *et al.*, 2011), but savings from either fuel costs or labour costs are not easy for an airline to achieve. As well as having problems with unstable fuel costs, the airline industry is also troubled by labour unions. For example, since 2001, the US airlines have faced numerous challenges as a result of union action (Wensveen, 2011). Increasing the passenger load factor is also hard to achieve. In recent years, airlines have usually adopted a cut-throat pricing strategy in order to obtain a competitive advantage (Roll, 2006). This action is harming the whole industry. However, by joining an alliance group, cost savings and increased load factor can be achieved by alliance group cooperation (Iatrou and Oretti, 2007). Thus, although the positive effects of joining an airline alliance group are limited, alliances group have opened up new thinking and directions for future airline operations.

6.2.2 Airline Alliance Group Membership Optimisation

The second major finding is that there may be an optimal membership number for airline alliance groups. This part of Hypothesis 2, which concerns airline alliance group membership numbers, was tested and the outcomes are presented below. There are no previous studies regarding membership numbers identified in the airline alliance literature so far. This study has found that membership numbers do not always have a positive impact on airline productivity and appear to be non-monotonic in shape. Graphs of the effect of membership numbers on productivity appear to have an inverted U-shape, with diminishing effects on airline productivity, and suggest that after the number of members reaches five, individual productivity will decrease as the number of members expands. On the other hand, the PRA results showed that the number of members does not have an effect on profitability, and the results from SFA using the Cobb–Douglas production frontier model and the trans-log production frontier model suggest that the number of members does not have any effect on production yield efficiency.

Nevertheless, potential optimisation for alliance group membership still exists. For the study period, 1995–2005, the Star Alliance had six members in its founding year (1997) and reached 15 members in 2003. It had 17 members in 2004 and reached 18 in 2005. OneWorld had seven members in its founding year (1999) and its membership remained at eight throughout the study period. SkyTeam had four members in its founding year in 2000, reached nine members in 2004 and remained unchanged in 2005. This shows that alliances are group continuing to expand. This is in line with previous literature, which suggested that by forming or joining an airline alliance group, airlines will enjoy the benefits of economies of scale that are created by the group effects, where having more airlines in the alliance means that group, the advantages for its members, such as reaching diverse destinations and increased buyer bargaining power when purchasing, can be achieved. (eg. Mak, 2004; Iatrou and Oretti, 2007; Mühlbacher *et al.*, 2006; Zhang, 2005; Kleymann and Seristö, 2004).

However, Star Alliance slightly exceeded its optimal membership size towards the end of the study period. The productivity result implies that all three alliances have all exceeded their

optimal size. As membership numbers increase, the existing members have to spend extra time and money in network integration; for newly joined members, a larger group means they have to face a more complicated internal group environment and must spend more time dealing with existing members. The study suggests that airline profitability does not relate to an expansion in membership. This is contradictory to most studies, which have suggested a positive relationship between profitability and economies of scale (e.g. Flamini *et al.*, 2009; Dent, 2008; Whittington, 2007; Grauwe, 2007; Fridson and Alvarez, 2002; Westernhagen, 2002; Kirchoff, 1994; Jong, 1993).

The findings suggest that an alliance group should maintain a certain number of members, which is contradictory to most studies in both the airline and business literature and that suggest that the creation of economies of scale will improve individual airline performance (e.g. Ulijn *et al.*, 2010; Clark, 2007; Iatrou and Oretti, 2007; Mak, 2004; Mühlbacher *et al.*, 2006; Zhang, 2005; Oum *et al.*, 2004; Kleymann and Seristö, 2004; Garten, 2000; Gomes-Casseres, 1996; Farrell and Scotchmer, 1988). As Gangopadhyay (2009) proposed, as the size of the group increases, the marginal costs of production for the firms in the group will decline due to economies of scale up to a point; beyond that point, diseconomies of scale set in due to supervision constraints. For the airline industry, an alliance group aims to create a global network and reduce unnecessary competition among members (Iatrou and Oretti, 2007). However, as the membership numbers continue to increase, the members will start to compete with each other due to the unavoidable duplicated routes. The study therefore suggests that alliance groups should also consider the optimal membership number to achieve maximum benefits.

6.2.3 Airline Alliance Membership Duration

The third finding is about the minimum duration of airline alliance group membership for receiving the benefits. Previous research related to airline alliance group membership duration has also not been identified in the airline alliance literature so far. This part of Hypothesis 2, which concerns airline alliance group membership duration, was tested and the results are presented here. The results from both the SFA and PRA studies show that

membership duration will not always positively impact on the members' performance. The results from SFA on airlines' production yield efficiency suggest that an airline will start to benefit from the membership after 5 years (in the Cobb–Douglas model). For airline productivity, the airline needs to remain in the alliance group for at least 1.75 years (21 months) so that it can benefit from membership. The results for airline membership duration and profitability suggest that during the study period, airlines experienced a continual drop in profitability, regardless of whether they were members of an alliance.

These findings are generally in line with most of the literature, which suggests that joining an airline alliance group will improve airline performance (Morschett *et al.*, 2010; Iatrou and Ortti, 2007; Kleymann, 2005; Kleymann and Seristö, 2004; Stern and Hutchinson, 2004). However, so far, no study has been identified that looks at airline alliance group membership duration and airline performance. This study firstly revealed that an airline's performance changes as a result of membership duration. The membership duration effects on an airline's operational TE and productivity both appear as U-shaped curves. This implies that the performance level will drop as membership duration increases until the membership duration reaches a certain point; after this, performance will start to increase over time. This suggests that when the airline has just joined an alliance, its performance may not necessarily increase. The airlines have to stay in the alliance for a certain period, as performance will start to increase as they remain in the alliance group.

In the above result, two things should be noticed. Firstly, the TE and productivity results have statistical evidence to support them. For alliance membership duration and profitability, the results show a negative coefficient that is statistically significant at the 10% level. This implies that during the study period, the airlines that were in an alliance group had a significant profitability loss. The main reason is because during the sample period, which is between 1995 and 2005, airlines experienced a downturn in profitability. Most airlines joined alliance group in the late 1990s. After joining the alliance groups, airlines suffered huge losses due to the 9/11 event in 2001 and the SARS outbreak in 2003 (Brauer and Dunne, 2012; Liu and Zeng, 2007; Ito and Lee, 2005a; 2005b). As a result, if ignoring the unrealistic results of membership duration on profitability, the study suggests that airlines generally have

to remain in an alliance group for more than 5 years so that membership will start to have a positive impact on airline performance (but not necessarily profitability).

Secondly, joining an airline alliance group does not necessarily improve an airline's performance immediately. Airlines have to face both financial and operational challenges when they first join an alliance group. These include factors such as operational integration, integration of information technology, personnel training and alliance group livery, which will bring huge costs for the airlines, especially for the members joining later (Kleymann and Seristö, 2004; Iatrou and Oretti, 2007). The results have confirmed these arguments and suggest that an airline will not benefit immediately after joining an airline alliance. During the study period, 1995–2005, many airlines sought to join an alliance group in order to overcome their financial difficulties. However, the results from both the DEA and SFA scores showed that airline efficiency did not necessarily increase after joining an alliance group. Thus for individual airlines, joining an alliance group expecting to solve problems quickly may, in fact, reduce operation efficiency and productivity, and may even worsen the airline's financial position.

6.2.4 Year Effects

The fourth finding from this study has to do with the year effects on airline performance. The pooled regression results from the DEA model suggest that, regarding TE, the allied airlines suffered more in 2002, 2003 and 2004. The PRA results showed significant negative impacts on productivity from year effects during 2000–2005 and significant negative impacts on profitability from year effects during 1999–2003. This implies that airline productivity has dropped significantly since the year 2000 and profitability has dropped significantly since 1999. This study also provides evidence that airlines were already sliding into difficulties before the 9/11 event in 2001. This is in line with some studies which have argued that the airline industry was already in difficulty before 2001 (Dettmer, 2003; Hanlon, 2007; Wood, 2008; Belobaba *et al.*, 2009).

In some of the years during the sample period, airlines showed poor performance. As Pilarski (2007) suggested, the cyclical nature of the airline industry is seen at the micro-level (the daily schedule) to the macro-level (the economic cycle). The same was found by Morrell (2007), who also showed that between 1990 and 2005, airlines' financial results had a cyclical pattern. Shaw (2011) suggested that the economic growth and trade cycle creates enormous opportunities and great challenges to the airline industry. During the last decade, the aviation industry suffered seriously from terrorism and the effects of political instability as a constant threat that had never been experienced before (Shaw, 2011). Moreover, many previous studies suggested that airline performance was greatly affected by two major events in the early 21st century: the 9/11 events and the SARS outbreaks (Brauer and Dunne, 2012; Liu and Zeng, 2007; Ito and Lee, 2005a, 2005b). This study also confirmed this previous research: for instance, the year dummy for 2001 had the greatest negative impact on airline profitability.

Nevertheless, within the alliance literature, it is suggested that creating an alliance relationship rather than competing in an uncertain environment will help airlines to get more control of the external factors that affect the airline operations (Fan *et al.*, 2001; Iatrou and Oretti, 2007). However, the research findings do not support the concept that joining an alliance group can make airlines more capable of coping with the uncertain external environment. When facing a major outburst event, such as 9/11 or SARS, no matter whether an airline is in an airline alliance group or not, its performance will drop. For example, US Airlines had very low efficiency scores during the 9/11 period in the profitability regression model, and the statistical evidence has shown strong negative year effects on airline profitability in 2001. Thus the research suggests that alliance group effects are limited in terms of affecting airline performance. Airlines should not consider joining an alliance group as a universal solution.

6.2.5 Comparison of DEA and SFA Methodology

The fifth finding is more related to methodology. This research has suggested that the efficiency estimates of the DEA and SFA results have a high degree of correlation. The Spearman rank correlation coefficients between the TE rankings obtained from the DEA approach and those from the two SFA approaches suggest that all three are positively correlated, and the two SFA models have a higher Spearman ranking for their correlation coefficients than the correlations between the SFA and DEA models. However, in this study, SFA provided statistical evidence for a cause–effect relationship between operation efficiency and alliance-related variables. This study therefore provides important guidelines for choosing between DEA and SFA as a research methodology.

There are many studies that have adopted both DEA and SFA for comparison purposes. The results of DEA and SFA usually have a high degree of correlation for efficiency estimates (Coli *et al.*, 2011; Cullinane *et al.*, 2006; Lin and Tseng, 2005). SFA may have a higher efficiency estimate than DEA because it accounts for exogenous or stochastic effects (Garcia del Hoyo *et al.*, 2004; Reinhard *et al.*, 2000; Hjalmarsson *et al.*, 1996). DEA is more robust and is presumably more relevant for inferring policy, and forecasts can be made from concordant results (Good *et al.*, 1995; Gong and Sickles, 1992). This research obtained very similar ranking correlation results between different efficiency models compared to the previous studies by Coli *et al.* (2011), Cullinane *et al.* (2006) and Lin and Tseng (2005).

With these results, both the DEA and SFA models have provided a vivid image of the changes in airline efficiency. DEA is a non-parametric method that does not account for statistical noise, such as measurement errors. In contrast, SFA has parametric functions that take care of statistical noise, such as measurement errors, weather, luck and special events beyond the control of firms. SFA and DEA estimate the same underlying efficiency values, but neither DEA nor SFA has superior results to the other because both methods can provide useful information about changes in airline efficiency.

6.3. Limitations and Further Research

6.3.1 Research Limitations

Although the research has provided some important insights into the airline strategic alliance group, filling the gaps in the alliance literature and research, this study still has the following limitations. First, the most important limitation of this research is the insufficient data provided by the ICAO database. The study was sampled between 1995 and 2005, which is considered to be the initial founding stage of airline strategic alliance groups. This period also includes downturns in the airline industry caused by three major events: the 9/11 attacks, the SARS outbreak and the oil crisis. These events caused the entire airline industry to suffer operational chaos, which may downplay the benefits of joining an airline strategic alliance group.

Secondly, still regarding limitations in the data, the quantitative methodology adopted in this study is based on the existing literature, knowledge and understanding, and has been extended to include the trans-log multilateral index procedure. This procedure has been modified into a new function compared to its original use by Oum *et al.* (2004). The main reason for this modification is caused by the unavailability of sufficient data due to airlines keeping some financial and operational data confidential. It is almost impossible to obtain these data. This could be a major drawback for this study and it cannot completely replicate the original study. Additionally, the study focuses on analysing the entire sample as a whole rather than the individual airlines. The effects on individual airlines were not revealed in this study.

Thirdly, another limitation of the study is related to attitudes towards economic or practical significance versus statistical significance. First, it is necessary to point out that economic significance is not the same thing as statistical significance, and both of these can exist without the other (Ziliak and McCloskey, 2008). The alliance group-related variables in the analysis, such as *Allied*, *Member* and *Duration*, have been found to be statistically insignificant. However, as they have the correct expected sign, the variables have an

important meaning in terms of practical significance. As Wooldridge (2013) suggested, the sign and magnitude of a variable determine its practical significance and allow us to discuss the direction of an intervention or policy effect. Moreover, the arguments between statistical significance and economic significance have⁴ still not been reached by economists. Nevertheless, the leading econometricians find, on reflection, that they agree and realise that most modern econometrics has to be redone, focusing on economic significance and not on mere statistical significance (Ziliak and McCloskey, 2013). It is necessary to pay attention to the statistical significance of the variables but, at the same time, economic or practical significance also needs to be considered in the analysis. The statistical insignificance of alliance effects suggest that the airlines joining an alliance group do not necessarily reap the benefits and therefore airlines should not consider joining an alliance group as a universal strategy.

6.3.2 Future Studies

Based on the research limitations, possible future studies are as follows. First, one possibility for further performance evaluation within the airline industry could be to collect data from other sources and for other variables affecting the airline industry. The data could be collected from individual airlines' annual reports over consecutive years. Annual reports could provide additional information, such as fuel costs, labour numbers and fleet numbers. This would give a more complete picture of the nature of the airline industry and could be used to test hypotheses related to joining an airline strategic alliance group. These data would make it possible to carry out a comparison study for two trans-log multilateral index procedures to check the differences between the two methods.

Moreover, individual annual reports could dramatically increase the sample numbers so the analytical model could be applied at a much higher level, representing the entire industry. This could provide an opportunity for future research covering a longer period, which may reveal the superiority of airline strategic alliance groups. Also, with regard to the duration of membership in an airline strategic alliance group, further studies could replicate and compare the pre-joining and post-joining stages, and also a longer post-joining period when the

alliance is at a more mature stage. Modern airline strategic alliance groups were new and young during the study period. They are now approaching maturity. Such a study could track the development of the alliance group as a whole concept in greater detail.

Secondly, studying the individual airlines (in other words, applying a case study research concept) would provide a different research angle. Another area of research could be to take a specific look at individual airlines and analyse them in more detail. Of particular interest are the reasons why an airline chooses to join a strategic alliance group, what the costs are prior to joining and how long it takes an airline to really integrate into the group system. Another point of interest is the exit costs of the members. In the decade that strategic airline alliances have existed (most of them in the premature stage), many airlines have entered and exited groups, or even changed the groups they joined. It would be useful to replicate and then test the findings of the exit costs of joining an alliance group. This would fill an important gap in the strategic alliance group theory and provide more knowledge and understanding about joining an airline strategic alliance group.

Finally, in terms of theoretical development, the research and literature reviews mostly focus on strategic alliances and redefine strategic alliances within the airline industry context. The next major step in researching the theoretical development would be to review other aspects of the alliance literature, such as strategic options and cooperation, in a study across other industries. This could be done through replication studies focusing on other industries. Moreover, further theoretical development could consider other aspects of the alliance relationship that have not been addressed in this study. This could include culture, branding, organisational learning, knowledge management and trust. These concepts also play an important role in alliance relationships and further research could be done into how these affect not only the airline industry but also other industries. Additionally, other performance indicators could be tested in a further study, such as the effect of joining an airline strategic alliance group on yields and unit cost change. The yields measure the average fare paid per mile per passenger, and unit cost is the cost per standard seat supplied by the airline, which may provide angles for exploring revealing alliance group effects.

7. Conclusions

This final chapter summarises the findings arising from the data analysis in Chapter 5 within the context of the literature reviews and the research questions. It also briefly assesses the methodology described in Chapter 3 and draws overall conclusions from the study. The findings offer contributions to the theoretical understanding of strategic alliances and the importance to the airline industry of forming strategic alliance groups. The conclusions should also provide further research directions, add to the theory and aid managers' decision making and airline operation processes. The main objectives of this chapter are to draw conclusions on the research questions and outline the implications and limitations of the research.

7.1 Summary of Research Findings

This research found a number of points. Firstly, it categorised and redefined the 'strategic alliance group' within the aviation context. It provided a more precise definition of a strategic airline alliance. Secondly, the research suggested that joining the alliance group has no effects on airline performance. The other factors related to airline operations have much more direct influence on airline performance. Thirdly, through parametric analysis, the research provided an inside view of the cause-effect relationships between various alliance group effects and airline performance. Depending on the different performance indicators used, the research suggested the optimal number of alliance group members and the minimum membership duration. Fourthly, the research also found that the airline industry experienced strong year effects, which resulted in an obvious performance cycle within the industry. During the downturn in the industry, even being in an alliance group could not compensate for the negative impacts, which further suggests the limited effects of joining an alliance group.

7.2 Conclusions from the Related Literature

This section summarises the key concepts within the existing literature. The focal theories for this study were strategies, alliance and strategic alliance cooperation, and the airline industry as a context for these. Background theory on the general area of strategy and alliance has been set out in Section 3.2 and a redefinition of strategic alliances in the airline industry is considered to be one contribution to general research. The study has also provided a combined analytical model to assess airline performance. Previous research has also applied these two methods together.

7.2.1 Approaches to Understanding Strategic Alliances

The study concludes that the strategic alliance within a business context is a specific form of cooperation partnership. Nowadays, it has been widely adopted by many businesses to diffuse new technologies, to enter a new market, to bypass governmental restrictions expeditiously and to quickly adopt the latest developments by industrial leaders. The strategic alliance distinguishes itself from other types of alliance due to its complex form of cooperation. The term ‘strategic’ usually involves a long-term partnership and two or more parties focused on achieving common goals. Moreover, a strategic alliance is the highest level of alliance type without any exchange of possessions. The next levels of cooperation between firms are joint ventures and mergers. However, for many international organisations and global businesses, joint ventures and mergers sometimes have strict restrictions imposed by governments or other regulatory bodies.

Forming a strategic alliance is often the best choice for many business entities. A strategic alliance can be viewed as an important form of cooperation representing two or more business entities. This kind of cooperation might be viewed as a lesser type of merger. An alliance is not quite a merger: alliance partners remain separate business entities and retain their decision-making autonomy. Although merger activities have been quite popular in recent years, strategic alliances are increasingly being adopted by businesses, especially network-oriented industries such as the airline, shipping, telecommunications, electronic

equipment, steel, multimodal transportation and logistics industries. The three global airline strategic alliance groups, Star Alliance, OneWorld and SkyTeam, are good examples. In the airline industry, strategic alliance cooperation has now become an important strategy.

Out of all the industries, the airline industry has the largest number of alliances. Airline alliances have been spurred on by regulatory barriers such as a lack of access to domestic markets by foreign carriers, limits of foreign ownership or simply the fear of being left behind (Gallacher and Odell, 1994). In order to attract more passengers in an increasingly competitive environment, international airlines have been seeking to extend the range of their networks and access to new markets. International alliances allow carriers to expand the reach of their networks to service many parts of the world where it may not be economical to do so on their own or where they may lack authority to operate their own flights. Alliances may provide opportunities for the partner airlines to reduce costs by coordinating activities in various fields: joint use of ground facilities such as lounges, gates and check-in counters; code-sharing operations; block space sales; joint advertising and promotion; exchange of flight attendants and so on. However, alliance relationships between/among airlines cannot be considered to be truly strategic alliances. A single cooperation agreement or even a cooperation agreement between a few airlines can only be viewed as a tactical alliance. A truly strategic alliance should have common goals that include long-term planning.

Currently, the only true strategic alliances within the airline industry are the three aforementioned global airline alliance groups. These alliance groups have a long-term strategic plan for the future and each member works towards the same goals. Moreover, these strategic alliances allow airlines to cooperate to the greatest possible extent. Within a true strategic alliance, it is very common to see several types of cooperation mixed up, rather than a single form of cooperation. As a result, as they work towards the same strategic goals, the strategic alliance partners may become more cost-effective and increase their competitiveness.

7.2.2 Approach to Evaluating Performance

In Chapters 2 and 3, it was pointed out that a strategic alliance could be a solution to help companies survive rather than to plan for the future. In general, the partners in an alliance have very strong self-interest. An alliance may face possible problems, such as a clash of cultures, a lack of trust, a lack of clear goals and objectives, a lack of coordination between management teams, and differences in operating procedures and attitudes among partners. However, evaluating the performance of alliance partners is an important topic. There is very little research on the quantitative empirical study of strategic alliances. The existing research in the airline context generally has some deficiencies, like using outdated data and study methods that assessed four airline alliance groups and applied qualitative research methods for economic analysis. Additionally, most existing research only considered either airline efficiency, or productivity and profitability, and no study has made a comprehensive study of the benefits that airlines receive from joining an alliance group. This present study aimed to provide a systematic analysis of the performance of individual members within airline strategic alliance groups by using new data from the period 1995–2005. Here, airline performance has been defined as operational efficiency, productivity and profitability. The research has adopted three different analysis methodologies (DEA, SFA and PRA) to demonstrate changes in airline performance that result from joining an alliance group.

No study has compared and contrasted three methodologies together to analyse the changes in airline performance that result from joining an airline alliance group. Thus this research has filled an important gap and made a significant contribution to the airline alliance literature. Moreover, the airline strategic alliance group phenomenon is relatively new to the industry and although it has drawn much attention within the industry, the research on airline alliance group performance is limited. Before this research, there was little quantitative empirical evidence about airline alliance group performance: theoretical review/qualitative research has been carried out by authors such as Iatrou and Alamdari (2005) on the perceived impacts of alliance groups, Oum *et al.* (2004) on bilateral alliance performance, Morrish and Hamilton (2002) on the benefits of an alliance group, and Rhoades and Lush (1997) on strategic alliance stability and duration. No quantitative empirical study has yet been found in

the literature. This current study certainly provides new insights into the benefits of joining the airline strategic alliance group, especially from a quantitative perspective.

7.3 Conclusions of the Research Objectives

In this section, the two main research objectives will be reviewed and discussed. The research objectives have been explained and discussed in the Introduction.

7.3.1 Research Objective 1

To explain how firms in the airline industry should define and understand the strategic alliances.

This research has revealed the nature of strategic alliances within the airline context. Rather than the simple, daily-based, tactical operational agreements, a strategic alliance partnership is a more profound cooperation between two or more airlines. Nowadays, the three largest global airline strategic alliance groups are those referred to when discussing strategic alliances in the airline industry. There are also some bilateral agreements between two airlines that have claimed to be strategic alliances. However, as the literature reviewed in the previous section indicates, it is not difficult to conclude that this cooperation falls into the ‘strategic’ category, which should have two main characteristics. On one hand, the parties involved should have common goals rather than a simple purpose. On the other hand, strategic cooperation should focus on the long-term rather than the short-term or an undefined period. By these definitions, the most appropriate examples of strategic alliances in the airline industry are the three global airline alliance groups.

The reasons are as follows. Firstly, there have been alliance groups in the history of the airline industry. However, those alliance groups were not truly strategic alliances and are now defunct, mostly due to a lack of long-term, common interests and strategic goals. Either airlines within those alliance groups had an individual interest in specific cooperation, or

cooperation was superficial and tactically focused. Secondly, cooperation between two airlines is unlikely to become strategic on a long-term basis. Cooperation between two airlines usually means that each airline has its own very specific interests. The strategic goals for two airlines are less likely to become the same. If they do not, then the two airlines will become competitors rather than cooperators. If they do, the two airlines will be merged into a single identity. Various regulations, such as anti-monopoly laws and anti-trust laws, further prevent two airlines from becoming strategic alliance partners. Lastly, the new form of airline strategic alliance groups is a good example of a strategic alliance. Within the airline strategic alliance group, the airlines are focused on long-term cooperation rather than the short-term and they have common goals specifically aimed at the development of the strategic alliance group.

7.3.2 Research Objective 2

To provide empirical evidence of the benefits brought to the individual members of an airline strategic alliance group.

There are two ways to identify and analyse the empirical evidence: by using quantitative or qualitative methods. In the economic area, quantitative research has become a more favourable approach in recent years, using mathematics and statistical methods to give empirical content to economic relations. In this study, the research adopts quantitative methods to provide empirical evidence of improvements in performance or the so-called 'benefits' after joining an alliance group. The research adopts and combines three different approaches to address the question. The methods include one non-parametric method (DEA) and two parametric methods, SFA and PRA. These methods either provide statistical or methodical analysis by using operational data from airlines to reveal changes in performance resulting from joining an alliance group. The first two methods, DEA and SFA, mainly focus on how analysing airline efficiency has changed from the pre-alliance period. PRA mainly provides an analysis of the change in productivity and profitability after airlines join an alliance.

The results of the DEA mainly include efficiency scores for each airline during the sample period. The research expected that all airlines in an alliance group would achieve maximum efficiency or would at least do better than the non-allied airlines. However, the results show that airlines that joined an alliance group did not always achieve maximum efficiency or better efficiency than the non-allied airlines. After joining an alliance group, airlines did not necessarily have better efficiency scores. For example, most airlines had a dramatic drop in efficiency in 2001 and 2002. This result explains the questions being raised about whether joining an alliance group can truly bring benefits for airlines. The DEA results also suggest that airline efficiency largely depends on the year and continent. American airlines had relatively low efficiency scores after the September 11 terrorist attack in 2001. Because the DEA is a non-parametric analysis method, it cannot illustrate the cause–effect relationships between variables (input and output variables); it only provides a direct view into of airline efficiency and the distributed characteristics.

SFA also analyses airline operational efficiency. Unlike DEA, SFA provides a parametric analysis and is able to illustrate the cause–effect relationships among the variables. The SFA results are mainly made up of three parts: the efficiency scores of each airline during the sample period, the production frontier function and the inefficiency model. The research expected the SFA results to demonstrate that airlines that are in an alliance group would have higher efficiency scores than airlines that were not in an alliance group, and that airline operations and production would not exhibit operational inefficiency. However, the results show that regarding the efficiency scores of sample airlines over the 1995–2005 sample period, the airlines that were in an alliance group did not always have better efficiency scores than airlines that were not in an alliance group. In the Cobb–Douglas production function and trans-log production function tests, airlines within an alliance group had better average efficiency scores than airlines that were not in an alliance group before 2001. After 2001, the non-allied airlines tended to have better efficiency scores. The changes in airline efficiency are very similar to those shown in the DEA results. This confirms that the time variables have a large impact on airline efficiency. Here, the research results suggest that September 11 and the SARS outbreak may be the largest contributing factors to the drop in efficiency.

As mentioned before, SFA is a parametric analysis that can investigate the causes and effects between variables. According to both the Cobb–Douglas production function and the trans-log production function, inefficiencies in airline operations occurred over the study period. The reasons airlines did not achieve maximum efficiency have been investigated by constructing an inefficiency effects model. The inefficiency effects model has been constructed to estimate how different variables contributed to airline inefficiency. Different variables were analysed to see their effects on airline inefficiency. Following the existing literature and in keeping with the nature of the study, the research chose three operation-related variables and five alliance-related variables to model inefficiency in airline operations. For the production frontier inefficiency models, similar results were found. First, the alliance status dummy in both models suggested that it was not related to airline efficiency, as both results were statistically insignificant. Second, the variable related to alliance membership numbers appears to be parabolic, with diminishing effects on airline efficiency. Exceeding the optimal size may result in higher membership numbers negatively affecting airline efficiency. Third, the SFA results show that airline alliance membership duration is U-shaped, with increasing effects over time. The minimum length of time an airline has to be in the alliance group before membership has a positive effect on airline efficiency is 5 years.

In the PRA, the research mainly focused on analysing individual airlines' productivity and profitability by adopting the sophisticated analytic models identified in the literature. The results show that the alliance status dummy has no effect on airlines' productivity and profitability, as both results are statistically insignificant. The results also found that alliance membership numbers and membership duration affect airlines' productivity and profitability. For airline productivity, alliance membership numbers affect airline productivity in a diminishing manner and appear to be parabolic. After the number of members reaches five, any further increase in membership numbers will have negative effects on airline productivity. Alliance membership duration has the opposite effect to membership numbers, as it has an increasing effect. An airline has to stay in the alliance for more than 1.5 years, after which, staying in the alliance will have positive effects on airline productivity. With regards to airline profitability, membership duration has decreasing effects, mainly due to the strong year effects on profitability.

The three different research methodologies complement each other and all suggest the possible benefits that airlines can obtain from joining an airline alliance group. They also provide a vivid image of the effects of joining an alliance group on airline performance. Moreover, although some of the results lack of statistical evidence, this insignificance may result from the strong year effects and insufficient data. The results from the two parametric models also suggested that, besides the strong year effects, other control variables, such as passenger load factors, carry a large amount of weight in terms of affecting airline performance. The alliance variables only have a limited influence on operational efficiency, productivity and profitability compared to other variables. This is why even airlines that joined an alliance group still sometimes appear to be unprofitable and unproductive.

7.4 Contributions

7.4.1 Contributions to the Theory

This research makes theoretical contributions to the strategic alliance literature, especially to research focusing on the airline industry. It fills in some gaps in the literature on strategic alliances and airline operations, namely:

- understanding strategic alliances within the airline context;
- understanding the link between the realisation of a firm's strategy and its use of strategic alliances.

The study has brought together theoretical insights and empirical evidence from the strategic airline alliance management literature to extend our theoretical understanding. The research makes two key contributions. First, it has identified and defined strategic alliances within the airline context, where a truly strategic alliance in the airline industry is cooperation between/among airlines that have common and long-term strategic plans and goals. The current literature has been confused by various relationships in the airline industry all being referred to as strategic alliance partnerships. However, some of those partnerships only

involve a very basic level of cooperation and cannot be viewed as strategic alliances. Second, the research uses mathematical and empirical analysis to reveal the benefits of joining a strategic alliance. The existing literature mostly discusses the benefits of a strategic alliance from a theoretical point of view.

7.4.2 Contribution to Research Methodology

The methodology used in this study involves quantitative data analysis and data collected from the ICAO database, which can be seen as the most authoritative data in this field. Three analytical methods are adopted in this study: a non-parametric method of airline efficiency (DEA), and a parametric method made up of the SFA method for airline efficiency and PRA for airline profitability and productivity. These three analytical methods have their own strengths and weaknesses in terms of assessing the existing relationships among variables and are summarised in the following paragraph.

DEA is a convenient method and does not require the specification of an explicit function for the production frontier and does not need a specific function of the production process. But the weakness of DEA is that it only provides relative efficiency scores and it cannot separate statistical noise or measurement errors from random errors (Lin and Tseng, 2005). SFA is a parametric method of economic modelling that allows random noise to be incorporated into the model. It can test hypotheses statistically and construct confidence intervals allowing for random errors. However, its main weaknesses are that it requires the explicit imposition of a particular parametric functional form representing the underlying technology and also an explicit distributional assumption for the inefficiency terms (Hossain *et al.* 2012). PRA is a statistical method that has the advantage of allowing us to identify economic models, discriminate between competing economic hypotheses, reduce estimation bias and provide micro-functions for aggregated data analysis (Baltagi, 1995; Hsiao, 2003). However, it faces problems of data availability and modelling the complexity of human behaviours, such as production is very demanding (Hsiao, 2007). These details are summarised in Table 7.1:

Table 7.1: Comparison of the DEA, SFA and PRA Methods

	Data Envelopment Analysis (DEA)	Stochastic Frontier Analysis (SFA)	
Theory	Both are efficiency frontier analyses, and determine a frontier and inefficiency based on that frontier		Explaining
Characteristic	Non-parametric method	Parametric method	
Efficiency Measurement	Relative technical efficiency, scale efficiency, productivity change, technological efficiency change, management efficiency change, scale efficiency change	Technical efficiency	Theoret
Cause-effect Relationship	It cannot determine the cause-effect relationship between input and output variables.	It can determine the cause of production inefficiency.	It can dete between th
Strengths	<ol style="list-style-type: none"> 1. It could handle measurement of multiple inputs and multiple outputs efficiently. 2. It doesn't need to assume function type and distribution type. 3. It will compare with relative efficiency when the sample size is small. 4. It does not need a specification function of the production process 5. Both CRS and VRS models have unit invariance. 	<ol style="list-style-type: none"> 1. It could handle measurement of multiple inputs and multiple outputs efficiently. 2. It accommodates statistical noise and measurement error. 3. It is able to test hypotheses. 4. It estimates the best technical efficiency of a firm rather than relative technical efficiency. 	<ol style="list-style-type: none"> 1. More 2. Great 3. It allo 4 5. It provi 6. It c 7. It
Weakness	<ol style="list-style-type: none"> 1. It only provided relative efficiency scores. 2. It doesn't accommodate statistical noise such as measurement errors. 3. It doesn't allow for hypothesis test. 4. When adding new DMU to the frontier, the whole efficiency measurement will change. 	<ol style="list-style-type: none"> 1. It needs the production function to be modelled in advance. 2. It requires enough samples to avoid a lack of degrees of freedom. 3. It requires an explicit distributional assumption for inefficiency. 	<ol style="list-style-type: none"> 1. It faces 2. The col samples 3. Modell demandin
Application	It has been applied to assess the performance of non-profit organisations or the branches of a firm.	It has been applied to measure the performance of for-profit organisations.	It has been including

(Coelli *et. al.*, 2005; Lan and Lin, 2003; Baltagi, 1995; Hsiao, 2003; Hsiao, 2007; Lin and Tseng, 2005)

None of the previous studies has adopted all three methods at the same time to assess airline performance in all aspects. By adopting three different methods, the research provides a vivid image of how airline performance changes as a result of alliance group membership. Moreover, by adopting a parametric study, the research provides scientific evidence to demonstrate that airline performance is affected not only by the influence of alliance membership but also by some other factors. The three performance indicators comprise an airline's operational efficiency, productivity and profitability. However, previous studies have applied DEA to airline operational efficiency (Coli *et al.*, 2011; Barros and Peypoch, 2009; Barbot *et al.*, 2008; Scheraga, 2004; Good *et al.*, 1995; Distexhe and Perelman, 1994; Schefcztk, 1993), SFA to airline operational efficiency (Coli *et al.*, 2011; Inglada *et al.*, 2006; Coelli *et al.*, 1999; Good *et al.*, 1995, 1993; Cornwell *et al.*, 1990) and PRA to airline productivity and profitability (Barbot *et al.*, 2008; Oum *et al.*, 2004; Oum and Zhang, 2001). This study is the first research to adopt three different analytical methods to evaluate airline strategic alliance group effects.

The study contributes to the literature in terms of adding to airline performance research by using a rich set of analytical tools and more current data. It also provides an in-depth review of improved airline performance as a result of joining a strategic alliance group. The DEA and SFA analyses provide a view of an airline's efficiency performance, while the regression model proposes a model for assessing the changes in individual airlines' productivity and profitability over consecutive years. The three methods complement each other and provide a rich picture of the change in airline performance after joining an airline strategic alliance group. With a theoretical explanation of how joining a strategic alliance can boost airline performance gains, the research has provided clear empirical evidence of the benefits of joining an airline alliance group. Combining the three approaches could provide a fundamental analytical tool and model for future studies. Also, the analytical method could be adopted by other industries to analyse similar performance changes.

7.4.3 Contributions to the Airline Industry

While many studies have looked at the various alliance partnerships in the airline industry, and some have looked at the benefits and performance, none have taken the approach of combining a theoretical review and an empirical analysis in a single study of the industry. This study contributes to our understanding of the complexity of alliance partnerships in a mature industry that face intense competition, an uncertain environment and continually increasing operational costs. The international nature of the airline industry now causes individual airlines to face competitive pressure from both home and overseas markets. A strategic alliance partnership is an efficient strategy for an airline to achieve a globalised focus instead of a traditionally home-based focus. Indeed, the study has shown that, while the strategic alliance groups are still in the seedling stage – so that the empirical evidence does not support the hypotheses – the players in the industry have mastered the rules of the game in alliance group formation and operations.

The study may also make a contribution to understanding the roles that strategic alliance groups play in the current airline industry and provide an important guideline for airlines as they decide whether to form new cooperation relationships with others or to operate new routes by themselves. It also provides non-alliance group airlines with guidelines for choosing a suitable alliance group for the future. The current airline industry is becoming more and more globalised but is limited by various rules and regulations which are almost impossible to abolish. Forming or joining a strategic alliance group will become a better choice for airlines rather than expanding overseas markets involving a lot of time, energy and costs. Thus this study contributes to our understanding of the interaction among alliance partners and strategy options when airlines consider entering an alliance.

7.5 Implications of the Study

In this section, the implications of the research and opportunities for further research are identified in the following areas.

7.5.1 Implications for Managers

As stated in Chapter 1, the airline industry faces great uncertainty while individual airlines face very tight rules and regulations regarding the nature of their business. Thus managers within the industry have to be aware of the emergent strategic alliance strategy, and also of how and why they make certain strategic decisions. Moreover, this study provides managers with an insight into the new competitive environment that has been brought about by the formation of strategic alliances. Not all managers have a complete understanding and knowledge of strategic alliances. In the airline industry, strategic alliance relationships used to be considered an inferior option during strategy planning. However, the current industry requires managers to have a full knowledge of the theories and practices of strategic alliances. Indeed, one of the motives behind the research was to explore the state of various aspects of the previous literature and to summarise this.

The study has shown no evidence to support the idea that joining an airline strategic alliance group can improve airline performance, including efficiency, productivity and profitability. The effects of joining are unclear. However, it is useful for managers to understand the nature and characteristics of the alliance groups they have joined or may join in the future. For the airline industry, the formation of three global airline strategic alliance groups has shaped the airline industry in terms of market share and competition, and has reduced the individual advantages from servicing a specific geographic location. As the strategic alliance concept matures, the industry now has to face new issues it has never faced before. For example, any airline that does not belong to any of the alliance groups will face competitive pressure from the three global alliance groups. Moreover, in recent years, there have already been signs of competition among the alliance groups when they are considered as a single entity for market promotion and campaigns.

Another outcome of the research is that it may assist managers to understand the benefits brought by joining an alliance group. One of the critical future themes for managers in the airline industry that has emerged from this research is running the business with the notion of continual growth in global strategic alliance groups while paying attention to other critical operational aspects. This research confirms that airline alliance groups can bring benefits to their members, but the direct benefits are limited. Thus airline managers should not consider joining an alliance group as a universal solution to get the airline out of a difficult situation. The focus should really be on other key aspects of operation, such as reducing operational costs and increasing load factors. Moreover, as the results from SFA and PRA suggest, the alliance groups need to consider their membership numbers. An airline should remain in its chosen alliance group for a certain period so that it starts to benefit from the effects of membership duration. Many airlines have sought to join an alliance group in order to solve their operational and financial problems quickly. However, this study suggests that joining an alliance group with a large number of members will reduce an airline's performance because it has to spend a lot of money and labour on integration into the alliance group. An airline also cannot solve its problems quickly because the study results suggest that airlines have to remain in the alliance group for a certain period before membership has a beneficial effect on performance.

7.5.2 Implications for Policy and Practice

As mentioned in Chapter 1, the airline industry is a very special industry that has a desire to operate freely but is limited by various rules and regulations for airlines, such as the anti-trust law. Cross-border cooperation often requires airlines to obtain anti-trust immunity. Moreover, government protection in individual countries has a major influence on the development of the airline industry. Of course, most of the time, this is a result of national security and homeland safety. The present research clarifies how and why airlines use or may use a strategic alliance as a strategy for overcoming difficulties. The research thus provides an important overview for policy makers regarding the great potential of the new form of strategic alliances group.

In practice, there have been two important turning points in the modern airline industry that have promoted the rapid progress of the freedom of the airline industry. One is the deregulation in the US in the 1970s and the pursuit of an open skies agreement, first started by the US and followed by the EU in the 1980s. Prior to the emergence and maturity of strategic alliances, especially the global strategic alliance groups, airlines were already enthusiastic about pursuing deregulation and open skies agreements. However, the formation and growth of the global airline strategic alliance groups have brought some obstructions to the promotion of deregulation and open skies agreements. Airlines are no longer as self-absorbed regarding the requirements of deregulation, obtaining anti-trust immunity and pursuing open skies agreements; instead, they are more interested in joining alliance group affairs. As pointed out previously, an alliance group may create a new form of competition in the airline industry, and once an alliance group has become completely mature and well developed, there will not be a chance for new entrants to compete with a large airline alliance group.

7.6 Overall Conclusions

Nowadays, international aviation markets are truly globalised and have become increasingly competitive. More and more carriers are using international airline alliances to strengthen their competitive advantage, extend their networks and access new markets under air traffic rights and resource limitations. The number of new alliance agreements has increased every year since 2001. Currently, the top three alliance groups, Star Alliance, OneWorld and SkyTeam, collectively account for over half of the world's passenger traffic, showing that international airline alliances have become mainstream in today's international airline industry. As market complexity increases and passengers demand full solutions rather than individual products or services, inter-firm collaboration has become a crucial component in the pursuit of airlines' competitive advantage. Multi-collaborations have been adopted by more and more companies. However, the alliances' collaborative arrangements are complex to manage successfully, partly because of the difficulty of matching the goals and aspirations of autonomous organisations. The good intentions and rational motives behind these alliances are often not congruent with the strategic direction of each airline on its own, let alone the

strategic direction of several in unison. Consequently, alliances exhibit instability and poor performance.

During the study period, which was prior to 2005, alliance groups were in a premature stage and airline joining the alliance group will were not likely to obtain obvious benefits from the various aspects of the alliance's group efforts. However, theoretically, an alliance group will also positively affect some important aspects of airline operations, such as load factors and operational costs. Because of the complicated external environment, fierce competition, limited resources and restricting regulations, airlines struggle to improve their operations in certain aspects. Joining an alliance group provides airlines with an opportunity to overcome many of these problems. However, due to the limited influence of an alliance group, airlines should not consider joining an alliance group as a universal problem-solving strategy. Airlines should attach themselves to an alliance group while continuing to increase their competitive abilities and survival in order to cope with a rapidly changing environment.

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Appendix

Table A: Decomposition of Productivity Change

Airlines	Variables	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AC (1997)	Prod Δ	0.995	1.032	0.942	1.069	0.927	0.943	1.058	0.924	1.088	1.040
	Techgl Δ	0.988	1.021	1.020	0.988	0.971	0.97	1.085	0.987	0.991	0.953
	Mgt Eff Δ	1.007	1.015	0.922	1.113	0.941	0.987	1.05	0.876	1.061	1.112
	Scale Eff Δ	1.001	0.997	1.001	0.972	1.015	0.986	0.929	1.069	1.035	0.981
LU (1997)	Prod Δ	1.026	1.034	1.034	0.904	1.051	0.914	1.066	0.953	1.014	0.992
	Techgl Δ	1.009	1.007	1.025	1.028	0.96	0.962	1.059	0.985	1.002	0.935
	Mgt Eff Δ	1	1	1	1	1	1	1	1	1	1
	Scale Eff Δ	1.017	1.027	1.029	0.879	1.095	0.950	1.006	0.968	1.012	1.061
SAS (1997)	Prod Δ	0.964	1.007	0.986	0.967	0.999	0.921	1.014	0.955	1.025	1.104
	Techgl Δ	0.987	1.038	1.003	0.969	0.975	0.973	1.055	0.994	1.002	0.959
	Mgt Eff Δ	0.972	0.976	0.977	1.070	0.970	0.931	0.964	0.972	1.028	1.165
	Scale Eff Δ	1.005	0.994	1.006	0.932	1.056	1.017	0.997	0.988	0.995	0.989
TA (1997)	Prod Δ	0.993	0.999	1.020	1.043	0.986	0.979	1.035	1.003	1.007	0.942
	Techgl Δ	0.993	0.999	1.020	1.043	0.986	0.979	1.035	1.003	1.007	0.942
	Mgt Eff Δ	1	1	1	1	1	1	1	1	1	1
	Scale Eff Δ	1	1	1	1	1	1	1	1	1	1
UA (1997)	Prod Δ	1.012	0.988	1.002	0.98	0.955	0.785	0.993	1.088	1.063	1.067
	Techgl Δ	0.989	1.026	1.011	0.985	0.968	0.976	1.053	0.995	0.998	0.950
	Mgt Eff Δ	1	1	1	1	1	1	0.882	0.981	1.117	1.035
	Scale Eff Δ	1.023	0.964	0.992	0.995	0.986	0.805	1.070	1.115	0.954	1.085
AA (1999)	Prod Δ	1.024	1.006	0.965	0.941	1.016	0.786	0.970	1.120	1.067	1.015
	Techgl Δ	0.986	1.027	1.034	0.998	0.966	0.974	1.051	0.999	0.998	0.945
	Mgt Eff Δ	1	1	0.945	0.984	1.02	0.907	1.102	1	1	1
	Scale Eff Δ	1.039	0.979	0.988	0.958	1.031	0.89	0.837	1.121	1.07	1.074
BA (1999)	Prod Δ	0.988	0.963	0.877	0.950	1.037	0.933	1.069	1.021	1.015	1.016
	Techgl Δ	0.993	1.001	0.877	1.023	0.971	0.954	1.059	0.985	1.002	0.960
	Mgt Eff Δ	1	0.988	1	0.989	1.014	0.983	1.001	1.041	0.985	1.043
	Scale Eff Δ	0.995	0.974	1	0.938	1.054	0.995	1.008	0.997	1.029	1.014
CP (1999)	Prod Δ	0.972	0.928	0.965	1.039	1.079	0.870	1.113	0.914	1.084	0.951
	Techgl Δ	0.972	0.974	1.026	1.012	0.975	0.952	1.059	0.985	1.002	0.944
	Mgt Eff Δ	1	0.957	0.948	1.011	1.102	0.913	1.052	0.934	1.078	1.004
	Scale Eff Δ	1	0.996	0.992	1.016	1.005	1	0.999	0.994	1.004	1.003

Table A: Decomposition of Productivity Change (Cont'd)

Airlines	Variables	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
IB (1999)	Prod Δ	1.023	1.015	1.006	0.861	1.047	0.995	1.041	0.968	1.010	0.964
	Techgl Δ	1.026	1.013	1.006	0.861	1.075	0.975	1.078	0.995	0.99	0.952
	Mgt Eff Δ	1	1	1	1	1	1	1	1	1	1
	Scale Eff Δ	0.998	1.002	1	1	0.974	1.021	0.965	0.972	1.02	1.012
FA (1999)	Prod Δ	0.953	1.036	0.997	0.986	0.961	0.956	0.993	0.975	1.03	0.978
	Techgl Δ	0.986	1.035	1.038	0.964	0.979	0.968	1.063	0.997	0.996	0.947
	Mgt Eff Δ	0.99	1.01	0.966	1.026	0.979	1.008	0.99	1.066	1	1
	Scale Eff Δ	0.976	0.991	0.995	0.996	1.002	0.98	0.943	0.917	1.035	1.034
SIA (2000)	Prod Δ	0.971	0.998	1.073	1.047	1.011	0.951	0.963	0.995	1.062	0.986
	Techgl Δ	0.984	0.982	1.045	1.029	0.966	0.959	1.059	0.985	1.002	0.943
	Mgt Eff Δ	0.989	1.015	1	1.015	1.045	0.984	0.909	1.013	1.059	1.045
	Scale Eff Δ	0.998	1.002	1.027	1.003	1.002	1.008	1	0.997	1.002	1.001
BMI (2000)	Prod Δ	0.862	1.020	1.016	0.952	0.990	0.932	1.032	1.005	1.028	1.067
	Techgl Δ	0.862	1.020	1.017	0.952	0.990	0.954	1.102	0.981	0.964	1.067
	Mgt Eff Δ	1	1	0.997	1	1	1	1	1	1	1
	Scale Eff Δ	1	1	1.002	1	1	0.978	0.936	1.024	1.066	1
AF (2000)	Prod Δ	1.008	1.045	0.990	1.014	1.027	0.974	0.993	0.989	0.997	1.013
	Techgl Δ	0.991	1.008	1.032	0.995	0.971	0.971	1.067	0.994	0.994	0.946
	Mgt Eff Δ	1.015	1.038	0.959	1.056	1.045	1	1	0.968	0.983	1.05
	Scale Eff Δ	1.002	0.999	1	0.965	1.012	1.003	0.93	1.028	1.019	1.019
DE (2000)	Prod Δ	0.964	1.069	0.958	0.929	1.005	0.838	0.991	1.004	0.997	1.045
	Techgl Δ	0.988	1.035	1.043	0.989	0.964	0.972	1.059	0.987	0.999	0.951
	Mgt Eff Δ	0.968	1.033	0.939	0.999	1.001	0.917	0.935	1.045	1.017	1.066
	Scale Eff Δ	1.008	1	0.979	0.94	1.042	0.94	1.001	0.974	0.982	1.031
KA (2000)	Prod Δ	0.921	1.078	1.056	0.97	0.968	0.962	1.088	1.003	1.003	1.005
	Techgl Δ	0.992	0.989	1.056	1.033	0.964	0.964	1.059	0.985	1.002	0.934
	Mgt Eff Δ	0.928	1.094	1	0.931	1.008	0.993	1.027	1.020	1.001	1.076
	Scale Eff Δ	1.001	0.996	1	1.009	0.996	1.004	1	0.999	1	1
CZ (2001)	Prod Δ	1	1.039	0.971	0.939	1.047	0.927	1.035	0.977	1.036	0.954
	Techgl Δ	0.991	1.007	1.005	1.006	0.977	0.955	1.056	0.993	0.992	0.972
	Mgt Eff Δ	1	1	0.935	1	1	1	1	1	1	0.969
	Scale Eff Δ	1.010	1.032	1.032	0.934	1.071	0.971	0.980	0.984	1.044	1.013

Table A: Decomposition of Productivity Change (Cont'd)

Airlines	Variables	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
THY	Prod Δ	1.030	0.954	1.081	0.797	1.436	0.823	1.089	0.912	0.944	0.944
	Techgl Δ	0.987	0.995	1.023	0.835	1.371	0.823	1.089	0.912	0.944	0.986
	Mgt Eff Δ	1.043	1	1	1	1	1	1	1	1	0.997
	Scale Eff Δ	1	0.959	1.057	0.955	1.047	1	1	1	1	0.960
MA	Prod Δ	0.994	0.907	0.988	1.011	0.913	1.095	1.23	1.007	1.021	0.841
	Techgl Δ	0.979	0.978	1.035	1.030	0.964	0.968	1.119	0.984	0.986	0.984
	Mgt Eff Δ	1.016	0.929	0.962	0.976	0.945	1.133	1.147	0.99	1.051	0.947
	Scale Eff Δ	0.999	0.998	0.993	1.006	1.002	0.999	0.959	1.034	0.986	0.904
VA	Prod Δ	1.109	0.898	0.995	0.908	1.009	0.975	1.060	0.959	1.026	1.015
	Techgl Δ	1.109	0.898	0.995	0.908	1.009	0.975	1.113	0.985	0.983	0.983
	Mgt Eff Δ	1	1	1	1	1	1	1	0.985	1.002	1.013
	Scale Eff Δ	1	1	1	1	1	1	0.953	0.988	1.041	1.020
AI	Prod Δ	0.995	1.076	0.975	1.075	1.072	0.930	1.079	1.029	1.092	0.915
	Techgl Δ	0.995	1.076	0.975	1.075	1.072	0.930	1.079	1.029	1.092	0.915
	Mgt Eff Δ	1	1	1	1	1	1	1	1	1	1
	Scale Eff Δ	1	1	1	1	1	1	1	1	1	1

Note: Prod Δ represents productivity change; Techgl Δ represents technological change; Mgt Eff Δ represents management efficiency change; Scale Eff Δ represent SE change. A score of 1 = 1.000. AA = American Airlines; AC = Air Canada; AF = Air France; AI = Air India; BA = British Airways; BMI = British Midland International; CP = Cathay Pacific; CZ = Czech Airlines; DE = Delta Air Lines; FA = Finnair; IB = Iberia Lineas; KA = Korean Airlines; LU = Lufthansa; MA = Malaysia Airlines; SAS = Scandinavian Airlines; SIA = Singapore Airlines; TA = Thai Airways; THY = Turkish Airlines; UA = United Airlines; VA = Virgin Atlantic Airways.