EFFICIENCY AND PRODUCTIVITY GROWTH IN THE EUROPEAN AIRLINES INDUSTRY: APPLICATIONS OF DATA ENVELOPMENT ANALYSIS, MALMQUIST PRODUCTIVITY INDEX AND TOBIT ANALYSIS

Thesis submitted for the degree of

Doctor of Philosophy

at the University of Leicester

by

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January 2000

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Abstract

In its early phase of liberalisation process along with some privatisation experiences, the European airlines industry provides a fascinating case study to investigate the recent performance record and assess the determinants of performance. We aim to analyse the performance of 17 European airlines over the period 1991 to 1995. We utilise the DEA Windows analysis to capture efficiency changes over time and the DEA based Malmquist productivity index to measure the productivity change and decompose any change into efficiency and frontier shift effects. Further we use Tobit analysis to determine the potential determinants of airline efficiency. We find that results from windows analysis reveal an increasing trend in the efficiency scores for most airlines in the sample whereas Malmquist analysis shows a decline in the first two periods, but some evidence of turnaround in 1993-1994, probably with the introduction of the third liberalisation package. The Tobit results show no significant role for state ownership, but indicates the importance of subsidy and concentration policies in explaining the inefficiency differences among airlines.

Keywords: Efficiency; DEA; Malmquist productivity index; Tobit; European airlines

Meryem Duygun Fethi

To my husband, Sami

and our son, Dervis D. Fethi

Acknowledgements

It is a great honour for me to have this opportunity to extend my thanks and acknowledge the contribution of many people who have helped me to produce my PhD thesis.

I would like to begin by thanking those who have helped me financially to start and complete my PhD thesis. I acknowledge a scholarship from the Association of Commonwealth University for the first three years of my study. I am grateful to Ms. Pat Greatorex and Professor Peter M. Jackson for providing me with the tutorship which enabled me to maintain the remainder of my study.

Many thanks should go to Professor Jackson again who has been my supervisor. Apart from supervising my thesis, I had the great opportunity to produce papers with him and present them at the international conferences. I thank him for his encouragement, advice and motivation.

The ten days I spent at the European Summer Institute (University of Warwick) gave me the chance to make insightful discussions, in particular with Professors Robert Dyson, Larry Seiford, Leopold Simar, Drs. Val Belton, Viktor Podinovski and Thierry Post. I must acknowledge Muhittin Kaplan for helping me with the econometrics and Recep Tekeli for helpful comments. I thank David Middleton for proof-reading my thesis.

Kees Veenstra, Deputy Secretary General of the AEA introduced me to the general problems of European airlines at the meeting we had in Brussels. Several companies kindly sent me their annual reports which enabled me to complete the empirical analysis. Joanne Grimble of IATA was kind enough to fax the relevant data. Dervis K. Deniz helped me to sort out the information in the annual reports. I thank them all.

Many friends need to be thanked, but in particular Ozlem Gorey and Cahit Ezel who have given me enormous support and encouragement throughout my study. Many thanks also go to the staff at the University of Leicester Management Centre, in particular Jenni Austen and Anjula Mehra for their continuous friendship.

Finally, I want to thank my parents and my in-laws for all their prayers, love and support. In particular I am indebted to my mum who looked after my son in order for me to complete this thesis. However, above all, my love and thanks go to my husband, Sami for always being patient and there for me when I needed him most. Now that I have completed, my son Dervis can have the time and attention from his mum that he deserves!

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Abbreviations

AEA	Association of European Airlines
ANA	Ansett Australian National Airways
ATK	Available Tonne Kilometre
BCC	Banker, Charnes, Cooper Model
C	Carrier
CAA	Civil Aviation Authority
CAB	Civil Aeronautics Board
CCR	Charnes, Cooper, Rhodes Model
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
DUMCON	Concentration Dummy
DUMSUB	Subsidies Dummy
DUMYE	Year Dummy
EC	European Commmission
ECAC	European Civil Aviation Conference
EM	Average of Entire Period
EU	European Union
EUR	European Flights
GLS	General Least Squares
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
INEFF	Inefficiency Score
INTER	International Flights
IRS	Increasing Returns to Scale
ITC	Inclusive Tour Charters
IV	Instrumental Variables
JAA	Joint Aviation Authorities
KLM	Dutch Airlines
L	Labour
LOAD	Load factor
LP	Linear programming
M	Malmquist productivity index
MC	Change in efficiency (Malmquist)
MF	Change in frontier (Malmquist)
MMC	Monopolies and Merger Commission
NFA	Non-flight Assets
NPA	Non-passenger Revenue
OC	Operating Costs
OECD	Organisation for European Economic Cooperation
OLS	Ordinary Least Squares
OWN	State Ownership
ROUT	Route Network Density
RPK	Revenue Passenger Kilometre
RPM	Revenue Passenger Miles
RTM	Revenue Tonne Miles
SAS	Scandinavian Airlines
SCHED	Scheduled flights
STAGE	Stage length
TAA	Trans Australian Airlines
TFP	Total factor productivity
TFW	Tactical fighter wings
UK	United Kingdom
US	United States
VRS	Variable returns to scale
WM	Weighted mean
Y	Output

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CHAPTER 1. INTRODUCTION

1.1 Motive of the Thesis

In its early days, the majority of Europe's major airlines were established by the states, or with the state support, as they exercised their right of sovereignty over airspace. Naturally they had the privilege to set up national carriers. For many, the carriers were regarded as symbols of independence and, to a great extent, of national prestige. They were also used for economic purposes, such as promoting trade, providing employment and offering services to small and remote communities. In some states, large-scale government involvement was justified on the grounds that air transport required large capital investments which could only be financed by the states. Given the existence of risk, the industry could only attract small number of private initiatives.

However, in recent years, the European air transport industry has been going through a gradual period of economic liberalisation. States are showing a tendency to reconsider their ownership positions, introduce more liberal regimes, and thus promote efficiency in the industry. There are clear forces driving this thrust. These include poor financial performances; efficiency concerns; national debt considerations; the massive need of investments and the moves towards global consolidation.

The industry has often been criticised on the grounds that it is inherently less efficient than the US carriers owing to having higher production costs. To confirm this, many studies have compared their efficiencies and shown that the deregulated US airlines are more efficient than their highly regulated European counterparts (Windle, 1991; Good *et al.* 1993, 1995). The deregulation reforms in the US increased competition, lowered prices and brought substantial benefits for consumers and increased productivity in the industry.

The demonstrable effects of successful US deregulation and ongoing inefficiency in the industry may have influenced the European Commission to introduce certain reforms to promote competition and thus increase the efficiency and productivity of the European airlines. This process is called liberalisation. Starting in 1987, subsequent reform packages were introduced to provide flexibilities in pricing, capacity sharing and market access. The most decisive liberalisation package, however, only came in 1993. It aimed at a fully liberalised Single Aviation Market. It became imperative for the airlines to improve their efficiency in order to remain competitive.

During the early phase of liberalisation process along with some privatisation experiences, the European airlines industry provides a fascinating case study to investigate the recent performance record and assess the determinants of performance. The co-existence of public and private airlines in a competitive environment constitutes an opportunity to examine the claim that private ownership of an airline leads to higher efficiency than public ownership. There may be other factors such as consolidation which could determine efficiency differences. Studying these factors may be of use for formulating relevant policies for the industry, which is seeking to improve its performance whilst passing through critical restructuring.

This thesis focuses on this aspect and analyses the early performance results of the liberalisation reforms in the European airlines industry. The analysis is based on a data set consisting of seventeen airlines over the period 1991-1995. This is the period where considerable reforms took place. The analysis is conducted using the recent methods for measuring efficiency and productivity and explaining the efficiency differences between airlines. The seventeen airlines included in this study are as follows: Aer Lingus (Ireland), Air France (France), Air Malta (Malta), Alitalia (Italy), Austrian Airways (Austria), British Airways (United Kingdom), Cyprus Airways (Cyprus), Finnair (Finland), Iberia (Spain), Icelandair (Iceland), KLM (The Netherlands), Lufthansa (Germany), Sabena (Belgium), SAS (Scandinavia), Swissair (Switzerland), Air Portugal (Portugal) and Turkish Airlines (Turkey).

Except British Airways and Icelandair, the rest in the sample has varying degrees of state ownership. All carriers in the data set are members of the AEA whose duty is to promote co-operation amongst members and represent their interests to the EC and other international organisations. Except Air Malta, Cyprus Airways and Turkish Airlines, the rest of the sample is EC airlines. Because of data limitations, eight AEA airlines were excluded from the sample (See Appendix 1 for more details on the exclusions).

1.2 Need for an Empirical Study

The issue of the relative efficiency of public and private firms has continuously fascinated economists. Many academics and policy makers draw their conclusions for privatisation and deregulation from the comparative studies on the relative technical efficiency differences between these two ownership types. Technical efficiency reflects the ability of a firm to obtain maximal output from a given set of inputs. Allocative efficiency reflects the ability of a firm to utilise the inputs in optimal proportions given their respective prices and technology. It is widely believed that the technical efficiency of private firms is higher than the public firms.

Several interrelated strands of theories have been influential in creating such a consensus. These are property rights, public choice and regulation theories. According to property rights literature which could be associated with the names of Alchian (1965) and Alchian and Demsetz (1972), the attenuation of property rights in public firms leads to monitoring problems and adverse behavioural incentives, creating mismanagement and inefficiency. A second strand, public choice theorists, following Niskanen (1971) argues that public sector managers, bureaucrats and politicians operating under insufficient competitive environments maximise their budgets. This self-interested conduct decreases cost reducing incentives. The final strand suggests that regulatory authorities, which consist of self-seeking bureaucrats, are 'captured' by special interest groups and serve the producers' interest more than the 'public interest'[1].

Though all three sets of theories conclude that private firms are more efficient than public ownership, the existing empirical studies on various industries provide mixed evidence (Millward and Parker, 1983; Boardman and Vining, 1989). In our opinion, any study on the airlines efficiency and productivity is an empirical question which necessitates industry specific studies.

[1] All these theories are detailed in Chapter 2.

1.3 Contributions and Methodologies

This thesis aims to contribute to the previous literature in three ways. Firstly, there is an extensive literature regarding the measurement of US domestic airlines deregulatory experience. These are mainly comparative studies, which examine the performance differences operating under regulated and deregulated environments. In contrast, there are few studies on airlines which examine the relationship between ownership structures and performance. None of the published studies is devoted solely to performance measurement in the European airlines industry. We seek to fill this gap by concentrating on European airlines and to investigate the effects of regulation and ownership issue as well as the operating characteristics. Secondly, many studies use data from the early 1980s. Given the recent trends towards privatisation and liberalisation, it seems that the studies need to be updated. We use new data over the years 1991-1995. In this period, the European airlines industry was significantly liberalised. Thirdly, many previous studies use unsophisticated measurement techniques. Those sophisticated ones attempt to use only one methodology from many existing sophisticated methodologies. We use non-parametric methodologies to measure efficiency and productivity. The DEA windows analysis (Charnes, *et al.*, 1985) is applied to capture efficiency changes over time. Secondly, the Malmquist productivity index (Färe *et al.*, 1992) is used to measure the productivity change and decompose any change into efficiency and frontier shift effects. Finally, the performance results are used in a second stage Tobit analysis (Tobin, 1958) to explore the determinants of inefficiency. This study which combines the DEA windows and the Tobit analyses is the first in the airlines literature.

The original contribution of the thesis is in the two empirical chapters (6-7). The first review chapter mainly offers a flavour of the evolving literature given the extensive amount of work in this field. The second review chapter provides the relevant studies and methodologies. The third chapter reviews the previous studies in airline performance measurement. The methodology chapter (4) details the three methodologies which are employed in the empirical parts of the thesis. The main aim is to use recent advances to evaluate efficiency differences and productivity changes for the European airlines. Further blending of DEA with Tobit analysis seeks to identify the sources of inefficiency, which could be of crucial importance in guiding the policies to enhance performance.

The non-parametric strength of DEA has become increasingly popular in applications where there are multiple inputs and outputs. The technique allows efficiency to be measured without having to specify either the production function or the weights used for the inputs and outputs. The DEA method measures the relative efficiency by estimating an empirical production frontier, employing the actual input and output data. The efficiency score of a Decision Making Unit (DMU) is then measured by the distance between the actual observation and the frontier obtained from all the DMUs under evaluation. Throughout the thesis, the term efficiency refers to technical efficiency, which is the distance of a DMU from the production frontier. Also, an input-oriented efficiency, that is, providing outputs with minimum input consumption, is specified in all analyses.

1.4 Thesis Outline

The structure of the thesis is organised as follows: In chapter 2, we briefly examine the theoretical background behind the relationship of ownership, regulation and efficiency. The theories include: property rights, public choice as well as the regulation theories with special emphasis on contestable theory. Chapter 3 includes a review of the literature on airline performance studies. Chapter 4 outlines the three methodologies, of which the first two are used to measure efficiency and productivity respectively. These are the DEA Windows analysis and the DEA-based Malmquist productivity index. Additionally, Tobit is used to provide the sources of inefficiency. Chapter 5 describes the ownership and privatisation experience along with the evolution of liberalisation practices in the European airlines industry. Chapter 6 analyses the technical efficiency based on the data set consisting of seventeen airlines over the period 1991-1995. Chapter 7 uses the efficiency scores from the DEA model conducted in Chapter 6 and extends the analysis to determine the sources of inefficiency by using Tobit analysis. Chapter 8 briefly summarises each chapter; presents the limitations of the study and finally concludes.

CHAPTER 2. THEORIES OF OWNERSHIP AND REGULATION

2.1 Introduction

Are there differences in incentives between privately and publicly owned firms which lead to differences in performance? Under private ownership, management is directly responsible to shareholders whereas under public ownership, management is monitored by governments which act as agents for the owners, the voting public. It is often argued that privatisation, that is the change of ownership from public to private sectors, lead to improved performance since privatisation can lead managers to consider profit goals rather than the 'public interest' objectives.

However, the effect is not a simple transfer of objectives. Government monitoring and control of the firms are substituted by shareholder monitoring and it is important to note that a number of factors, including the ownership structure may affect the incentive structure of firm's managers. This chapter seeks to tackle the differing incentive structures by analysing the interrelated strands of theoretical literature. This attempt has particular importance for accompanying privatisation proposals.

We identify three strands of literature – property rights, public choice and regulation theories – which seek to investigate the possible effects of ownership and regulation on performance. We examine each strand in different sections and suggest any possible applications into the airlines industry. Section 2.5 concludes.

2.2 Property Rights Theories

The property rights literature (Alchian, 1965; and Alchian and Demsetz, 1972) views an organisation in a 'team' in which an interdependence among individual members of the team is established with contracts and monitored by management. In such a situation, it is usually difficult to 'meter' individual efforts, therefore this demands a specialised 'monitor' who can ensure that individual members do not 'shirk'[2]. Where the monitor prevents the shirking problem in a team, the result is high productivity and low cost. However, this task can be performed efficiently when management has clearly defined incentives[3]; otherwise it is highly likely that there would be suboptimal monitoring effort, thus inefficiency.

The owner / manager of a small firm may have incentive to prevent 'shirking' and other activities which may increase costs of production. Any inefficiency within the firm may directly affect his residual income, thus reduce his pecuniary and non-pecuniary incomes[4]. On the other hand, in a large firm, ownership and control are in different hands. This may change the objectives, since the property rights to control resources is given to management whereas the right to benefit from residual income stays with the owners. It is the responsibility of the owners to impose pressure on management to monitor factor inputs or output efficiently.

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[2] Shirking is the disability to show maximal effort in working.

[3] Incentives are provided in terms of a) 'prices' which take the forms of productivity and profit sharing schemes, and b) directives and control procedures which can be related to different techniques disciplining and job specification procedures (Millward and Parker, 1983).

[4] Pecuniary items include different forms of financial receipts and non-pecuniary items are other rewards, which arise from pleasant working environment.

Turning to public and private firms[5], Alchian was the first to note the difference between these two ownership types as the high cost which public ownership generates on the transfer of property rights. A taxpayer is unable to sell or exchange property rights, whereas a shareholder in a private firm can sell his shares, and thus capitalise his profits.

What are the implications of the limited transferability of property rights in both ownership types? Firstly, specialisation in ownership can be encouraged to achieve an increase in welfare when the ownership is transferable. Alchian (1965: 825-828) notes the two functions of specialisation in ownership as "controlling and risk bearing" and claims that specialisation of individuals in those functions would produce comparative advantage effects and enhance efficiency. This is due to the fact that there are differences among individuals with respect to abilities and knowledge. Alchian (1965) argues that private ownership guarantees that specialisation of ownership reduces monitoring costs by allowing ownership by those who have special skills in the areas where they are knowledgeable. In contrast, in public ownership, specialisation possibilities are eliminated as all members of the state have only an equal and very small share in a public enterprise and are unable to sell this ownership.

Secondly, in private ownership, the monitor or management acts as the residual claimant to the profit and loss of the firm, thus providing an incentive to maximise profit. However, this is not the case for public ownership, in which rights to profits are diffused and uncertain. Bureaucrats or politicians are usually prevented from

[5] The US literature on property rights assumes a polarisation, i.e. public and private firms. However, there is another form of ownership, i.e. agencies, which operate commercially but remain responsible to a government Minister (See Hartley *et al,* 1991 for more details).

directly benefiting from the residual. For example bureaucrats may only have an incentive to enlarge the size and scope of the public enterprise since this may increase their power in civil service. Similarly, politicians may have an incentive in promoting low prices and high employment to maximise votes. As a result, there may be no direct incentive for government to enforce the management to minimise production costs and maximise the residual (Millward and Parker, 1983). Public management then feels secure from the consequences of any future gains or losses and they can neither be rewarded nor punished, as can their private counterparts.

Thirdly, the inability to transfer public ownership attenuates property rights of the public. For example, the managers of public firms have the rights to acquire and allocate resources whereas the government has the rights to capitalise profits and losses in a public firm. At the end, the final owners, the tax payers that are represented by the government are not directly affected by the appropriation of profits and losses by the government. Since there are no marketable shares, the citizens cannot react by selling their shares when the firm performs poorly. The only choice they have is either to leave the country or vote other politicians who promise to change the public enterprise. These circumstances, however, imply high transaction costs, which decrease the incentive of the citizens to monitor. Since the citizens may find it highly costly to monitor public managerial behaviour, this may increase discretionary and opportunistic behaviour by the managers and bureaucrats. Hence, 'for any given level of output, public firms will have higher total costs than will private firm and may even use more of all inputs' (De Alessi, 1974:9). In contrast, shareholders can sell their shares when they are not pleased with the firm's performance.

Finally, the non-transferability of ownership weakens the monitoring effects of the capital market on the performance of government managers. When a public enterprise does not engage in a competent business strategy, it is affected exactly the same way as is the private firm in final product markets. However the consequences for discretionary behaviour of managers differ. This is due to the fact that the financing of public enterprises is different compared with that of the private firm. (Davies and Brucato, 1989). De Alessi (1974:7) put this view as follows: "the managers of political firms ...are less constrained by market considerations ... and find it easier to obtain subsidy and to mask bad management under the guise of fulfilling other 'social' goals. Government firms ... can survive for long periods ... [with] grossly inefficient management."

The above discussion on the restricted transferability implies that there are differences in incentives between public and private firms arising from the ability of owners to monitor managers. (Alchian, 1965; Furubotn and Pejovich, 1972; De Alessi, 1980). One can summarise that under public ownership, management is monitored by government, which in turn can be considered as an agent of the citizens or the voting public. Under private ownership, the arrangement for monitoring the performance of management is conducted by shareholders. It is claimed that in private ownership, there is a direct relationship between shareholders and managers whereas in public ownership, there exists more complicated links (Yarrow, 1989: 55).

A useful way of analysing such relationships is from the perspective of agency theory[6] (Ross, 1973). This could be particularly of use in the context of comparison between public and private firms since both ownership types involve similar principal-agent problems but different monitoring structures.

The principal-agent problem arises when the objectives of principals and agents diverge or any conflict of interests occur. In an agency relationship, 'principals' should provide incentives to 'agents' to ensure that agent acts in principal's interest. When the principal does not have full information about the behaviour of the managers, monitoring problems in a firm are likely to occur. Further, the principal may not have the incentive to devote time and resource to monitoring the agent for they do not benefit directly from the performance of the firm.

A large firm in private ownership is managed by agents. A shareholder in a joint stock company is not necessarily the sole owner, he is not engaged in the 'team' activities as members of the production process, therefore he is at an information disadvantage, which leads to sub-optimal monitoring. Even where there is no such information asymmetry, individual shareholders may not have incentive for monitoring given that any improved performance will not only benefit themselves but also the other shareholders. However, in this case, it is often argued that the market for corporate control in which the capital markets function as a monitoring mechanism, will discipline the managers with threats of take-over and bankruptcy. Since the shares are marketable, the private shareholder can, by selling shares, capitalise his profits and losses (Alchian and Demsetz, 1972).

[6]The issues involved in agency and property rights literature are similar, but they have developed independently.

Large publicly owned firms also have principals and agents. The voting public acts as principals and delegate powers to ministers (agents); and ministers become principals and delegate powers to the managers of the public firms (agents). Hence the managers act as agents of government and, more indirectly, the voting public. Ultimately, government becomes responsible for monitoring managerial performance. Since there are no marketable shares, and hence, no market for corporate control, it is claimed that managerial incentives may be weaker than in private firms. Further, there exists information asymmetry for the voting public who wants to monitor the performance as it may have direct interest either as consumer of the final products or as tax payers. Nevertheless, as Yarrow (1986:332) puts it "the market for political control is highly imperfect and the incentives for efficient *monitoring* of public enterprises can, as a result, be rather weak." Hence, higher monitoring costs will reduce incentives to minimise costs and increase inefficiency.

In 1970s, cost minimisation in public enterprise has had low priority. Rather social objectives were imposed on public enterprises. This could, however exacerbate the cost minimisation problem by leading public enterprises to inefficient means of production. Experience in the UK demonstrated that governments interfered in public enterprises to specify input purchases or insisted on a re-timing of investment (Utton, 1986). Perhaps, the best example could be given from airlines industry since costly intervention took place when governments enforced the aircraft purchase from domestic manufacturing industries. According to Pryke (1981:132), the reason of British Airways' high operating costs was related to the enforced aircraft procurement policies[7]. However, intervention was usually justified on the grounds that aircraft purchases were large capital investments, which may affect the surplus/deficit on the balance of payments. (Rees, 1984:20).

Even though public enterprises are criticised for not seeking cost minimisation, according to managerial theories, the same problem could be prevalent in large private firms (Tirole, 1988:36-55). Therefore a high degree of managerial rent seeking might be expected in these industries. The property rights literature however is rather optimistic about the disciplining power of capital markets on private firms, which could bring higher managerial effort.

Nevertheless, when Grossman and Hart (1980) questioned the role of capital market on performance, they found that the market for corporate control generated a number of significant imperfections. For example, due to transaction costs and free rider problems, capital market pressure may not be a strong factor for dispersed shareholdings. Any small shareholder may underestimate his sell or hold decision on increasing the market value of his company if he receives an offer from a raider. Therefore he may prefer not to sell his share and still benefit from the change in control. Hence if many shareholders act in the same way, no successful takeover can take place. Compulsory acquisition rights in British company law aim to overcome the free-rider problem (Vickers and Yarrow, 1988); but implementing them requires high regulation costs.

Furthermore, among others, the relationship between company performance and the likelihood of takeover has been empirically investigated by Singh (1971, 1975).

[7] Air France and Lufthansa are other good examples of this.

Singh showed that the chance of takeover was inversely related to the valuation ratio - that is, the ratio of the stock market value of a company to its book value. Singh found weak support for the notion that a relative poor performance increases the chance of takeover threats. In contrast, the probability of a takeover was found to be inversely related to firm size, suggesting that larger firms are less vulnerable to takeover bids.

The role of capital market pressure is of crucial importance for the post privatisation process. As Domberger and Piggott (1986:150) clearly emphasised "efficiency gains from privatisation arise essentially out of the interaction of product and capital market pressures". The size of such privatised firms as British Telecom and British Airways in the UK raised serious concerns since they were sold without any significant size change, which mitigated the possibilities of exposing these firms to capital market pressures. As Utton (1986:205) put it, "the more protected the newly privatised firm is, naturally the higher the selling price will be". If we consider British Airways, the increased sale price is due to landing rights and international arrangements underwritten by the British government (Veljanavoski, 1989).

It is important to note that the 'paradox of privatisation' (Kay and Thompson, 1986) in the UK is that the increased competition pressure on managers in industry makes it extremely difficult to obtain the support of public sector managers for ownership transfer. In order to ensure support, therefore, high salaries are offered to existing managers and competition pressure is reduced in the post-privatisation period by leaving the firms largely intact.

Given that capital market pressures are, as mentioned earlier, usually weak to achieve an increased efficiency in the privatisation process, the role of liberalisation, that is the promotion of both potential and actual competition by removing restrictions on entry, is likely to be of crucial importance. This concern has led economists to switch their attention to the role of competition or the market structure rather than ownership transfer per se. One view argues that: "competition and regulation are likely to be more important determinants of economic performance than ownership. Hence, where there are deficiencies in these areas, the policy priority should normally be to increase competition and improve regulation, not to transfer productive activities to the private sector" (Yarrow, 1986:364).

Millward and Parker (1983) surveyed the existing empirical work on public versus private ownership and highlighted the importance of competition over ownership and declaring that inefficiency is not an inherent characteristic of public ownership. They concluded that "there is at present no general support for the proposition that public enterprises are less cost efficient than private firms".

Another view which is associated with testing the property rights theory, claims that ownership does matter because public ownership is fundamentally inefficient (Veljanovski, 1987). According to this point of view, privatisation is more than the simple transfer of ownership and involves the redefinition of a complex bundle of property rights, which affects a firm's performance by changing incentives and creating a new penalty-reward system.

In order to make the case for privatisation, many scholars have compared the performance of private and public firms producing similar goods and services. Has the evidence confirmed the property rights theory? Boardman and Vining (1989) tested performance of public, mixed and private firms in competitive environments by using a variety of indicators in terms of profitability: return on equity, return on assets, return on sales and net income. In contrast to Millward and Parker (1983), they found that after controlling for a wide variety of factors, private firms perform substantially better than similar mixed and publicly owned enterprises.

2.3 Public Choice Theories

The Property rights approach focuses on the differences in incentives between public and private firms arising from the ability of owners to monitor management and the problems that appear when the goals of owners and their agents, the managers diverge. The public choice[8] approach concentrates on political coalitions and their effect on cost minimisation. In short, the main emphasis in both approaches lies in the incentives to reduce costs, where the concern is on the incentives of owners in the property rights and on the incentives of bureaucrats and politicians in the public choice literature.

Though these two approaches have similarities in several aspects, they differ in the sense that the principal emphasis of the public choice is that the public sector lacks sufficient competition compared to the private sector. Competition can increase productive and allocative efficiency for private goods in a market economy. However, the political process, which governs public resource allocation, can be highly inefficient in the absence of clear motives and the disciplinary powers of competitive markets. The budgeting process, for example, is handled between public managers and politicians in a sequential process of negotiation in which incentives may seldom exist to ensure that budgets are allocated efficiently. This process can be

[8] See Mueller (1976) for the formal definition of public choice theory.

regarded as a series of principal-agent relationships among voters (taxpayers), politicians and bureaucrats. In the end the decision on budget allocation is made.

Such important decisions made within public organisations, however, raise important questions on how these decisions are made and how well the political process serves the interests of taxpayers. Studying non-market allocations and decisions is pioneered by the public choice school, associated with the names of Buchanan and Tullock. Particularly, they focused on the importance of non-market decision-making within public sector bureaucracies.

Throughout this section, bureaucracy simply refers to public enterprises and bureaucrats refer to public sector managers. The concept of bureaucracy is formally defined in Jackson (1982: 5) as:

> a certain kind of formal organisation, characterised by a complex administrative hierarchy, specialisation of skills and tasks, and prescribed limits on discretion set forth in a system of rules and impersonal behaviour with respect to clients.

Within the public choice framework, government and its agencies (bureaux) are known as the end results of individual behaviour. The choice process is achieved by individuals, who 'shape and guide the outcomes of government'. This contradicts the view which sees the public sector as a 'super individual' who pursues the 'public interest' (Jackson, 1982).

Economists' interest in bureaucratic behaviour was initiated with the seminal work by Niskanen (1971). This influenced a body of literature on bureaucracy (De Alessi, 1974; Jackson, 1982). Niskanen developed "a large set of hypotheses concerning the level of government budgets, the productive efficiency of bureaus, the level of output of government services, the combination of factor inputs, and the effects of the structure of the bureaucracy and review process" (Niskanen, 1975: 64). More specifically, in Niskanen' model of bureaux, the bureaucrats

a) act to maximise budgets rather than profits;

b) dominate the government with their informational superiority.

As a result of this monopoly power arising out of asymmetric information, Niskanen's model predicts that the bureaucrat will maximise his budget and output levels that are excessive relative to the social optimum. This is based on the behavioural assumption that bureaucrats act out of self-interest for utility maximisation. Therefore the factors which motivate decision-makers in the private sector are likely to influence the bureaucrats in the public sector. These are called the "three P's": Pay, Power and Prestige.

Accordingly, bureaucratic public managers will maximise those "three P's" by adopting pricing rules and investment patterns which maximise the number of people working for them and the amount of budget they can decide upon. Therefore, bureaucrats in public firms, compared to the private sector managers, 'push' their programs more strongly (Borcherding *et al.*, 1982:137).

It is important to note that, along with utility-maximising bureaucrats, there are also vote-maximising politicians, as described by the public choice theorists (Buchanan and Tullock, 1962) who have interests in the way public firms are run. Even though their objective function includes the voter preferences through the political process, vote-maximising politicians may not necessarily serve the public interest. Mainly, the incentive of politicians is to balance costs and benefits to obtain positive benefits to their constituency (Couch *et al.*, 1992). This may lead to political optimisation. This can work against cost efficiency.

Relevant examples of political optimisation include the attitudes of governments to liberalisation reforms in the European aviation. There are very close links between airlines companies and governments in most European countries. Governments own the majority stake in their 'flag carriers' for national interests. Although politicians usually welcome the possible outcomes of liberalisation, i.e. lower prices, improved services and greater efficiency, they are mostly reluctant to risk the survival of their airlines in the post-liberalisation period. It took a long time for European governments to balance the cost and benefit of the reforms before implementing the European airline liberalisation process (McGowan, 1993:85).

Within the realm of public choice, a model commonly used to explain political behaviour and decision-making is that of the median voter (Bergstrom and Goodman, 1973). Voter preferences are represented by a symmetric distribution, which occupies the median and hence the dominant positions. In a competitive political environment, politicians need to act in the interests of the median voter. Thus, their behaviour minimises allocative inefficiency. Nevertheless, the assumptions implicit in the median voter model can be unrealistic in complex voting systems where there may not be any dominant median voter (Jackson, 1993).

An alternative view to the public choice approach has been developed by Fiorina and Noll (1978) and Posner (1984) among others. They argue that bureaucrats and politicians act in the public interest and are satisfied with a very well done job like the successful private firm managers. Since both public and private sector managers are from the same social and cultural backgrounds, they also possess similar values towards their jobs.

2.4 Regulation Theories

The final strand of literature is drawn from the literature on regulation theories. This has motivated the deregulation movement in the US and investigates the effects of alternative regulatory regimes on private firms' incentives. Like the public choice approach, the origins of deregulation were based on notions of government or bureaucratic failure. Regulations were originally introduced for the 'public interest'. Governments concern centred on improving economic efficiency by identifying and correcting market failure which may arise from two main sources: the abuse of market power by monopolies and oligopolies and the existence of externality problems, both of which may lead to market imperfections (Bator, 1958).

In addition, there are other motives such as asymmetry of information in connection with prices and product quality, unemployment, income distribution and the strategic industries. In the case of air transport, for example, concern on safety and financial aspects induce governments to introduce economic controls. These are mainly pursued to serve the public interest by ensuring that air safety standards are maintained for all users. Standards are set and industry is required to conform. Further, governments limit entry into the industry in order to remedy the financial instabilities which may arise from excessive competition. To undertake these tasks, regulatory authorities were established in many countries [9].

A number of studies during the 1960s and 1970s questioned the excessiveness of regulatory constraints, which were established, with the assumption of increasing efficiency. A seminal article written by Averch and Johnson (1962) examined the incentive behaviour of a monopoly, which is subject to 'rate of return' type regulation. The monopoly is regulated due to the concern that it can raise prices above marginal cost and earn excessive returns on its assets. Under the rate of return regulation, the firm has an incentive to use more capital to increase the revenues allowed and to expand to 'unprofitable new lines'. Thus the capital/labour ratio of this regulated firm is excessively high for its level of output. The authors apply their theoretical analysis to the telephone and telegraph industry and find that these industries are excessively capital intensive. Averch-Johnson (A-J) thesis on 'regulatory bias' had been relevant to evaluating market behaviour in other industries.

Due to the shortcomings of this type of regulation, the UK adopted 'price cap' or RPI-X regulation (Littlechild, 1983) for the newly privatised industries. RPI is the retail price index (i.e. the rate of inflation) and X is a number specified by the government. The aim of this regulation was to provide incentives for cost minimisation. It was believed that price cap regulation would be more effective in the industries with many firms in which technology is changing slowly (Beesley and Littlechild, 1989). However, it has been suggested this type of regulation may be less effective in maintaining service quality (Vickers and Yarrow, 1988).

[9] In 1938, the Civil Aeronautics Authority (CAA) and the Air Transport Licensing Authority were set up in the US and the UK respectively. The name of CAA was changed to Civil Aeronautics Board (CAB) in 1940.

In the early 1970s, Chicago school economists or public choice theorists initiated a strand of research, which regarded existing regulation as an outcome of political and economic processes. In the path-breaking article of Stigler (1971:114) the central thesis is 'as a rule, regulation is acquired by the industry and is designed and operated primarily for its benefit'. Stigler listed the main protective policies which an industry may seek from the state: direct subsidy, control of entry, tariff or quota and price fixing. The first two policies demanded by the industry are linked. Once the state offers subsidies, the industry asks for more control over entries through licensing to preclude the subsidies be dissipated among too many firms. For example, for many years the CAB subsidised the airlines for social reasons[10] and continued its control over entries to prevent the subsidies from attracting new entrants.

Stigler's theory, which was also known as 'capture theory', was extended by Peltzman (1976) into a 'general economic theory'. The focus is on 'self-interested political behaviour and the importance of organisation and information costs.' The determinants of supply and demand are used to explain the presence of regulatory schemes. Regulation is perceived as being a commodity which can be purchased and sold. The regulator is assumed to provide a cartel management service, which can be bought by well-organised groups, i.e. the producers.

Additionally, it is argued, that in reality, 'the costs of regulation probably exceed the cost of private monopoly' (Posner, 1974). When the regulatory agencies constrain the price levels, they are most likely distort the supply and demand. Thus the input prices which will be reflected onto the secondary users as increased prices.

[10] For example, airlines were subsidised to provide service to small communities.

Since the monitoring of a firm's conduct and performance requires vast amount of information, the administration and monitoring costs are also likely to be high. Once the complexity of regulation grows, such costs will increase even more.

In the US airlines, for example, the regulatory constraints on price led to an increase in non-price competition, thus an increase in the costs of the industry. Non-price competition forces airlines to compete in terms of service quality, i.e. increased flight frequencies, wider range of meal services, seat spacing, entertaintments, etc. It was shown by Bailey and Panzar (1981) that in some cases, these services were offered to those consumers who were not willing to consume them. Also, the increase in flight frequencies resulted in low seat occupancy rates, i.e. low load factors.

However, in the mid-70s, a reform movement towards deregulation in air transport was presented after a consensus was reached that the political and economic benefits of airline regulation had attenuated. The contestable theory (Bailey and Panzar, 1981; Baumol *et al.* 1982; Bailey *et al.* 1985) is remarkable in providing policy debate on both regulation and anti-trust. Subsequently it has been frequently cited as an economic rationale for deregulation. With the development of this concept, empirical studies in most industries or markets have shown important scope for competition. The idea behind this theory was that potential competition would be sufficient for the firms to price compete regardless of the type of market.

Although perfect competition, that is, many firms and consumers who have perfect information about the conditions in the market with free entry and exit, is desired by economists, the advocates of contestable theory point out that it is more general than the theory of perfect competition since contestable markets do not require many firms to achieve optimal performance. For entry and exit conditions, Baumul *et al.* (1982) assumed that entry is absolutely free and exit is absolutely costless. Since sunk costs are also assumed to be zero, these costs, will not deter a firm's entry into the market or impede its exit from the market. Both actual and potential firms will face the same production techniques and market demands. Therefore, the cost functions of these firms will be identical. New entrants are predicted to undercut the incumbent's prices by forcing the latter either to reduce the costs of production or exit the market without incurring costs. Therefore all firms are forced to be productive efficient due to the threat of competition or what Baumol terms as 'hit-and-run' competition. The implications of contestable theory for the airlines industry are detailed in Section 5.5.3.

2.5 An overview of privatisation, liberalisation and deregulation

In narrow terms, privatisation is the sale of public sector assets to private sector. However, privatisation is more than the simple transfer of ownership. It provides a change in the relationships between those responsible for the decision-making and the beneficiaries of residual profits. In fact, this is a change in the allocation of property rights which leads to incentive differences for management. Hence this could influence both managerial behaviour and company performance (Vickers and Yarrow, 1988). According to property rights approach, the ability of shareholders in private sector to trade their shares forces managers to feel responsibility to manage efficiently and pursue high profits. Another intellectual strand, public choice approach, also suggests that public sector is less efficient than private sector. Specifically, public choice theorists argue that bureaucrats have similar tendency as individuals to maximise their interests rather than the public at large. Therefore the result could be an inefficient public sector.

However, it is important to note that along with ownership factor, product market competition and the degree of regulation are significant factors which determine managerial behaviour. To define regulatory reforms in the US and the UK respectively, deregulation and liberalisation concepts are used. In the airline literature, these concepts are used interchangeably. The idea of deregulating or liberalising a market is related with the withdrawal of state from its interventionist role to entrepreneurial spirit (Weyman-Jones, 1994). Both public choice and regulation failure theories approach the liberalisation or deregulation from the public interest perspective. According to public choice, utility-maximising individuals in firms pursue rent-seeking behaviour and demand for political favours in the form of rents or economic regulations. These could be entry controls which aim to favour existing firms. Alternatively, regulation theories suggest that the regulators in their operations are 'captured' by the industries not the general public interest.

2.6 Conclusion

In this chapter, we reviewed the theoretical literature on the possible link between ownership, regulation and performance. These theories in general suggest the superiority of private firms over public firms. A common view is that lack of profit motive and competition in public firms reduces the incentives to cut costs, and thus increase efficiency. This is subject to criticisms since private ownership does not always guarantee that managers would act in the best interests of owners or shareholders.

The issue of the relative efficiency of public and private firms was extensively studied in particular to justify the privatisation proposals. It is evident that the empirical literature is also inconclusive to find superior private firm performance. Rather, competition and regulation may be important determinants of a firm's performance. Nevertheless, a more solid conclusion could only be reached by an empirical analysis. The coexistence of public and private airlines in the European airlines industry offers a good opportunity to find out the determinants of performance in a liberalised environment.

CHAPTER 3. PREVIOUS STUDIES

3.1 Introduction

This chapter reviews the previous empirical literature on the performance of airlines industry in which major publicly owned and privately owned airlines coexisted, and usually operated under highly regulated markets. There is an extensive literature on airlines studies, because airline performance has always been the focus of attention of governments, institutions and individuals. Naturally, either as owners or regulators, governments have an interest in the performance of their own airlines. Performance is also of primary concern to the management of airlines. Management may use performance measures as tools with which to plan and control the prcesses of the enterprise. Moreover, investors, lenders and shareholders are all expected to concern themselves with the efficiency and productivity of their companies.

Some general comments can be made on this literature. Firstly, it is mostly based on data regarding the US domestic airlines deregulatory experience, which has been used as a laboratory experiment for most studies. These studies either concentrate on measuring the effects of US deregulation or compare the productivity differences between US airlines and European airlines that operate under deregulated and heavily regulated environments respectively. Some comparative studies, however, consider the impact that different types of ownership forms have on performance. Particularly, the performance of Australia's public and private airlines was extensively studied. Later, Australia's two airlines were compared with those of the US. As far as we are aware, none of the published studies is devoted solely to the role of ownership and liberalisation policies on European airline performance. Secondly, many studies use data from the early 1980s and thus are out of date. The likely reasons are that airline statistics are usually published with a considerable time lag. Data may well be available from annual company reports, but may, perhaps, be time-consuming for researchers to reach the report of each company. Finally, most studies use unsophisticated measurement techniques. Mostly, these include 'conventional indicators (partial and total factor productivity, average cost, and financial ratios) of performance which are restricted to measuring the achievement of allocative objectives but they fall quite short of the true concept of efficiency' (Pestieau, 1989:30). Sophisticated methods, which go beyond such measures, only emerged from the late eighties. These include linear programming (LP) and econometric techniques and measure the technical, allocative and overall efficiency by estimating frontier and production functions.

The review in this chapter contains the methodologies used in various studies with particular reference to the type and period of the sample data, the variables, aims and findings of the studies. The studies are classified under seven broad headings according to the type of techniques used. These are namely, ratio analyses, multivariate analysis, value added analysis, unit costs and labour productivity analyses, total factor productivity analyses, parametric and non-parametric analyses.

3.2 Ratio Analyses

Comparisons between international airlines using global indicators often appear in the popular press. For example, efficiency is usually measured in physical terms, such as total available tonne kilometre (ATK) per employee or in economic terms, cost per ATK. These ratio measures are readily calculated from the latest available information, but they need to be treated cautiously for they do not represent a firm's total activities (Doganis, 1986). This section reviews four studies of airline performance which use ratio analyses. The first two compare the performance of two Australian carriers to test the property rights literature. The remaining two evaluate the efficiency of these two Australian carriers against those of the US.

Davies (1971, 1977) aimed to test the hypothesis that a private firm was more efficient than a similar public firm. The author proposed that the experience of Australia's two intercontinental airlines could be considered for this purpose due to the existence of similar public and private airlines. These airlines both operated under the Commonwealth Government Policy which was designed to make these two firms similar in many respects. They used similar fleets, networks, routes, as well as identical ports of call and frequencies of stops. The Government strictly regulated the entries and the prices charged by the two airlines.

The only difference was that one airline was public (Trans Australian Airlines (TAA)) and the other was private (Ansett Australian National Airways (Ansett ANA)). Given the similarities, Davies argued that any differences in observed productivity should be attributed mainly to differences in the performance of labour.

As measures of productivity, Davies used the following three ratios:

1. The tons of freight and mail carried to the number of employees
2. The number of paying passengers carried to the number of employees, and
3. The revenue earned to the number of employees.

The data used in his (1971) and (1977) studies covered the period of 1958-1969 and 1958-1974 respectively. Davies found in both of these studies that the productivity results obtained for the private airline was always greater than the public airline. For instance, the average number of passenger carried per employee by the private firm was over 20 per cent higher than the average of the public firm in each year observed. According to Davies, this evidence proved that the private airline was more efficient than the public. His contention was based largely on the fact that the property rights associated with alternative forms of organisation bring different incentives to the managers or owners of private and public firms.

Davies' proposition was challenged by Forsyth and Hocking (1980) and Jordan (1982). Forsyth and Hocking were highly critical of the methodology used in Davies' studies. They argued that there were substantial problems with the use of such ratios because they did not differentiate the flight stage lengths among airlines. To eliminate this bias, they used the productivity ratios of passenger-kilometre per employee and total tonne-kilometre (freight and passenger) per employee to measure overall productivity. The sample included the period 1964-1976.

Contrary to the findings of Davies, they found similar productivity results for both public and private airline. Furthermore, they made a brief comparison between three domestic US trunk carriers and the two Australian carriers. Again they used the ratio of tonne-kilometre per employee for only two selective years, 1961 and 1975. The results showed that the US airlines, which operated in a less regulated environment performed better than the Australian two domestic airlines. Moreover, they criticised Davies' findings for focussing solely on the role of ownership on performance improvement. Instead, they underlined the role of the regulatory environment in enhancing performance and suggested that the reason for Australian airlines producing similar results was the regulatory system in which they were operating.

Jordan (1982) extended the analyses in the previous studies by investigating both the effects of the role of regulation and of government ownership on performance. He used similar ratio analysis to measure the performance of two Australian carriers along with the US and Canadian ones. The sample included fourteen airlines operating under regulatory monopolies. These were two Canadian mainline carriers, five Canadian regional carriers, three selected US trunk carriers, and four US local service carriers.

First, these fourteen carriers were compared with the four major intrastate carriers operating under regulatory duopolies whereby these systems were less regulated systems and allowed new entries. Second, Jordan compared the performance of government owned Air Canada with the privately owned Canadian and US airlines within regulatory monopolies. The time period for these comparisons included the years between 1975 and 1978. Finally, the author made an extensive analysis for the two Australian airlines for the period between the period 1974 and 1980.

Jordan suggested that identical regulatory environments produced similarities in airlines performance in terms of fares, operating expenses and profits. He utilised a number of performance indicators such as fares per mile, total operating costs, operating ratios, revenue tonne-miles per employee, total labour payments, employee payments per revenue tonne-mile and fuel; prices; and utilisation. With the aid of a series of graphs, he plotted the above ratios against the average stage length, which was regarded as a significant operating variable.

As regards fares, the results showed that federally regulated fares were very similar for both US and Canadian mainline carriers, but they were 50%-100 % higher compared with the less regulated intrastate carriers' regular fares per mile. Moreover, the operating expenses of US trunk and Canadian mainline carriers were higher than that of the US intrastate carriers'. Additionally, the profitability of US intrastate carriers was as high as the high-cost regulated carriers. In order to explain the differences, Jordan examined the expenditure on two major inputs: labour and fuel. The results showed that there were great differences between the cost and expenditure of labour among the airline groups. The intrastate carriers, for example, enjoyed substantial competitive advantage due to lower average employee wages and higher employee productivity. However, this group paid the highest average prices for the fuel.

In conclusion, the performance of federally regulated airlines in the US and Canada produced similar results regardless of ownership, whilst the performance of these carriers differed substantially from that of the US intrastate carriers operating under less regulated systems. Furthermore, contrary to Davies' findings, Jordan concluded that there was no difference between the privately owned airlines and the government owned ones when they operated under regulatory monopolies. This finding was also valid for the Australian carriers. Finally Jordan argued that when regulations in the industry were eliminated, the performance difference owing to ownership could arise.

3.3 Multivariate Analysis

The study by Kirby and Albon (1985) also challenged the findings of Davies (1971, 1977) on Australian two airlines. The authors argued that there were deficiencies in the previous studies regarding Australia's domestic airlines because the techniques employed were not adequate to deal with the question of relative efficiency. They claimed that the ratio measures were only able to measure one facet of a firm's operations. Therefore they used multiple regression techniques to estimate an econometric model which aimed to address different aspects of the firm operations by allowing for any differences in operating conditions.

When an econometric model is correctly specified – that is, when all relevant explanatory variables are included, regression techniques can produce accurate results in examining and comparing different aspects of airline efficiency. Obviously, this depends a lot on the accuracy and validity of the data. This could, however, be problematic in cross-sectional studies, which may include different countries. The data should be consistent between the airlines as well as over time. It is important to note that econometric models may have also drawbacks in handling the multiple output industries, i.e. airlines industry.

Kirby and Albon (1985) analysed a sample, which included two major Australian airlines and eighteen US local service and trunk airlines over the eight-year period from 1971 to 1978. The dependent variable in the model was the total operating cost of each airline. The explanatory variables were: the number of airports served; average stage length; average load factor; average aircraft size; the average numbers of departures per port; the proportion of total output, that is passenger traffic and that is operated with scheduled services; the factor price for labour; and the factor price for fuel. In addition, four dummies were used. The two were for the two Australian airlines and the other two dummies captured the effects of the US deregulation in the years 1977 and 1978.

Estimating the model using ordinary least squares, Kirby and Albon (1985) found that the private airline performed slightly better than the public Australian airline. The operating costs of the latter appeared 5% higher than the private one. They pointed out the difference between the cost efficiency of Australian carriers and the US carriers. The total operating costs incurred by the Australian airlines appeared to be the order of 55 percent higher than those of the US airlines before deregulation. The overall variation explained by the model is 0.998.

Kirby and Albon (1985:539) concluded that "while there appears to be some theoretical and empirical evidence that the state firm is less efficient than the private one, this difference is likely to be small compared with the inefficiencies of both operators which are due to the current policies of economic regulation".

3.4 Value Added Analysis

Morrell and Taneja (1979) contended that value added productivity, in terms of net value added per man-year of labour and capital equipment, was a better measure than the conventional performance indicators. Valued added measure was used to remove the effects of changes or differences in productivity that supply inputs to the industry under evaluation. Valued added measure could then be defined as the total value of output, less the value of all purchases of goods and services from other firms.

Further, the authors suggested that depreciation could also be eliminated from output and labour could be measured in terms of the average number of employees on the airline's payroll over the year, or "man-years". This measure may be useful to evaluate productivity for the studies undertaken in a single country. The different bookkeeping practices in various countries, however, may cause more difficulty to obtain the 'net' airline value added.

Morrell and Taneja used the value added concept of productivity for a sample which included fourteen US and fourteen European scheduled airlines for the year 1975. They developed regression models in order to explain productivity variations among the airlines whereby large variations in productivity could be explained by differences in the level of service, demand patterns and route characteristics. The logarithm of productivity was regressed on the following explanatory variables: level of service reflecting the two principal components- convenience and choice; specialisation- the percentages of charter and freight traffic; seasonality of traffic; traffic density over route sectors; traffic density over stations; average annual load factor; average stage length; ratio of sectors to stations; and topological network length to diameter.

The empirical findings showed that the productivity of European airlines was lower than that of the US airlines. Nevertheless, European airlines like Lufthansa, SAS, Alitalia, and Swissair had high levels of productivity similar to the US carriers whereas the lower level of productivity for the rest, could be explained by the differences in the level of service offered, demand patterns and route characteristics. Moreover, as regards route patterns and networks, Morrell and Taneja suggested that the European airlines could raise their productivity levels by 26 % by changing the network shape. This could be influenced by a more liberal policy in operations and traffic rights in the EC along with greater specialisation and consumer choice, with higher frequency and multi-services. The overall variation explained by the model is 0.84.

3.5 Unit Costs and Labour Productivity Analysis

In the field of economic analysis, there is an increasing consensus that 'productivity is the ability displayed by production factors to produce' (Thiry and Tulkens, 1989:10). Any deviation from this, then leads to productivity losses or gains. When only one production factor is considered, productivity is called partial. It could be productivity of labour, capital or any other input.

There are, however, two main shortcomings from using labour productivity as a performance measure. First, it may not accurately reflect the possible interactions between labour and other inputs. Second, all labour categories are considered to have the same impact on productivity (Windle and Dresner, 1992).

A total factor productivity (TFP) measure, which could assess all relevant production factors, is always suggested as a remedy to overcome the shortcomings of labour productivity. TFP is conducted when an entire diagnosis of the firm's behaviour is pursued. This is detailed in section 3.6.

This section reviews the study by Tretheway (1984) which used partial productivity measures to examine the performance of international airlines. This work was only a part of a large project which aimed at gathering evidence from the diversifying experiences of international airlines. This included the data on the role of regulation, ownership, industry organisation and taxation/subsidy for each airline. Models explaining carrier performance were then estimated using regression analysis. The sample covered a cross section of one hundred and ten scheduled world's carriers for the year 1981.

Two measures of performance were used in this study. The first measure was labour productivity (LP). It was computed as the ratio of output Y, to labour input L. The second one was unit costs and was computed as total operating costs divided by output. The Cobb-Douglas functional form was used rather than a linear functional form due to the large variation of the variables in the data set (Tretheway, 1984). The models developed aimed to explain labour productivity and unit costs in terms of three operating characteristics: output, trip length, and load factor.

The regression results showed that all three operating characteristics were positively correlated with labour productivity and negatively correlated with unit cost. Further, the trip length had a strong and significantly positive effect on labour productivity. As expected, labour productivity and unit costs had an inverse relationship. Generally, the results were consistent with Caves *et al.* (1981) where a similar analysis for airlines was conducted using the data of a single country, the US. The overall variation explained by the model is 0.47.

Additionally, the results revealed that public airlines had a significantly lower level of performance than the private ones. However, the author advised not to draw any conclusion from these results owing to the simplicity of the models that the public ownership *per se* was the cause of the lower performance. An alternative explanation could be that public carriers were charged with social goals rather than economic efficiency. In conclusion, it was emphasised that there was a need to control measures of carrier performance for social goals.

3.6 Total Factor Productivity (TFP) Applications

There is an extensive literature, which increasingly focused on measuring TFP, where productivity can be compared across firms or industries, over time or across firms over time. The basic idea behind productivity is a comparison between outputs and inputs. More specifically, TFP measures how a set of inputs could be transformed into a set of outputs.

In order to handle the problem of multiple inputs and outputs, the index number method is proposed (Diewert, 1976). This method aggregates the set of inputs and outputs into single numbers by weighting them individually. The weighting procedure for inputs and outputs are different. Individual inputs are weighted by their share of total production costs whereas individual outputs are weighted by their share of total revenue for a firm. TFP is then obtained by dividing total aggregated output by total aggregated input. While the resultant

TFP numbers allow for comparisons between firms as well as years, the major problem with TFP is that it could be time-consuming and costly to collect data and to conduct the relevant analysis.

This section reviews five TFP applications in airlines industry. Of the five, the first two are US studies. The remaining three include the comparison of international airlines.

TFP applications in airlines industry are highly popular. Caves, Christensen and Tretheway (1981) estimated the relative levels of total factor productivity (TFP) for the eleven US trunk carriers over the period 1972-1977 by utilising the index-number approach. Further, they investigated the sources of growth and differences in levels of productivity using regression analysis. TFP was computed as the ratio of total outputs to total inputs using the translog multilateral index procedure, as proposed by Caves, Christensen, and Diewert (1982a). The translog multilateral comparison of outputs of two airlines, k and l, was written as follows:

$$\ln \mathrm{TFP}_k - \ln \mathrm{TFP}_l = \sum_i \frac{R_{ik} + \overline{R}_i}{2} \ln\left(\frac{Y_{ik}}{\widetilde{Y}_i}\right) - \sum_i \frac{R_{il} + \overline{R}_i}{2} \ln\left(\frac{Y_{il}}{\widetilde{Y}_i}\right) - \sum_i \frac{W_{ik} + \overline{W}_i}{2} \ln\left(\frac{X_{ik}}{\widetilde{X}_i}\right) + \sum_i \frac{W_{il} + \overline{W}_i}{2} \ln\left(\frac{X_{il}}{\widetilde{X}_i}\right) \quad (3.1)$$

where Y_{ik} and X_{ik} are the output and input of type i for airline k respectively. R_{ik} and W_{ik} are the shares of total revenues and costs accounted for by output i and input i for airline k respectively. $\widetilde{Y}_i$ and $\widetilde{X}_i$ are the geometric means of input i and output i over all observations in the sample respectively. $\overline{R}_i$ and $\overline{W}_i$ are the arithmetic means of the revenue shares and input cost shares for airline k

respectively. The use of revenue shares as weights implies that the production structure showed constant returns to scale and the prices of outputs are proportional to their marginal costs (Caves *et al.* 1980).

The assumptions used in TFP are as follows (Oulton and Mahony, 1994: 26):

1. Each industry's technology is described by a constant-returns-to-scale (CRS) production function.
2. Firms maximise profits and are price takers in product and factor markets.
3. The production function for each industry is translog. Output is a function of intermediate input, capital input, labour input and the time factor.

To compute TFP, data on five categories of inputs and five categories of outputs were collected. The inputs were labour, fuel, flight equipment, ground property and equipment, and materials. The outputs were first class passenger-miles, coach class passenger-miles, charter passenger-miles, freight ton-miles and mail ton-miles. Adapting the formula above, labour input indices were constructed from fifteen labour categories. The weights used in the labour indexes were based on the percentage of total compensation realised by each of the fifteen labour categories. The second input, fuel was based on an index obtained from the number of gallons consumed and from corresponding expenditure. Flight equipment was computed as a multilateral index of eight plane categories. The index required weights that reflected the annual capital cost of each type of aircraft whereby this data was estimated by using the lease data available[11]. Using the perpetual inventory method, the real stock of ground property and equipment

[11] The estimated total capital cost was computed for each carrier and each year by multiplying the estimated lease payment with the number of planes. The total aircraft capital cost was then computed as the sum across the eight categories of aircraft.

was estimated. Further, the annual cost of using ground property and equipment was estimated by imputing interest and depreciation expenses adjusted for income taxes, property taxes, and capital gains. Finally, the “materials” category referred to a wide variety of inputs other than labour, capital and fuel. The quantity indices of materials was estimated by applying a price deflator to expenditures on materials.

Of the five categories of output, three categories of passenger service and two categories of freight services were selected. Indices in passenger services were based on revenue passenger-miles (RPM) whilst the two freight service indices were ton-miles of revenue freight (RTM). To complete the weighting procedure, the authors computed the share of each carrier’s total revenue accounted for by the five output categories.

More specifically, they investigated whether the large differences were due to the differences in total output, average stage length, load factor and capacity. It is important to note that, contrary to the findings of the previous studies, they discovered no evidence of any statistically significant relationship between average stage length and productivity performance. However, they did find that TFP was positively associated with load factor and output.

The study by Caves, Christensen and Tretheway (1983) built upon on the Caves *et al* (1981). They extended their previous study by including the local carriers into the sample, updating the time period to 1970-1980, estimating a pooled analysis of covariance model for both trunks and locals and ascribing productivity growth to specific covariates.

The methodology used in this study was exactly the same as in 1981 study. The index number procedures to compute the annual levels and growth rates of output, input, and productivity of each airline were applied separately for the trunk and local service carriers. The TFP was measured for the first five years of the transition (1976-1980) and the resulting performance was compared with that of the preceding years. Further, the authors differentiated between the two types of growth. The first was the growth due to the changes in quantifiable operating characteristics[12]. The second one was the residual, or unexplained productivity growth. This type of growth was difficult to quantify and occurs owing to the changes in regulation, managerial efficiency, and other factors. To discriminate between these two, Caves *et al* (1983) estimated an analysis of a covariance model. The TFP was taken as a dependent variable. Covariates were introduced for operating characteristics and binary variables were used to capture an average annual productivity growth, which was not explained by covariates.

The overall variation explained by the models for trunk and local services is 0.88 and 0.69 respectively. In the first five years of the transition to deregulation, the US airlines achieved very rapid growth in output and productivity. However, the industry experienced a decrease in both productivity and output in the year, 1980. The results of this study confirmed the findings of Caves *et al.* 1981. The bulk of the increases in TFP for trunk airlines were explained by increases in output and load factor, and an decrease in the excess growth capacity. Airline output grew around 75% faster during the 1975-80 period than the preceding period. For the local service airlines, however, the important source of TFP

[12] These characteristics were namely output level, load factor, average stage length, and available capacity.

growth was increases in output and stage length. Even though this study could not provide any exact information on how much of the acceleration in productivity growth could be ascribed to deregulation, the authors estimate that the magnitude of the cost savings for both trunk and local carriers due to deregulation would be equal to $4.9 billion by the year 1980.

Forsyth, Hill and Trengove (1986) attempted to measure the total factor productivity for 17 international airlines for the period of 1979 to 1984. Just as Morrell and Taneja were concerned with the conventional productivity measures, Forsyth, Hill and Trengove (1986) argued that the usual productivity measures would be misleading in total productivity measurements. They proposed the productivity measure, cost per ATK, as an alternative measure of performance. However, they were aware of the fact that cost per ATK had two drawbacks even though all inputs purchased by the airline were included in this measure. First, differing prices among countries needed to be accommodated. Second, when the performance was examined over time, costs needed to be deflated. They suggested that the cost per ATK could be useful when differing prices of input and outputs among the airlines were 'standardised' with appropriate indices.

Using the equation (3.1), TFP indices were computed for the 11 trunk carriers and substantial variations were observed. Forsyth *et al.* then found it worthwhile to examine the determinants of TFP in order to justify the wide variations occurred. The authors calculated an input price index, which was derived by weighting the significance of every input according to its contribution as a determinant of total cost. This index was then used to adjust the total costs for input price differences faced by different airlines. Forsyth *et al.* argued that this method would give identical results like the total factor productivity, but it would be expressed as the 'real' cost of producing a unit of output, rather than the output produced per unit of aggregated input. Since this cost measure could take account the inflation, it could be used for comparing airlines either in time series or in cross-sectional settings.

Moreover, Forsyth *et al.* handled the multiple output characteristics of airline operations with a similar weighting procedure based on the relative cost of producing different types of output. Using the output characteristics (average aircraft size, the stage length, and the weight load factor) as well as the input prices in US dollars, output and input adjustments were formulated. The input price adjustment was done using the Tornqvist (1936) index.

The authors found it convenient to take the output level of an airline as a reference or standard so that they could compare and express other airlines' outputs in *relative* terms. British Airways' (BA) performance in year 1983 was taken as a reference. They calculated the level of output (ATKs) which each airline would have produced compared with British Airways' output characteristics. The modified cost per ATK was then calculated by using standardised rather than actual output. The findings showed that both aircraft size and long stage lengths had strong effects on the unit cost.

In this study, only four categories of input were identified. These were labour, fuel, capital and 'other'. Using the input price index, the modified cost per ATK was computed for each of the 16 airlines, relative to BA. US airlines along with the Japan airlines had recorded the largest difference because of their higher wages compared to the 'reference' airline, BA. The authors recommended that the adjustments between these airlines and BA showed the competitive potential of these carriers, which could be beneficial in forecasting the possible effects of the deregulated international aviation market.

Finally, Forsyth *et al.* combined the two adjustments to measure airline efficiency as the ratio of standardised cost to standardised output and to show the performance trends over time. The lower the ratio the more efficient the airline would be. The results confirmed the findings of the previous studies that the North American airlines performed well relative to the European airlines. However, the evidence revealed that there were great differences among the European airlines as well. Lufthansa, Air France and KLM showed an outstanding performance compared to that of BA.

Another study by Caves, Christensen, Tretheway and Windle (1987) analysed the effects of deregulation for both non-US and US airlines. The non-US airlines were treated as a control group for the US carriers. Except for the US deregulation, which took place in 1978, relatively less deregulatory changes in the international airlines industry in other countries until 1984. Hence, the performance of these airlines was assessed against the US carriers under deregulation. The sample covered the period of 1970 to 1983. In particular, the performance of all airlines in the 1970-1975 period was compared with the performance in the 1976-1983 period where the first period was regarded as the pre-deregulation and the latter the post-deregulation period for the US airlines.

The data consisted of annual observations on 27 non-US and 21 US trunk and local carriers. The methodology for productivity measurement used in this study was the same as in the preceding studies. In this study, however, two productivity changes were discerned which arose from the changes in operating characteristics and changes in technical efficiency. For this purpose, the authors utilised a neo-classical cost function. The cost function was of the form:

$$C_V = C_V(Y,W,K,Z,t,f,g)$$

where C_V is a variable cost, Y is aggregate output, W is a vector of input prices, K is the real flow of services from the capital input, Z *is* a vector of output characteristics, t is a vector of time shift variables which represent changes in technology, f is a vector of firm shift variables, and g is a binary variable representing government ownership.

The treatment of the inputs and the outputs for the US airlines was identical with the previous studies. Five categories of inputs and four categories of outputs were employed. For the non-US airlines, however, some of the data were handled in a different way. The labour index was formed using only three types of labour since there was no consistency in defining the labour data from different countries. Purchasing power parities were used for inter-country links for materials indexes. Further, due to unpublished data on fuel for non-US carriers, the data was estimated using different operating characteristics. Moreover, there were some modifications in the definition of output. In this study, output was meared as deflated revenues rather than as a direct output index. Hence, the output quantity index was constructed as the ratio of total deflated revenue to the output price index.

The results showed that US productive efficiency grew from 3.0% per year in the pre-deregulation period to 3.4% per year in the post-deregulation period. The rate of growth of non-US productive efficiency, however, decreased from 4.5%

per year to 2.8% per year. The productivity results reflected all sources of change in productive efficiency. The cost function analysis further distinguished productivity changes due to the changes in input prce, operating characteristics (represented by traffic density, firm size, stage length, load factor and capital utilisation) and changes in technical efficiency (associated with time, firms, and government ownership). Hence, the source of productivity was ascribed to the increase in the operating characteristics for both non-US and US airlines. The authors used the experience of non-US airlines to infer the situation of US airlines in the absence of deregulation. They estimated that owing to deregulation US airlines saved over $4 billion in 1983.

Lastly, Windle (1991) used the same data set along with the same TFP procedures in Caves *et al.* (1981, 1987) to undertake another international study. The main focus was on the absolute differences in TFP between 14 US airlines and 27 non-US airlines in 1983. The inputs and outputs used in this study were already defined in Caves *et al.* (1987). Further, using the cost function results by Caves *et al.* (1987), Windle (1991) decomposed the differences in unit costs for six regional groupings: US firms, all non-US, European, East Asian, Canadian, and other firms which did not belong to any of these categories.

Likewise, in the previous productivity studies, the results in this study also confirmed the superiority of US airlines over European carriers. The rank ordering of airlines by TFP showed the larger US airlines in the top half of the sample and many of the European firms in the lower half. The exception was KLM, which ranked highest among European carriers. In the rest of the regional groups, East Asian carriers showed the best productivity performance. When these carriers were further examined, it was found that the productivity performance was due to their longer stage lengths. Moreover, they enjoyed the lowest unit costs in the sample.

Unit cost comparisons among the rest of regional groupings indicated that US airlines productivity advantage was reduced by higher input costs. Similarly, most European airlines were also disadvantageous due to high unit costs. Only British Airways achieved lower unit costs but the productivity of this company, however, was not high. The sources of difference between productivity and unit costs across airlines were further analysed using a translog variable cost function. The regression analysis determined the variables that had the largest impact on unit costs and established that large unit cost differences between US and European airlines were largely associated with traffic density and government ownership. In order to eliminate these differences, the author suggested a number of ways to increase the traffic density: achieving traffic growth through an increase in population; reductions in fares; reconfiguring the route networks; merging, or closing down the airlines. Windle (1991:47) argued that mergers or failures of firms were not popular policies, particularly for state-owned companies, therefore, he suggested that "the greatest improvements in productivity will come from deregulation that enables air carriers to increase their traffic density". Finally, privatisation of state airlines was also suggested as a panacea to improve the productivity of the European airlines.

3.7 Parametric Applications

Since the seminal article by Farrell (1957), there have been two strands of methodological development in frontier production function estimation. These are parametric and non-parametric approaches. The parametric approach pioneered by Aigner and Chu (1968) is used to estimate a parametric function that leads to the development of the stochastic frontier mode. The non-parametric method uses piecewise linear approximations to model the best practise reference technology and results in the development of the Data Envelopment Analysis (DEA). The other distinguishing feature of the two methods is that the DEA approach is based on the linear programming (LP) techniques whilst the stochastic frontier model is based on regression techniques.

The parametric frontier production function estimated by Aigner and Chu (1968), was defined by the following Cobb-Douglas form:

$$\ln(y_i) = x_i\beta - u_i \qquad i = 1,2,...,N, \qquad (3.2)$$

where y_i is the scalar output for the i-th firm; x_i is a row vector; β is a column vector of unknown parameters to be estimated; and u_i is a non-negative random variable which refers to the technical inefficiency of the industry evaluated. This model is an example of a deterministic frontier since the observed output is bounded above by the non-stochastic or deterministic quantity, $\exp(x_i\beta)$. One of the major criticisms of the above model is that neither measurement errors nor other noise in the data can be accommodated. All deviations, however, are regarded as the result of technical inefficiency (Coelli *et al.,* 1998).

Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) considered the inclusion of a random term, v_i, to account for the measurement errors and other random factors, on the output variable such as the weather, along with unspecified input variables in the production function. The specified model is defined by:

$$\ln(y_i) = x_i\beta + v_i - u_i \qquad i = 1,2,\ldots,N. \qquad (3.3)$$

Aigner, Lovell and Schmidt (1977) assumed that the v_is were independently and identically distributed (i.i.d.) normal variables with zero mean and constant variance, and u_is were also (i.i.d.) and non-negative terms that allow for technical inefficiency which were also assumed to be exponential or half-normal random variables. The model defined in (3.3) is an example for a stochastic frontier production function because the output values are bounded above by the stochastic random variable, $\exp(x_i\beta + v_i)$.

The primary advantage of a stochastic frontier model over a deterministic model is that statistical tests are possible by using maximum likelihood methods. However, the stochastic model is criticised on the grounds that there is no *a priori* justification for the selection of any particular distribution for the u_is. The efficiency measures obtained are highly dependent on the distributional assumptions (Coelli *et al.*, 1998).

This section reviews four studies which apply parametric methodologies. The first three studies use stochastic frontier models to compare the technical efficiency in airlines under regulated and deregulated environments. The last study employs econometric techniques and focuses on the ownership issues for international airlines.

The study by Barla and Perelman (1989) adopted the estimation of a stochastic frontier to measure technical efficiency for twenty-six airline companies from OECD countries over the period 1976-1986. The sample consisted of six US trunk companies, three Canadian airlines, fifteen European carriers, one Australian and one Japanese carrier. There was, however, a major difficulty in decomposing the error term into the random and the inefficiency elements. Two alternative approaches were proposed to handle this problem: the conditional distribution approach and the time varying effects approach. The first approach was developed by Aigner, Lovell and Schmidt (1977) and Meusen and Van den Broek (1977). This was based on the distribution assumption of u_{it} which was half-normal, exponential and gamma. Using maximum likelihood methods, components were then estimated. The second stochastic approach was presented by Mundlak (1961) for panel data applications. The introduction of individual fixed effects in regression analysis led to a special class of coefficients, called "within" estimators, for all exogenous variables.

Only two inputs were defined for the analysis. These were capital and labour. Capital was represented by total available aircraft capacity. This figure was obtained by multiplying the total available aircraft transport capacity with the number of operating days. Labour was measured with the number of flying personnel only. Due to missing data on energy input, this study failed to consider fuel input as an exogenous variable. Output was assumed to be endogenous and represented by the total number of ton-kilometres available. Furthermore, another four variables were assumed as exogenous indicators of output characteristics: the average weight load factor, the output composition, the average stage length and the average speed of aircraft. The average weight load factor was the ratio of ton-kilometres performed over ton-kilometres available. The output composition represented the rate of freight in total output and the average speed of aircraft was included as an indirect measure to consider network density and environmental conditions.

The overall variation explained by the model is 0.992. The results indicated that only the average speed of aircraft was found to be an important factor influencing the output capacity of the airline. Surprisingly, this study found no difference between the US, European and other countries' carriers over the whole period 1976-1986. This means that the operating environments were insignificant in determining performance in any group of airlines. Following the method adopted by Nishimizu and Page (1982) the authors defined total factor productivity growth as the sum of estimated technical efficiency change and technical progress. The results of this analysis showed that there was a substantial improvement in the technical progress of all airlines in the study period. However, the US airlines performed at higher rates of productivity than European airlines. This was due to the fact that US airlines with larger scale airlines achieved faster technological progress. Finally, the authors suggest that among the two approaches employed, the "conditional distribution" approach appear more reliable than the time varying effect approach.

The study by Good, Nadiri, Röller and Sickles (1993) examined the technical efficiency and productivity growth comparisons among the 4 largest European carriers and 8 US carriers. The sample covered the period 1976 to 1986. This was regarded as the period when the US deregulation took place and the first liberalisation reforms in Europe were nearly introduced.

The Cobb-Douglas stochastic frontier production model was specified. Three alternative statistical treatments were considered in this study, namely the within, or dummy variables estimator, generalised least square (GLS), and efficient instrumental variables (IV). The results obtained were quite comparable for the stochastic frontier models. These estimators were detailed in Cornwell, Schmidt and Sickles (1990).

A set of three airline inputs was constructed. These were labour, aircraft fleet, energy and other materials. The input indices were aggregated using the Divisia multilateral index number procedure by Caves, Christensen and Diewert (1982a). In addition to the total number of aircraft, the percentage of wide-bodied fleet and turbo propulsion provided measures of potential productivity of the aircraft and the speed of aircraft respectively.

Three components and three characteristics of airline output were also calculated. These were passenger service, cargo operations and incidental services.[13] Again, these components were aggregated by using the multilateral index procedure. The three characteristics of airline output included load factor, stage length and a measure of network size. Load factor was used as a measure of service quality and is widely used proxy for service competition in most airline transportation studies (Good *et al, 1992*). Stage length provided a measure of the

[13] These services included equipment leasing and maintenance provided to other carrier's equipment.

length of individual route segments in the carrier' network. Finally, the number of route kilometres provided a measure of total network size.

The overall variation explained by the model is 0.999. The empirical results showed that the US carriers increased their efficiency over the study period. They were nearly 15% more efficient than their European counterparts. All three estimated models showed that the efficiency gap was the same. The authors argued that the liberalisation in European aviation would force

the firms to close this efficiency gap. Accordingly, they estimate savings (in 1986 prices) of $4 billion per year would occur if the European airlines were brought up to the US performance average. Moreover, they demonstrated that the potential cost savings would exceed the amount which would be needed to compensate displaced workers.

The situation of 4 European carriers in the sample showed differences among firms. Only British Airways showed a 2% annual increase in technical efficiency while for Air France, Alitalia, and Lufthansa there was 0.7% average annual decline in technical efficiency. Good *et al.* suggested that the success of British Airways stemmed from the reorganisation which took place in British Airways following privatisation. It was argued that Great Britain, contrary to the other European countries, was a strong supporter of the liberalisation attempts.

Likewise the previous study, Good, Röller and Sickles (1995) aimed at identifying efficiency and productivity differentials between European and US carriers. In this study, however, the authors used two alternative methodologies – a parametric one using statistical estimation, and a nonparametric one using a linear programming technique. Moreover, the firm-specific and time-dependent efficiency and productivity differences were used to rank carriers through time. Finally, they simulated the potential benefits that could be achieved were the airlines operated under less regulated environments. This stochastic frontier model imposed strong distributional assumptions and parametric structure on the data. The data set covered the period of 1976-1986 and consisted of a panel data of the eight largest European carriers and the eight largest American airlines.

The aggregation of multiple output was done using multilateral index. This index converts outputs into a single y_i for the numerator. The denominator was then modelled as a parametric function of inputs, and the vector of input and output characteristics. A functional form of the Cobb-Douglas was specified using the model developed by Cornwell, Schmidt and Sickles (1990). One of the significant properties of this model is that it allows econometric assumptions regarding the correlations between the measured and unmeasured firm characteristics. As in Barla and Perelman (1989), Good *et al.* utilised the 'within' special case of Cornwell, Schmidt and Sickles (1990). Moreover, this model allows for firm specific and time effects.

A set of three airline inputs was constructed in a similar way as in the previously review studies. Additionally, three characteristics of airline output and two characteristics of the capital stock were calculated. They included load factor, stage length, a measure of network size, the percent of the fleet (wide-bodied), the percent of the fleet (turboprop propulsion). Load factor was used as a proxy for service quality. Stage length provided a measure of the length of individual route segments in the carrier' network. In this case, the percent of wide-bodied fleet and propulsion provided measures of potential productivity of the aircraft and the speed of aircraft respectively.

The results of this study showed that the US carriers were around 15-20% relatively more efficient. This was also confirmed with the lower productivity growth of European. However, allocative inefficiencies were present in both European carriers, with most of the inefficiency coming from over-utilisation of materials with less capital. Among the European carriers, only Lufthansa and British Airways showed positive trends in their efficiency scores. The authors suggested that the institutional and organisational developments in these companies were the primary reasons of their success.

Moreover, it was calculated that European carriers would save approximately $4 billion per year (in 1986 dollars) if they became productively efficient as the US carriers, which operated under deregulation. As a result, they argued that the pace of deregulation in European aviation should be gradual so that the carriers and the industry as a whole may restructure. Organisational and structural changes are imperative if the European carriers are to close the efficiency gap between their US counterparts.

Ehrlich, Gallais-Hamonno, Liu and Lutter (1994) developed a model of endogenous and firm-specific productivity growth to identify the firm-specific capital as engine of growth at firm level. They tested the implications of this model to determine the factors, which influence the accumulation of the firm-specific capital. They showed that productivity growth and cost declined at firm level for a panel data of 23 international airlines over the period 1973-1983.

The airlines in this sample had varying levels of state ownership. Using this data set and relevant econometric techniques, the authors focused on the effect of state versus private ownership on the productivity growth and cost decline. The main variables used in the study were ownership, output, capital quantity and price indices, labour quantity and price indices, fuel indices, Total Factor Productivity (TFP) indices and productivity trends, technical factors, regulatory measures, and firm and country-specific variables.

Output, inputs, and TFP variables were constructed using a multilateral index procedure proposed by Caves, Christensen, and Diewert (1982). Ownership data consisted of the percentage of equity owned by the state. Technical factors were accounted by the airlines' stage length, number of airports served, and load factor. Two dummies were used to capture the effects of regulatory changes which started at the beginning of 1976 and 1978 in the US and North Atlantic markets respectively. Additionally, dummy variables and gross domestic product were used to account for the possible firm-specific and country-specific effects.

Contrary to the findings of Caves and Christensen (1980) which related the inefficiency of state enterprises to the absence of competitive forces, Ehrlich *et al.* concluded that their findings were consistent with Boardman and Vining (1989) that the ownership type determined the lesser efficiency of state enterprises. Moreover, they pointed out that the superior performance of private enterprises was stable in the dynamic context of productivity growth.

3.8 Non-parametric Applications

This section reviews three studies where the nonparametric strength of Data Envelopment Analysis (DEA)[14] is used to measure the efficiency and productivity of the airlines industry. DEA has some advantages over stochastic frontiers. Firstly, DEA can handle the multiple-output industries such as airlines without imposing a parametric functional form on the technology. Secondly, in the conditions where prices are difficult to define or are distorted owing to regulatory practices, DEA can be used safely. Finally, there is no need to impose behavioural assumptions such as profit maximisation or cost minimisation, particularly for the 'flag' carriers, since government ownership may entail other considerations such as employment and/or other social goals.

The study by Schefczyk (1993) presented a new approach to measure operational performance. He criticized the previous studies on productivity on the grounds that they did not consider the operational efficiency or the efficiency of the 'internal factory' and they were mostly limited to airlines in a single country. In order to provide an international benchmarking, he developed a model which aimed to overcome the difficulties of international comparability of financial information and thus measure the international airlines' operational efficiency.

This model defined a general view of the airlines' operations. For modelling purposes, the resources required to produce certain services were defined to connect the relevant inputs with the outputs of the airline operation. The objective of the management was to produce given outputs with minimum consumption of inputs. In this model of an airline operation, three inputs and two outputs were

[14] The methodology of DEA is detailed in Chapter 4.

defined. The inputs were available tonne kilometre (ATK), operating cost, and non-flight assets. The outputs were revenue passenger kilometre (RPK) and non-passenger revenue. Further, it was assumed that 'operations' excluded the marketing and the financing activities. Based on this model, DEA was used to analyse the performance of fifteen large international airlines for the year, 1990.

Schefczyk believed that the DEA methodology was superior to other analytical methods in the literature. It was selected as the most appropriate methodology owing to its ability to connect all factors of efficiency by evaluating the links between each input and output thus obtaining a scalar measure of performance. He argued that for the analysis "constant returns to scale were assumed since the airlines were constrained to operate on certain routes owing to tight regulation practices in most regions". Besides, he suggested that a constant returns to scale[15] model had certain analytical advantages when the sample size was small. When the variable returns to scale was assumed, most DMUs could appear efficient.

The input efficiencies were computed using DEA. Four airlines, Cathay Pacific, Federal Express, Singapore Airlines and UAL Corporation appeared the most efficient airlines. They scored 100%. All four European airlines in the sample, British Airways, Iberia, KLM and Lufthansa were inefficient, with the efficiency scores less than 100%. For instance, under the constant returns to scale technology, the input efficiency score of 79.3% obtained by Iberia indicated that this airline could save 20.7% of its input consumption and maintain its current

[15] According to White *et al* (1979) CRS prevail in the airlines industry since all current trunk and local carriers reached a size at which scale no longer affects unit costs.

output levels. Schefczyk continued his analysis with regression analysis to determine the relationship between these efficiency scores and some strategic variables, e.g. profitability, focus of the airline, revenue growth or load factors. The findings implied that the efficient, well-utilised and passenger-focused airline was most likely to be profitable.

The second study reviewed is Distexhe and Perelman (1994). This study aimed to evaluate the consequences of deregulation. The authors measured the airlines' technical efficiency and productivity growth over the period 1977 to 1988. The sample was composed of thirty-three airlines operating in scheduled international markets. These airlines were classified in three groups: Asia and Oceania, Europe and North America. There were nine carriers in the first group, fifteen carriers in the second group and nine in the last group. DEA was used to construct several production frontiers of airline activities. Then they followed the approach by Färe, Grosskopf, and Roos (1992) to estimate the Malmquist productivity index and decompose this index into technological progress or efficiency change.

The production technology was defined with two inputs and one output. The inputs were labour and aircraft. The output was available tonne kilometre, in freight and passenger services. Labour was measured in terms of the number of flying personnel and capital was by total available aircraft capacity weighted by the number of days. The authors suggested that the reason for using this labour measure was to eliminate measurement bias, which could occur from the subcontracting policies applied by different airlines. Moreover, they maintained that the study would be misleading unless some specific route network and output characteristics were included. The impact of changes, which took place in the aftermath of US deregulation, was accounted for by introducing two attributes of the airlines' activity. On the input side, the reciprocal of average stage length was included to represent the network density whilst on the output side, weight load factor was included to represent the market performance.

The input efficiency was determined by using DEA whereby four frontiers were constructed for three-year periods 1977-79, 1980-82, 1983-85 and 1986-88 by incorporating the two attribute variables. The same procedure was repeated to obtain efficiency scores without including these attributes. Further, they adopted the framework in Färe, Grosskopf, and Roos (1992) to construct a Malmquist index of productivity. This allowed estimation of the productivity growth by using the panel data on production activities. This index was obtained as the product of efficiency change and technological progress. The first factor, also called the catching up effect, was obtained as the ratio of efficiency scores between the periods t+1 and t. Alternatively, technological progress also known as frontier effect, was obtained as the geometrical mean of changes observed at the frontier in two periods. This was done by estimating distance functions for observations in period t+1 with respect to the frontier evaluated in period t.

The results suggested that, regardless of the method used, the average levels of technical efficiency in the eighties were higher than those obtained in the seventies. Again, as was found in previous studies, the European carriers, on average, were technically less efficient than the other carriers in the sample. Among the European carriers, Lufthansa, KLM and Air France recorded high efficiency scores, whereas British Airways, Alitalia and Swissair could not achieve more than 80% efficiency level. The results for small carriers improved when the two characteristics were taken into account, e.g. Finnair and Aer Lingus recorded higher efficiency scores.

The results obtained by the Malmquist indices of productivity were similar to the findings achieved by DEA. Lufthansa, Finnair and Air France obtained the best results along with the Japan Airlines, Singapore Airlines, American and TWA. North American and European airlines obtained low scores during the period 1980-1982 due to the impact of the second oil crisis. "The Asia and Oceania" group achieved best scores in all periods due to their ability to gain from technological process.

3.9 Conclusion

The deregulatory experience of US, which took place in the late 1970s, boosted the performance studies in which regulated and deregulated environments were compared. Most studies came to the conclusion that US airlines performed better than European airlines owing to the differences in operating characteristics, which mainly arise from operating environments. There were fewer studies focussing on ownership issues. Australian airlines are a notable example. The lack of published empirical studies solely on European airlines motivated this thesis to concentrate solely on European airlines. Regulation and ownership issues, as well as the operating characteristics are considered in measuring and defining the operational efficiencies and their determinants for the European carriers.

In this chapter we reviewed nineteen empirical studies on airlines performance measurement. These studies were classified under seven broad groups and covered a range of methods diversifying from unsophisticated ratio analyses to sophisticated parametric and nonparametric methodologies. Each methodology was briefly discussed with respect to their strengths and weaknesses. This extensive review aims to be of use in selecting the right methodology alongside the appropriate variables that will be used in the empirical applications of this thesis. Given the virtues of the non-parametric methodologies in measuring the performance for airlines industry, this thesis employs DEA methodology. The following chapter presents how efficiency is determined by using the DEA.

CHAPTER 4. METHODOLOGY

4.1 Introduction

This chapter details the three methodologies, which were employed in this thesis: The Data Envelopment Analysis (DEA), the Malmquist productivity index, and the Tobit analyses. The DEA and the Malmquist index are used to measure the technical efficiency and productivity respectively whereas the Tobit model is used to explain the factors influencing the (in)efficiency.

The idea of measuring technical efficiency was originally developed by Farrell (1957) who used the non-parametric frontier approach to measure efficiency as a relative distance from the frontier. This measure, known as productive or technical efficiency by economists, was later extended by operational researchers, notably Charnes, Cooper and Rhodes (1978) (henceforth CCR model). They named the technique the Data Envelopment Analysis (DEA).

Since then the DEA method has been extensively used in empirical studies to analyse both cross-section and panel data. (See Seiford, 1996 for a current bibliography). Several papers employed DEA to examine the efficiency of non-profit or public sector organisations. For example, DEA has been applied to evaluate educational strategies (Charnes *et al.* 1981), criminal courts (Lewin et al. 1982), hospitals (Banker *et al.* 1986 and Boussoffiane *et al.* 1991) and council rates departments (Thannassoulis *et al.* 1987). A method for applying DEA to panel data is provided by the windows analysis methodology of Charnes *et al.* (1985).

Contrary to the bulk of applications in the public sector, there have been fewer in the private sector, and mainly in banking and electricity industries. Institutions in the private sector to which DEA applications has been made are banking (Sherman and Gold 1985; Rangan *et al.*, 1988; Berg *et al.*, 1992; Drake and Weyman-Jones 1992, 1996), electricity (Färe *et al.*, 1983, 1985) and farms (Thompson *et al.*, 1990 and Grabowski and Paskura, 1988).

Moreover, there has been impressive development in DEA methodology. Early uses of the CCR model assumed constant returns to scales and strong disposability. Alternative DEA models were developed later to handle variable returns to scale (Banker, Charnes, and Cooper,1984) (henceforth BCC model) and weak disposability (Färe and Grosskopf, 1983). In addition, Färe and his colleagues exploited the direct link between the concept of distance functions and Farrell's measures of technical efficiency in productivity analyses whereby DEA was used to compute the Malmquist productivity index. Surveys of DEA methodology are given in Charnes and Cooper (1985), Ahn, Charnes and Cooper (1988), Seiford and Thrall (1990) and Boussofiane *et al.* (1991), among others.

This thesis aims to utilise the non-parametric strength of DEA to analyse the panel data of European airlines. DEA windows analysis is used to capture efficiency changes over time whilst the Malmquist productivity index is used to measure productivity change. Since all these extensions originate from Farrell (1957), this chapter begins with an overview of Farrell's efficiency measurement. The CCR and BCC models are presented in section 3. The fourth section illustrates a basic graphical presentation to reveal the determination of DEA efficiency measures under different technologies. DEA windows analysis is detailed in section 5. The Malmquist index and its graphical representation are introduced in sections 6 and 7 respectively. In section 8, the focus is on the Tobit analysis. Section 9 concludes.

4.2 Farrell's Efficiency Measure

Historically, production analysis was employed by estimating the average practice technologies. The frontier nature of a production function in economics was first recognised with the works of Debreu (1951) and Koopmans (1951). Debreu (1951) was the first to provide a measure of technical efficiency. Debreu's 'coefficient of resource utilisation' represented the smallest proportion of resources required for the production of certain output level. Koopmans (1951:60) provided a formal definition of technical efficiency: a producer is technically efficient if an increase in any output requires a reduction in at least one other output, or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output.

In Farrell's seminal work in 1957, the first empirical treatment of the production function as 'frontier' was also accomplished. Farrell decomposed the overall (productive) efficiency into two components: the allocative efficiency and the technical efficiency. Farrell's idea was to measure efficiency as a relative distance from the production frontier. Both technical and allocative efficiency measures were defined accordingly as the ratio of potential and actual performance. This is illustrated in Fig 4.1, where it is assumed that an organisation utilises only two inputs, X1 and X2, to produce an output Y.

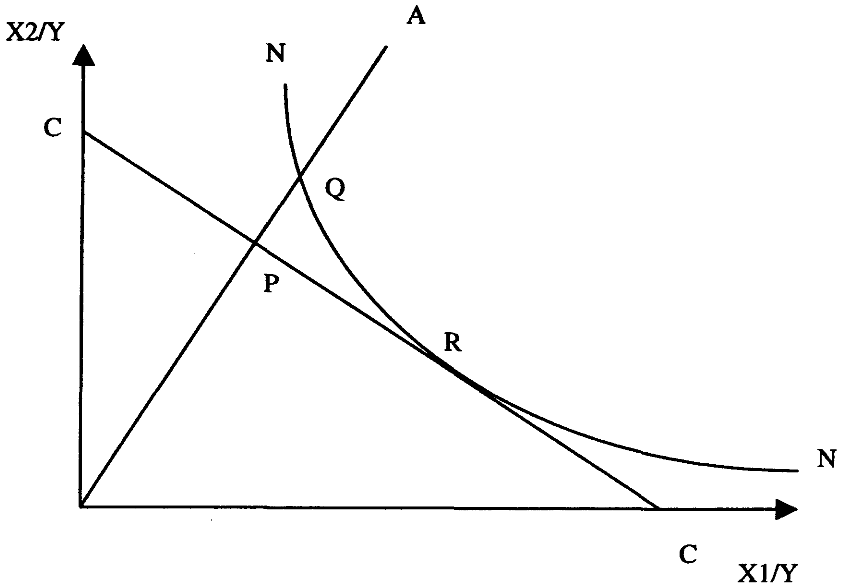

Fig 4.1 Farrell's Input Efficiency Measures

The curve NN is an output isoquant, which represents combinations of X1 and X2 to produce a given level of output. The line CC is a cost minimising plane or isocost line that represents the ratio of factor prices. In this figure, the organisation at point A is inefficient since it produces unit output with more inputs than needed. Its technical efficiency is OQ/OA, which is the radial distance A has from the isoquant, or in other words, the ratio of potential to actual input utilisation. Alternatively, the allocative efficiency is OP/OQ. This is also the radial distance from the cost minimisation plane. In both cases, the efficiency measures are less than unity, which represents the inefficiency. The overall or Pareto efficiency is computed as the product of price and technical efficiency ratios:

$$OP/OA = OP/OQ * OQ/OA$$

Farrell developed these measures under two assumptions: constant returns to scale and strong disposability of inputs. The latter implies that utilising more of an input cannot reduce output, and keeping others constant. When constant returns to scale hold, the production frontier in Fig 4.1 is characterised by unit isoquant, 1 = f (x1/y, x2/y). Full efficiency is obtained at point R where technical and allocative efficiencies are achieved simultaneously.

The technical inefficiency of A is then measured as (1-OQ/OA), indicating the proportion of inputs that could be reduced without reducing output[16]. As the performance of A worsens, the distance from the frontier increases, thus the technical efficiency ratio approaches toward zero. Alternatively, the efficiency ratio rises to unity, as the performance improves. Hence, the technical ratio in general is

$$0 \leq \text{Technical efficiency} \leq 1$$

Farrell's notion of the 'best results observed in practise' insists on the relative nature of the frontier concept. Since this pioneering work of Farrell, two general approaches have been developed to construct production frontiers: parametric or stochastic versus nonparametric or linear programming methodologies. The parametric methods require the functional form to be pre-specified whereas non-parametric methods impose no *a priori* functional form.

In such cases where there is no exact knowledge about the analytic form of production function, non-parametric methods are safely used to avoid the risk of imposing wrong parametric form and wrong distributional assumption about inefficiency and random error. In the case of European airlines insufficient information about the production function provides rational grounds to employ non-parametric methods and determine the best practise technology.

Besides this principal advantage, there are other reasons why non-parametric methods were employed in this thesis. Handling multiple outputs characteristics of

[16] Analogous arguments apply to the determination of allocative efficiency measure.

the airlines would be more convenient with non-parametric methods. The inputs and outputs are assigned weights by linear programming techniques to produce the efficiency measure, and construct the efficiency frontier.

It is important to note that these computations are done for each observation separately through a series of optimisations, which allows identification of both efficient and inefficient observations at individual level.

The parametric approach, on the other hand, accommodates only one output from several output variables and estimates the efficiency frontier by using econometric techniques. The efficiency frontier in this case is estimated by a single optimisation, which applies each unit in the data set. However, this approach does not differentiate between efficient and inefficient observations.

The frontier constructed by non-parametric methods may be sensitive to extreme observations and measurement errors. These assume that random errors are not existent so that all deviations from the frontier are regarded as inefficiency. In the parametric approaches, however, stochastic noise in the data is handled by imposing restrictive assumptions on the distribution of inefficiency and random error. The lack of statistical assumptions prevents the use of statistical inference tools in a non-parametric approach. Because of this limitation, there has been an increasing effort to develop stochastic non-parametric models (See Grosskopf, 1996 and Lovell, 1993 for selective overviews).

The input and output variables that will be used in nonparametric methods require a proper *a priori* selection since the number of variables can affect the discriminatory powers of the method. As the number of variables approaches to the number of DMUs (decision making units), the number of efficient DMUs tends to increase. This arises from the increasing number of facets[17] whereby a given set of DMUs can be efficient. It is suggested therefore, that the number of variables be small compared to the total number of DMUs under study. According to the DEA literature, there should be at least three times more DMUs than the sum of the number of inputs plus outputs (Charnes et al. 1990:621). In studies with multiple periods, windows analysis can be used to increase the number of observations, thus accomplishing an effective discrimination.

Having distinguished between the non-parametric and parametric approaches, the bulk of this chapter is devoted to the detailed discussion of the efficiency measurement using non-parametric methods, Data Envelopment Analysis or DEA and its extensions.

4.3 Data Envelopment Analysis (DEA)

DEA is a nonparametric technique used to construct empirical production frontiers and provide a comprehensive evaluation of the homogenous organisations, processes or DMUs. These DMUs typically perform the same function by consuming multiple inputs to produce multiple outputs. One of the most important features of DEA is its ability to manage the multiple characteristics of a DMU, which may use several inputs and outputs.

[17] The concept 'facet' is borrowed from geometry where a portion of the surface of a polyhedron is called a facet. This is analogous to the portion of the surface of the efficiency frontier, which forms a polyhedron in a multiple dimensional space (Yue, 1992:33).

In such circumstances when a DMU consumes only one input and output, efficiency is simply measured as:

$$\text{Efficiency} = \frac{\textit{Output}}{\textit{Input}}$$

However, in general, DMUs produce more than one input or output. The above equation can then be modified to consider the multiple input and output characteristic of the DMU by reducing these inputs to a single input and output. This is done by weighted average of inputs and a weighted average of outputs:

$$\text{Efficiency} = \frac{\textit{Weighted sum of outputs}}{\textit{Weighted sum of inputs}}$$

In order to use the above measure, DMUs under study require common set of weights where in practise, it may be very difficult for all DMUs to emphasize similar importance for the same inputs and outputs (Boussofiane *et al.*, 1991).

The DEA or CCR model proposed by Charnes Cooper and Rhodes (1978) handle this problem by allowing each DMU to adopt its own set of weights, thus maximising its own best possible efficiency in comparison to the other DMUs. Under these circumstances, the efficiency for a DMU is determined as a maximum of a ratio of outputs to weighted inputs. The algebraic model for the CCR (input based) ratio form is as follows:

The CCR Model

$$\max \quad h_c = \frac{\sum_{r=1}^{s} u_r y_{rc}}{\sum_{i=1}^{m} v_i x_{ic}}$$

$$\text{subject to} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad (4.1)$$

$$u_r, v_i \quad \geq 0$$

$r = 1,\ldots,s;\ i = 1,\ldots m$ and $j = 1,\ldots,n$

where

c = a specific DMU to be evaluated

y_{rj} = the amount of output r from DMU j

x_{ij} = the amount of input i to DMU j

u_r = weight chosen for output r

v_i = weight chosen for input i

n = number of DMUs

s = the number of outputs

m = the number of inputs

The objective function defined by h_c aims to maximise the ratio of weighted outputs to weighted inputs of the DMU under scrutiny. This is subject to the constraint that any other DMU in the sample cannot exceed unit efficiency by using the same weights. It is important to note that these weights are assumed to be unknown, but obtained through optimisation, performed separately for each unit to compute the weights and the efficiency measure h_c.

The optimal values of the weights v_i^* and u_r^* have shadow price interpretation. They indicate the relative importance of each input and output respectively in determining the efficiency score of the DMU. As a result, this makes it possible to calculate both marginal rates of substitution between inputs and marginal rates of transformation between outputs[18].

The efficiency score obtained by the problem setting (4.1) is consistent with Farrell's interpretation. If the efficiency score is equal to one, a DMU is considered relatively efficient. In this case, a DMU performs 'best practise'. Alternatively, a DMU is regarded as inefficient when its efficiency score is less than one. The subset of efficient units represents the 'reference set' for the inefficient DMUs. Consequently, the efficiency measure ranges from zero to one.

The problem setting in (4.1) is a fractional program. This can be converted into linear program (LP) form by restricting the denominator of the objective function h_c to unity, and adding this as a constraint to the problem. The LP version of the fractional setting is shown in model (4.2):

Primal

$$\max \quad h_c = \sum_{r=1}^{s} u_r y_{rc}$$

[18] The marginal rate of substitution is the rate at which an input is decreased while another input consumption is increased, but the level of outputs produced is still same. Likewise, marginal rate of transformation is the rate at which one output is reduced while another output is increased, but the amount of inputs consumed stay unchanged.

subject to $\sum_{i=1}^{m} v_i x_{ic} = 1$

$$\sum_{r=1}^{s} u_{rc} y_{rj} - \sum_{i=1}^{m} v_{ic} x_{ij} \leq 0 \qquad (4.2)$$

$$u_r, v_i \geq 0$$

r = 1,...,s; i=1,...,m and j = 1,...,n

The maximising LP setting in (4.2) assumes constant returns to scale technologies. When the formulation constrains the weighted sum of the inputs to unity as in (4.2), and maximises the outputs, this becomes an input-based efficiency measurement.[19] That means, given outputs, DMUs minimise the use of inputs.

In this case, the efficiency score h_c of a DMU is determined by maximising the sum of weighted outputs. The maximising is pursued subject to the constraints that the sum of its weighted inputs equals to one, and the weighted outputs of all DMUs, minus the weighted inputs of all DMUs, is less than, or equal to, zero. As in (4.1) the setting in (4.2) also implies that the fully efficient DMUs are on the efficiency frontier with the efficiency scores equal to one. Those DMUs, which are below the frontier, have efficiency scores less than 1.

To correct the problem setting (1), Charnes, Cooper and Rhodes (1979) introduced the strict positivity requirement on those weights, which are non-negative weights. Thus CCR (1979) constrain the weights u_r and v_i to be greater than, or equal to, a small positive constant ε, which is also known as non-Archimedean or infinitesimal, usually of the order of 10^{-6}. Despite the fact that the positivity

[19] An alternative formulation constrains the sum of the weighted output to unity, and minimises the inputs. This is an output-based efficiency measurement.

requirement creates a 'lower bound constraint', and does not allow the efficiency frontier to have horizontal or vertical facets, the inclusion of ε does not create significant differences in the results (Bjurek et al, 1990). Moreover, the inclusion of ε makes it difficult to relate the efficiency results to Farrell's efficiency analysis (Chang and Sueyoshi, 1991)[20].

One possible solution to the LP (the primal) in (4.2) is to formulate a dual companion. By denoting the input weights of DMU c by θ_c and the input and output weights of other DMUs in the sample by λ_j the dual form of the maximising problem is formalised as follows:

Dual

$$\min \quad h_c = \theta_c$$

$$\text{subject to} \quad \sum_{j=1}^{n} \lambda_j y_{rj} - s_i^+ = y_{rc} \tag{4.3}$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_c x_{ic}$$

$$\lambda_j, s_i^-, s_i^+ \geq 0$$

$$j=1,\ldots,n.$$

Despite the fact that the solution to primal and dual provides the same information, computing the dual is computationally faster. This is because the number of constraints in the dual is less than the constraints in the primal. There are

[20] Therefore, in the empirical implementation of this thesis, ε is ignored.

n+s+m+1 constraints in the primal model whilst the dual has only s+m constraints[21]. It should be noted however that the shadow price interpretation of the variables in primal is no longer available for the dual. This is because the dual seeks weights (λ_j) on DMUs rather than on inputs and outputs. The dual weights (λ_j) are non-negative.

Determining the efficient use of inputs for DMU c in (4.3) is subject to two constraints. First, the reference DMUs should produce as much output as DMU c, i.e. $y_{rc} \leq \sum_{j=1}^{n} \lambda_j y_{rj}$. Second, the weighted inputs corrected by the efficiency of the DMU c should be at least equal to the amounts consumed by the reference DMUs, i.e. $\theta_c x_{ic} \geq \sum_{j=1}^{n} \lambda_j x_j$. Since θ determines the amount by which DMU c should reduce its use of inputs in order to be fully efficient, the objective is to minimise this correction fraction θ. These constraints represent the envelopment principle. Indeed an optimal solution covers or 'envelops' the outputs of DMU c from above via the first constraints. Similarly, the inputs of DMU c are enveloped below via the latter constraints. Thus the data envelopment analysis (DEA) is named after this envelopment process.

The DMU c is regarded as efficient if the θ_c is equal to one and the slacks (s_i^- and s_i^+) are zero. That is, if and only if,

$$h_c^* = 1 \text{ with } s_i^{-*} = s_i^{+*} = 0, \text{ for all c and j,}$$

where the asterisk denotes optimal values of the variables in the dual. It is important to note that these conditions are also the conditions for Pareto efficiency. When the

[21] The dual form is solved in the efficiency computations reported in Chapters 6 and 7.

DMU is fully efficient, it is impossible to improve its observed values of input or output without worsening other input or output values.

The DMU is regarded as inefficient if the θ_c is less than one and/or positive slack variables. For these inefficient DMUs, the optimal values of λ_j construct a hypothetical DMU, which is formed by the subset of the efficient DMUs. Moreover, the optimal values of λ_j provide a target for the DMU under examination. Thus an inefficient DMU c can be adjusted to move to efficiency frontier. This projection is formed by the following formulae:

$$x_{ic}^{t} = \theta_{c}^{*} x_{ic} - s_{i}^{-*} \qquad i=1,\ldots,m$$

$$y_{rc}^{t} = y_{rc} + s_{i}^{+*} \qquad r=1,\ldots,s \qquad (4.4)$$

where x_{ic}^{t} and y_{rc}^{t} are the target values whilst the * denotes optimal values. Examining the differences between the target values and the optimal values, one can provide diagnostic information about the inefficient DMU c. In other words, the difference ($x_{ic}^{t} - x_{ic}^{*}$) gives insight into how the efficiency of DMU c can be improved through the reduction of inputs in an input-orientation problem. Alternatively, the difference ($y_{rc}^{t} - y_{rc}^{*}$) represents the amount of outputs required for the proportional augmentation of output in an output orientation problem.

The BCC model developed by Banker, Charnes, and Cooper (1984) considers the existence of variable returns to scale in the production and measures the pure technical efficiency. Utilising the constant returns to scale dual, BCC included $\sum_{j=1}^{n} \lambda_j = 1$ as an extra constraint to the model (3):

The BCC Model

$$\min \quad h_c = \theta_c$$

$$\text{subject to} \quad \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_c x_{ic}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_i^+ = y_{rc} \qquad (4.5)$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j, s_i^-, s_i^+ \geq 0$$

$$j = 1, \ldots, n.$$

This constraint requires convexity, which means that all solutions will be determined by referring to the convex combinations. The efficiency frontier becomes a convex hyperplane and allows for variable returns to scale. Thus this condition occurs when $\sum_{j=1}^{n} \lambda_j = 1$, otherwise

$\sum_{j=1}^{n} \lambda_j \prec 1$ implies increasing returns to scale (IRS); and

$\sum_{j=1}^{n} \lambda_j \succ 1$ implies decreasing returns to scale (DRS).

Following the work by BCC, there was a move to separate technical efficiency from scale efficiency. If convexity constraint is dropped, the frontier technology changes from VRS to CRS technologies. Scale efficiency is simply measured by dividing the efficiency scores obtained from constant returns to scale, CRS technologies by the efficiency scores of variable returns to scale, VRS, technologies, $\theta_{CRS}/\theta_{VRS}$. This is explained more clearly with the graphical representation in the following section.

4.4 Graphical Representation of DEA

The following graph reveals the determination of DEA efficiency measures under different technologies. To understand how the efficiency frontier is determined by DEA, consider a simplified airlines operation consisting of DMUs or carriers which utilise one input X, to produce a single output, Y. The input-output combinations of six carriers are located on the points denoted by C1 to C6 for an input oriented problem.

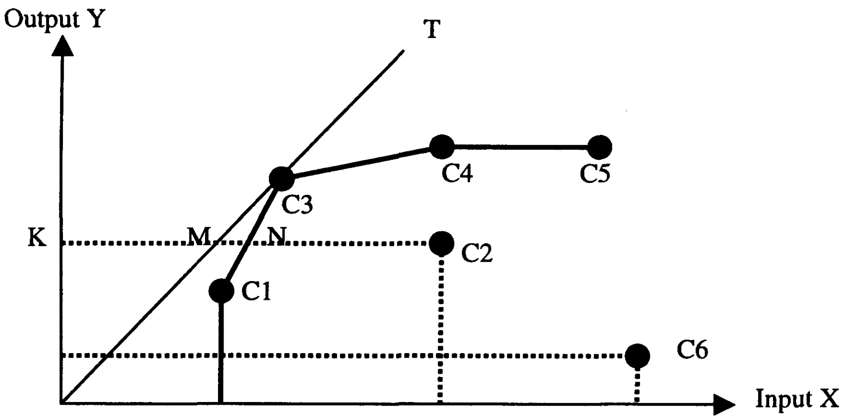

Fig 4.2 Determination of DEA Efficiency Measure Under Different Technologies

The ray OT, passing from the origin assumes that constant returns to scale (CRS) hold. Only carrier C3 lies on the frontier and is considered efficient, with an efficiency score of one, whereas the rest of the carriers are inefficient, having efficiency scores of less than one. If these scores are subtracted from one, it is possible to measure the proportional reduction in input usage that could be achieved without worsening any other input or output. This is the ratio of the efficient use of input to the actual use of input, i.e. the input saving efficiency score of C2 is KM/KC2, taking output as given.

Under the assumption of variable returns to scale, it is possible to decompose the input saving efficiency measure (technical efficiency) into two parts: pure technical efficiency and scale efficiency. Referring to Fig.4.1 the efficiency frontier now is a piecewise linear curve (convex) that passes through the points C1, C3, C4, and C5. In this case, there are only two inefficient carriers C2 and C6. Keeping output constant, efficient use of input X for carrier C2 is obtained at point N at the frontier. Accordingly, the efficiency score for carrier C2 is obtained as KN/KC2. However, the inefficiency of carrier C2 stems from partly from a scale effect MN. The input saving scale effect of C2 is KM/KN. It is also possible to obtain the scale efficiency from a ratio of CRS and VRS efficiency scores ($\theta_{CRS}/\theta_{VRS}$).

It is important to note here that, for the inefficient units, DEA provides a set of peer groups, which are composed of efficient units. The performance of inefficient units could be improved accordingly in comparison with that of the peer units. C2 is both technically inefficient, scale inefficient and has an efficiency score of less than one. For C2, the peer group consists of the carriers C1 and C3. They both lie on the frontier and are efficient. Moreover, they utilise less input than C2 to produce the same level of output. The efficiency score of C2 can be used to set a target point on the frontier so that this target could behave like a guidance for C2 to improve its performance.

For example, the target point for C2 is point N at the VRS frontier and M at the CRS frontier. Recalling the formula (4.4), the target performance of C2 to reach point N is as follows:

$$\theta^*_{C2} \prec 1$$

Input target: $\theta^*_{C2} x_{iC2} - s_i^{-*} = (x_{C1}\lambda^*_{C1}) + (x_{C3}\lambda^*_{C3})$

Output target: $y_{rC2} + s_i^{+*} = (y_{C1}\lambda^*_{C1}) + (y_{C3}\lambda^*_{C3})$

The target performance for C2 (in a simplified case of one input and one output) is equal to the linear combinations of the peer units, C1 and C3, where $\lambda^*_{C1}, \lambda^*_{C3} \succ 0$. The target for carrier C2 is a radial (equi-proportionate) contraction in inputs plus any further contractions in inputs suggested by non-zero input slacks (i.e. s_i^{-*}). In input oriented problem, there is no radial adjustment to outputs. However, the existence of non-zero output slacks may require the augmentation of output (Ganley & Cubbin, 1992).

In addition to measuring scale efficiencies, it is also possible to find out whether the carrier is operating in the region of increasing, constant or decreasing returns to scale. This can be achieved by comparing the results of efficiency scores under different technologies. For example, referring back to Fig.4.1, in the case of input saving orientation, scale inefficiencies of the carriers on the VRS frontier can be evaluated by examining the sum of weights, with CRS technology. Carrier C3 is the only carrier that experiences CRS. If the sum of λ_s on the CRS frontier is less than one, then the adjusted point on the VRS frontier experiences IRS. This means that the best practice points determining the CRS frontier are scaled downwards when defining the reference points on the CRS frontier. Correspondingly, if the sum of λ_s is more than one, the adjusted point on the VRS frontier experiences DRS.

4.5 The DEA Windows Analysis

In many empirical applications, DEA is utilised in cross-sectional analysis in which DMUs are evaluated in a single time period. However, in some applications data may be available on multiple time periods. This allows an opportunity of providing a thorough assessment of the relevant DMUs over time. A method for applying DEA to panel data is provided by the Windows analysis methodology of Charnes *et al.* (1985).

DEA Windows analysis is a dynamic approach which detects the efficiency trends of each DMU relative to a technology. The performance of each DMU is compared through time whereby a DMU within each time period is treated as a different DMU. Windows analysis works on the assumption of moving-averages (Day *et al.*, 1994:217). The subsets of the data are evaluated through a moving window, which is constructed in a way that provides the series of overlapping sub-periods or windows to examine the DMU efficiency over a period of time. Applying DEA, it is possible to derive an efficiency score after the DMU at a given time is contrasted not only with its own performance at different periods but also with the performance of other DMUs (Yue, 1992).

In this method the whole set of time periods, T, is divided into 'windows', or sub-periods for i = 1,...*I* DMUs whereby the width of each window, p, is always equal. In the first assessment, the first window consists of n DMUs within the time period of (1,…,p). The second window then has periods of (2,…p+1) and this goes on to the last period (T-p+1,…,T). Each unit in the sub-periods is treated as a different unit.

Let $Y_{it} = [\, y_{1it}, \ldots, y_{Mit}]$ be a M.1 vector of outputs of DMU i = 1,...*I* in period t = 1,...T, and let $X_{it} = [\, x_{1it}, \ldots, x_{Sit}]$ be a S.1 vector of inputs of DMU i = 1,...*I*. An input-oriented DEA envelopment problem for DMU_c in period t can be presented as follows:

$$\min \theta$$

$$\text{subject to } Y_{ct} \le \sum_i Y_{it} \quad \lambda_{it}$$

$$\theta\, X_{ct} \ge \sum_i X_{it} \lambda_{it} \qquad (4.6)$$

$$\lambda_{it} \ge 0$$

This set up allows for constant returns to scale, and it does not impose strict positivity on the dual variables of the output and input constraints. Windows analysis increases the number of DMUs available for assessment from *I* to *I**p. The DEA problem is solved *I**p for every sub-period or window. This is an important feature of windows analysis since solving DEA problem for *I**p increases the sample size, and improves the discriminatory power of the results.

In order to explain windows analysis, Charnes et al (1985) employed a case of aircraft wing maintenance for 14 DMUs or tactical fighter wings (TFWs). They defined a window of p=3-month period. Each wing is represented as if it were a different wing for each of 3 successive months. This is continued with a new 3-month period or window, that is constructed in a similar way, but shifted to the second month. The process is repeated to the last wing (TFWN) to obtain the results. A DMU can achieve different efficiency scores for the same year in different windows. In this case, the efficiency of each TFW is determined whenever the comparator set is changed and/or the time progresses. Thus DEA windows analysis provides a kind of sensitivity analysis in the sense that the behavioural and trend properties can be clearly detected within the DMUs.

It should be noted, however, that choosing the window size is usually determined by experimentation. Besides this drawback, Lovell (1996:336) emphasized another limitation that'...[windows analysis] provides no evidence on the nature of the technical change, and little information on productivity change'. Rather, windows analysis detects the efficiency trend for each DMU relative to a technology which changes through the sequence of overlapping sub-periods. We utilise, therefore another methodology in section 4.6, that is, the DEA based Malmquist productivity index, which provides evidence on the productivity change with two components: namely technical change and efficiency change.

4.6 Malmquist Productivity Index

The Malmquist productivity index is utilised to identify productivity growth between two time periods. A change in total productivity occurs either by a change in relative technical efficiency of a DMU or by a change in technology. The index was originally presented in a consumer theory context. Malmquist (1953) measured the quantity of consumption that an individual needed to consume in a certain year in order to achieve the same utility level as in the previous year.

This quantity index, or the proportional scaling factor, can also be interpreted as a ratio of two distance functions in different time periods. The idea of using distance functions in productivity analyses was developed by Caves, Christensen and Diewert (1982) in the framework of a general production function. Caves *et al.* distinguish between input based and output based productivity indices where this corresponds to input saving and output increasing Farrell measures. This direct link between the distance functions concept and Farrell's (1957) measures of technical efficiency was exploited by Färe *et al.* (1992) who recognised that the distance functions are reciprocal to Farrell measures of technical efficiency.

In the empirical applications, they use DEA in order to construct either input based or output based Malmquist productivity indices. For example, Färe, Grosskopf, Norris, and Zhang (1994) analyse the productivity growth in OECD countries over the period 1979-1988 by constructing a Malmquist output based index. Another study by Färe, Grosskopf, Yaisawarng, Li, and Wang (1990) utilise an input based index to evaluate the productivity growth in Illinois electricity utilities during 1975-1981. Färe, Grosskopf, Lindgren and Roos (1992) have used the input based approach to calculate the Malmquist productivity for a sample of Swedish pharmacies over the period 1980-1989. In all these studies, the productivity growth is decomposed to provide information on the source of overall production change in that particular sector.

In particular, they show that a Data Envelopment Analysis based Malmquist index could be decomposed into two parts, one accounting for the changes in efficiency and the other accounting for changes in frontier technology. This is an important contribution in that it provides insight into the measurable sources of productivity change. Contrary to Caves *et al.*, their models do not require any assumption on the economic behavior of production units. In addition, there is no requirement on the resource prices.

In this study we adopt the DEA based Malmquist productivity index because of these virtues. First, imposing a behavioural assumption such as profit maximisation or cost minimisation, particularly for the 'flag' carriers in the sample, would be inappropriate since government ownership traditionally entails other considerations such as employment. Second, either it may not be possible to obtain price information for all inputs and outputs or prices could be distorted due to regulatory practices. Third, decomposing the sources of productivity change, the growth in productivity over the study period can be attributed either to airlines catching up with their own frontier or frontiers shifting over time, or both. Fourth, in using the non-parametric strength of DEA, which does not require a parametric functional form on the technology, we can handle multiple input and output characteristics of the airlines industry. Lastly, decomposition allows us both productivity change and its sources to be airline-specific and time-varying.

The DEA based Malmquist productivity index has been increasingly used in panel applications to question the influence of certain government policies. [See Berg *et al.* (1992) for the deregulation of Norwegian banking, Price and Weyman-Jones (1996) for the privatisation of the UK gas industry and Griffel-Tatje and Lovell (1996, 1997) for the deregulation of Spanish savings banks].

To construct a Malmquist index for a panel data set, two ways can be used, namely the adjacent and fixed base periods. With the adjacent method, a Malmquist index is calculated for each period: for example for the first adjacent period (t+1, t); then for the second adjacent period (t+2, t+1) and this continues to the end of the sample. Alternatively, a Malmquist index can be calculated for all periods but to a relative fixed base period. Even though these two ways generate the same values for the relative technical efficiency change component, they can produce different values for the technical change component if the production frontiers coincide. Thus the Malmquist productivity index generates different values.

In this thesis, we use adjacent periods to examine the recent productivity performance of European airlines to assess the results of the liberalisation reforms over the period 1991-1995. We specify an input-oriented index, providing outputs with minimum input consumption. This orientation is more consistent with the constraints or pressures faced by the airlines. To construct an input based productivity index, we follow Färe *et al.* (1992).

Considering a unit in two periods t and t+1, the latter being the most recent period, let $x^t \in R_+^N$ and $y^t \in R_+^N$ denote the input and output vectors respectively. Then an input-based Malmquist productivity index for adjacent periods is defined as

$$M_i^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\frac{D_i^t(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} \frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^{t+1}(y^t, x^t)} \right]^{1/2} \qquad (4.7)$$

This index is the geometric mean of two Malmquist indexes as defined by Caves *et al.* (1982). Moreover, they assume that $D_i^t(y^t, x^t)$ and $D_i^{t+1}(y^{t+1}, x^{t+1})$ are equal to 1 for all observations and periods. According to Farrell (1957), this means there is no allowance for inefficiency. However, Färe *et al.* (1992) relax the assumption to allow for inefficiencies and decompose the productivity index into two components:

MC which measures the change in efficiency and MF which measures technical change; or alternatively the catching up effects and frontier shift effects. Equation 4.7 can be rewritten as

$$M_i^{t+1}(y^{t+1},x^{t+1},y^t,x^t)=\frac{D_i^{t+1}(y^{t+1},x^{t+1})}{D_i^t(y^t,x^t)}\left[\frac{D_i^t(y^{t+1},x^{t+1})}{D_i^{t+1}(y^{t+1},x^{t+1})}\frac{D_i^t(y^t,x^t)}{D_i^{t+1}(y^t,x^t)}\right]^{½} \qquad (4.8)$$

where

$$MC_i^{t+1}=\frac{D_i^{t+1}(y^{t+1},x^{t+1})}{D_i^t(y^t,x^t)} \qquad (4.9)$$

and

$$MF_i^{t+1}=\left[\frac{D_i^t(y^{t+1},x^{t+1})}{D_i^{t+1}(y^{t+1},x^{t+1})}\frac{D_i^t(y^t,x^t)}{D_i^{t+1}(y^t,x^t)}\right]^{½} \qquad (4.10)$$

As a result the total productivity growth, M, is the product of MC and MF:

M = MC * MF

The Malmquist index will indicate productivity growth when the index is more than unity and productivity decline when it is less than unity. If it is equal to 1, that denotes there is no change in productivity. Within the DEA framework, we assume a constant returns to scale model since this assumption is mostly consistent with the airline literature. [See White, 1979]. Using the settings in Färe *et al* (1990 and 1992) we assume that we have k = 1,2, ..., K airlines which use n = 1,2, ...N inputs $x_n^{k,t}$ at each period t = 1,2,...T to produce m = 1,2, ...M outputs $y_m^{k,t}$ at each period t = 1,2,...T.

To measure the relative productivity of an airline k between t and t+1, we need to compute the following LP problem stated below:

$$[D_i^t(y^{k,t}, x^{k,t})]^{-1} = \min \lambda$$

subject to $y_m^{k,t} \leq \sum_{k=1}^{k} z^{k,t} y_m^{k,t}, \quad m = 1,2,...,M,$

$$\sum_{k=1}^{k} z^{k,t} x_n^{k,t} \leq \lambda x_n^{k,t}, \quad n = 1,2,...,N, \tag{4.11}$$

$$z^{k,t} \geq 0, \quad k = 1,2,\ldots,K.$$

All the other distance functions needed to construct the Malmquist productivity index, i.e. $D_i^t(y^{k,t+1}, x^{k,t+1})$, $D_i^{t+1}(y^{k,t+1}, x^{k,t+1})$ and $D_i^{t+1}(y^{k,t}, x^{k,t})$ are computed in a similar way expressed in (equation 4.11).

In equation (4.11), λ has the same interpretation as θ in equation (4.6) and the $z_n^{k,t}$ are DMU weights as the same as the λ_{it} in (4.6).

4.7 Graphical Representation of the Malmquist Productivity Index

Figure 4.3 below illustrates the construction of a Malmquist index for a carrier, C which uses the inputs x^t and x^{t+1}in years, t (pre-liberalisation) and t+1 (post-liberalisation) periods to produce the output y^t and y^{t+1}. Between these two time periods, the frontier shifts from f (t) to f (t+1). In year t, carrier C is observed at (x_1, y^t). The technical efficiency of carrier C when measured against the benchmark frontier f (t) is computed as

$$D^{t,t} = \frac{x_{11}}{x_1}$$

The index changes when it is measured against the benchmark frontier f (t+1):

$$D^{t+1,t} = \frac{x_{21}}{x_1}$$

Correspondingly, in year t+1, the technical efficiency of carrier C relative to the benchmark frontier f (t) is

$$D^{t,t+1} = \frac{x_{12}}{x_2}$$

The index changes when t is measured against the frontier f (t+1):

$$D^{t+1,t+1} = \frac{x_{22}}{x_2}$$

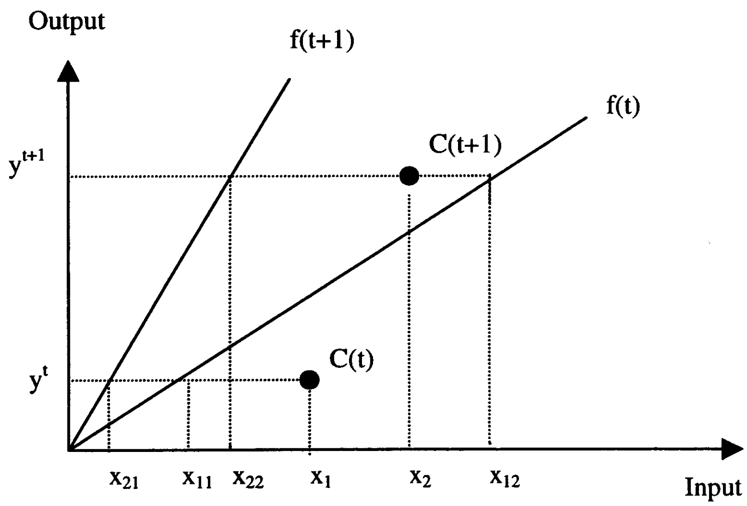

Fig 4.3 Construction of Malmquist index

The Malmquist input-based productivity index, M_t constructed against f(t) is defined as

$$M_t = \frac{x_{12} / x_2}{x_{11} / x_1}$$

and M_{t+1} is obtained when the index is measured against f(t+1)

$$M_{t+1} = \frac{x_{22} / x_2}{x_{21} / x_1}$$

The Malmquist index can be decomposed into two components, MC, the catching up effect and MF, the frontier shift effect:

$$MC = \frac{x_{22} / x_2}{x_{11} / x_1}$$

The catching up effect is measured by the relative efficient distance of the carrier from its own frontier. The frontier shift effect is defined as

$$MF = \left(\frac{x_{12}}{x_{22}} * \frac{x_{11}}{x_{21}} \right)^{1/2}$$

This frontier shift effect is measured by the relative distance between the frontiers at the post-liberalisation level of output. However, there are other alternatives available for selecting a benchmark frontier. For example, the frontier shift can be measured as (x_{11}/x_{21}), that is the relative distance between the frontiers at the pre-liberalisation level of output, or at the geometric mean of the pre- and post-liberalisation outputs. The latter procedure employed by Färe *et al.* (1990) is adopted in this thesis.

4.8 Explaining Efficiency with Tobit Analysis

DEA efficiency scores are used as performance indicators to determine whether the DMUs are operating in a technically efficient way. Hence, it is also of considerable interest to explain DEA efficiency scores by investigating the determinants of technical efficiency when the results are expected to guide policies aimed at improving performance.

In such cases, it has been customary to use a two-stage procedure. In the first stage, technical efficiency is assessed on a reference technology whilst in the second stage, the first stage results, i.e. DEA efficiency scores, are explained by relevant variables not directly included in the DEA analysis. This is done by appropriate statistical techniques (Lovell, 1993:53).

Selecting the relevant variables at each stage has proved to be a somewhat controversial issue. According to Boussofiane *et al* (1991) and Golany and Roll (1993) environmental variables, i.e. socio-economic and demographic factors, should be included in DEA analysis as inputs. Others argue that aiming at reducing environmental variables in the first stage is not meaningful so that such variables belong to the second stage (Ray, 1988, Lovell, 1993 and Viitala and Hanninen, 1998). They maintain that explanatory variables can only affect technical efficiency, and not the transformation process in which inputs generate outputs.

DEA efficiency measures obtained in the first stage will be dependent variables in the second stage. An appropriate multivariate statistical model in the second stage should then consider the characteristics of the distribution of efficiency measure. As defined in equations (4.1) to (4.6) the DEA score falls between the interval 0 and 1 ($0<h^*\leq 1$), making the dependent variable a limited dependent variable.

Regression models are inappropriate for handling models involving limited dependent variables. Dependent variables may have continuous and discrete values. Since there is a positive probability that a particular value, zero, will occur in the data, regression models are not appropriate for such data. Limiting the range of the values of the dependent variable to a non-zero mean of the disturbance and to biasedness of the dependent variable and inconsistency of the least squares estimators. Therefore we cannot obtain consistent estimates of βs using the least squares estimates when the error terms have positive mean. Rather than OLS, to overcome these problems, The Tobit model is suggested to (Grosskopf, 1996:165)

In more formal terms, estimation with an Ordinary Least Squares (OLS) regression of h^* would lead to a biased parameter estimate since OLS assumes a normal and homoscedastic distribution of the disturbance and the dependent variable (Maddala, 1983). However, the expected errors will not equal zero in the case of limited dependent variable model or the Tobit model. This model was first suggested in econometrics literature by Tobin (1958). In his pioneering work, household expenditure on durable goods was analysed using a regression model in which the range of dependent variable is constrained. That means, the dependent variable of the model (expenditure in Tobin's model) cannot be negative. Tobit models are also known as truncated or censored regression models.[22]

It is important to distinguish between these two models. Truncation occurs when some observations for dependent variable, y, or the explanatory variables, x, are missing. On the other hand, in a censored regression model, there are observations for all explanatory variables, x, but some observations on the dependent variable, y, are missing (or censored) if y^* is above (or below) a threshold level (Maddala, 1992). Hence, there would be a concentration of observations at a single value.[23]

The censored regression or Tobit model can be employed to accommodate DEA efficiency scores since DEA produces a concentration of efficiency scores at unity[24]. It can be argued that a truncated regression model cannot be used for modelling DEA scores because DEA analysis does not exclude observations greater than one, but mathematical formulation of a DEA model simply does not allow any DMU to obtain a value (efficiency score) more than one (Chilingerian, 1995:561).

There is a substantial literature on modelling data using Tobit models in which the distributions of dependent variables in such studies are also similar to DEA scores (see, e.g. Fair, 1978 and Witte, 1980). For example, the dependent variables in these studies are the number of extra marital affairs and the number of

[22] "The model is *truncated* if the observations outside a specified range are totally lost and *censored* if one can at least observe the exogenous variables" (Amemiya, 1984:3).
[23] Those unobserved values are also called 'latent' variable and denoted as y^* (See equation 4.12).
[24] For computational purpose, however, Greene (1993) suggests the use of censoring point at zero. Therefore, using the formula in (4.13), the DEA efficiency scores are transformed and censoring point concentrated at zero.

arrests (or convictions) per month after release from prison respectively. For the majority of observations, the dependent variable in each case are censored at a single value, i.e. zero marital affairs and zero arrests. Thus, these values could be associated with 'best practising' carriers, which could achieve a maximum efficiency score of one.

In recent years, many DEA applications employ a two-stage procedure. For example, Luoma *et al.* (1996) and Chilingerian (1995) conduct both DEA and Tobit analyses in health sector applications to estimate both inefficiency and the determinants of inefficiencies. Viitala and Hanninen (1998) apply DEA with Tobit models for the public forestry organisations in Finland. The study by Bjurek *et al.* uses a similar approach to measure the performance of public day care centres in Sweden. Another recent study by Kirjavainen and Loikkanen (1998) applies both DEA and Tobit for the Finnish senior secondary schools.

A similar procedure is conducted in transportation studies. For example, Oum and Yue (1994) use DEA efficiency scores with a Tobit model to analyse the influence of certain variables on the performance of European railways. Kersten (1996) evaluates the performance of French urban transit companies. In the same way, Gillen and Lall (1997) analysed the airport productivity. Thus, all these studies use a two-stage procedure, first to determine the efficiencies and then for policy purposes, use Tobit model to explain the efficiency distributions.

Following Gillen and Lall (1997) and Chilingerian (1995) the Tobit censored regression model is used in this thesis to accommodate the censored DEA efficiency scores. DEA efficiency scores computed by the equation (4.6) are used as dependent variables. Recall that solving DEA windows problem increases the sample size, thus the discriminatory power of the results. The DEA score, which is obtained by taking the reciprocal of DEA score minus one:

$$y_i = (1/\theta) - 1 \tag{4.12}$$

The best practising airline with an efficiency score of 100% is traormed to zero. With this transformation, airlines, which have efficiency scores less than 100% become any positive value. Thus, transformation bounds the DEA score in one direction and censors the distribution at zero value.

For this purpose, the standard Tobit model can be defined as follows for observation *i*:

$$\begin{aligned} y_i^* &= \beta' x_i + \varepsilon_i \\ y_i &= y_i^* \text{ if } y_i^* \succ 0, \text{ and} \\ y_i &= 0, \text{ otherwise,} \end{aligned} \tag{4.13}$$

where $\varepsilon_i \sim N(0, \sigma^2)$[25], x_i and β are vectors of explanatory variables and unknown parameters, respectively. The y_i^* is a latent variable and y_i is the DEA score.

Since the mean function of the Tobit model is

$$E[y_i|x_i] = \Phi\left(\frac{\beta' x}{\sigma}\right)(\beta' x_i + \sigma\lambda_i) \tag{4.14}$$

---

[25] u_{it} are unobserved firm-specific effect and ε_{it} are residuals that are independently and normally distributed, with mean equals to zero and common variance, σ^2.

It is important to note that β cannot be interpreted as the marginal response of the mean of $\mathrm{E}(y_i|x_i)$ to a change in *x*. We conclude that β overstates the true marginal response.

Given the censoring, the marginal effect is

$$\frac{\partial E[y_i|x_i]}{\partial x_i} = \beta_j \Phi\left(\frac{\beta' x_i}{\sigma}\right) \quad (4.15)$$

where *y* is the dependent variable, β is the coefficient of the model and Φ_i is the cumulative density function of a standard normal variable evaluated at $\frac{\beta' x_i}{\sigma}$, *x* represents the independent variable and σ is the standard deviation[26].

The likelihood function (L) is maximised to solve β and σ based on 51 observations of y_i and x_i is

$$L = \prod_{y_i=0}(1-F_i) \prod_{y_i>0}\frac{1}{(2\Pi\sigma^2)^{1/2}} \times e^{-[1/(2\sigma^2)](y_i-\beta x_i)^2} \quad (4.16)$$

where

$$F_i = \int_{-\infty}^{\beta x_i/\sigma} \frac{1}{(2\Pi)^{1/2}} e^{-t^2/2}\, dt$$

The first product is over the observations for which the carriers are 100% efficient (y = 0) and the second product is over the observations for which carriers are inefficient (y >0). F_i is the distribution function of the standard normal evaluated at $\beta' x_i/\sigma$.

[26] See Greene (1997:963). Also this provides a good approximation for the marginal effects of dummy variables.

4.9 Conclusion

The non-parametric strength of DEA has become increasingly popular in efficiency analyses. Recent theoretical and mathematical research haalso contributed in the development of DEA models. Moreover, the DEA efficiency scores obtained in the first stage can be used for the Tobit analysis in order to identify the sources of inefficiency. Blending the DEA with Tobit can determine the determinants of performance and provide results, which guide the essential policies to enhance performance.

Compared with the conventional indicators of performance, this methodology can handle multiple inputs and outputs and avoid the aggregation problems. In addition, it is of use in cases where the price information is either missing or distorted. Because of these virtues, the DEA is thoroughly used in this thesis for the performance measures in the European airlines industry.

Having described the industry in the following chapter, Chapter 6 measures the efficiency and productivity for the European airlines by using the non-parametric strength of DEA. Accordingly, Chapter 7 explores the determinants of performance by using the Tobit model.

CHAPTER 5. THE EUROPEAN AIRLINES INDUSTRY

"Any study of air transport regulatory reform and public policy should begin with an understanding of the industry and its institutions" (Gillen, Oum, and Tretheway, 1985:55)

5.1 Introduction

This chapter seeks to describe the characteristics of the European airlines industry with a special emphasis on the evolution of regulatory practices. The European airlines industry is passing through a gradual period of economic liberalisation. One of its significant features is the existence of charter operations, which may indicate a growth potential if flexibility in rate and route regulation is promoted in the industry.

Traditionally, airlines are endowed with highly regulated domestic and international markets. These are mainly state-owned airlines that enjoy duopolistic conditions created by bilateral agreements. However, the subsequent reforms recently introduced by the EC aimed to increase competition by providing certain flexibilities in pricing, capacity sharing and market access. The Third Liberalisation Package in 1993, however, has been the most decisive among these reforms.

This chapter is organised as follows. Section 2 describes the characteristics of the industry. Ownership and privatisation practices are explained in Section 3. Section 4 details the recent alliance attempts in the industry. The evolution of regulatory policy is detailed in Section 5 with special emphasis on the role of the

EC and the US domestic deregulation on the recent liberalisation reforms in European air transport. Finally, Section 6 concludes.

5.2 Characteristics of the Industry

Commercial airline services in Europe are provided on both scheduled and non-scheduled basis. Scheduled services operate over a specified route according to a published timetable, whilst the latter services are usually inclusive tour charters (ITC) and sold as part of holiday packages. Charters are not allowed to provide scheduled services whereas scheduled airlines may provide both scheduled and charter services. Compared with the scheduled services, charter operators charge lower prices. The charter flights are also less regulated (See Section 5.5).

First charter companies were established in the UK in the early 1950s. Then, these were followed by the ones formed in Scandinavia and later in Germany and other countries. Charter operations carry ITC traffics between northern and western Europe and the resort of the Mediterranean. Since these services are not subject to strict regulations, they grew much more rapidly than the scheduled operations in the early 1970s (Doganis, 1991). In 1990s, the charter market still plays a significant role within the total European market (see Table 5.1). Around half of the traffic volume in 1991, as measured in revenue passenger kilometres (RPK), is provided by charter operations in Europe.

Table 5.1 *Percentage distribution of European Airline Traffic by Type of Service*

	1985		1991	
	Passengers carried	RPK	Passengers carried	RPK
Scheduled	74%	58%	76%	51%
Charter	26%	42%	24%	49%

Source: Compiled from the Association of European Airlines (AEA) Yearbooks

The scheduled operations are divided into domestic, intra-European and international flights. Domestic services are provided within any country. Intra-European services are within Europe. International flights are the flights between Europe and the rest of the world. The types of airlines in Europe which provide all these services are classified into a number of broad categories (OECD, 1988).

- The first group consists of 25 "flag carriers" such as Air France, Lufthansa, Alitalia, etc. They are mostly the national carriers and are state owned. This is the most popular group since these carriers provide the main intra-European and international services.

- The second group is composed of charter operators that provide non-scheduled services; for instance, Air Charter in France, British Airtours in the UK, among others. They have financial links with the flag carriers.

- The third group provides both charter and domestic services. They are larger than the second group carriers. For example, Air UK, Britannia and Air Europe in the UK and Air Inter in France. They are involved in commercial operations with the national carriers. In some cases this could be with an airline from another nation, i.e., KLM holding 14.9% of Air

UK. These links may take different forms: extensive commercial co-operation, financial investments, and franchisees and alliance agreements.

- In the final group there are around 60 small airlines (with less than 250 employees). They mainly conduct domestic, cargo or minor charter flights.

The existence of different groupings prevents European aviation being a single market. Along with the many sovereign states, which have varying degrees of approaches to domestic and international aviation policy, there are other institutions which are exclusively concerned with civil aviation in Europe (Button and Swann, 1991). The largest economic block is the European Community (EC) which has 15 member states. The EC has recently increased its involvement with many aspects of air transport (see section 5.5.2). In addition, there is the ECAC (The European Civil Aviation Conference) which 'overlaps' this block and acts as an advisory body to the EC on co-ordinating matters. Eurocontrol controls cross-border flights over the airspace of member states. Further, there is the Joint Aviation Authorities (JAA) which is an inter-governmental forum aimed at co-operation on aircraft safety, maintenance and technical matters. Airlines, alongside with the manufacturers and crew unions, participate in this forum.

Additionally there are international agencies involved in similar matters, i.e. International Air Transport Association (IATA) and International Civil Aviation Organisation (ICAO) (See Section 5.5). Finally, the trade association, AEA, is the largest in Europe embracing 25 carrier members. AEA promotes co-operation amongst its members and represents their interests to the EC, the ECAC or any other international organisation.

The AEA is one of the three important geographical concentrations within the world scheduled airline industry (See Table 5.2 below). The other two are the markets in North America and Asia and Pacific. The total international air traffic between AEA or Europe and the rest of the world is quite significant. The largest traffic flows in both 1993 and 1996 occurred between Europe and North America.

Table 5.2 *Regional distribution of scheduled traffic 1993 and 1996*

	1993	1996
Traffic within	%	%
Europe	7.8	8.5
Asia and Pacific	11.1	15
North America	34.6	33
Traffic between Europe and		
Asia and Pacific	8.3	8.7
North America	13.9	11.5
Traffic between N. America and		
Asia and Pacific	10.1	7.7
All other traffic flows	13.2	15.6

Source: Compiled from the AEA Yearbooks

However, compared with the domestic US market, which commands the largest share of world airline traffic 34.6% in 1993, the overall passenger kilometre performed within Europe in the same year, represents around 7.8% of the world total. This reflects the shorter average stage lengths. On the other hand, the US and Asian airlines attain longer stage lengths in their domestic aviation markets. Therefore, in terms of total scheduled passenger kilometre performed European airlines are relatively smaller than the US. In 1993, for example, only

BA and Lufthansa from Europe rank in the top 10 airlines. The rest were US major airlines. (IATA World Air Transport Statistics, 1993).

Moreover, the European airlines have often been criticised on the grounds that they fall behind the US carriers in maintaining their cost structures to prevailing market conditions. Partly due to the stage length and aircraft size, the overall operating costs confronted by the major US airlines are lower than that of the European airlines (AEA). US airlines generally encounter lower non-avoidable production costs (i.e. fuel, landing) and reducible costs (i.e. ticketing, crew, ground handling) [See Pelkmans (1990) for the characteristics of European vs US air markets).

However, various studies confirmed that some of the higher cost differences arise from lower productivity rather than higher input prices. As detailed earlier in Chapter 3 that, among others, Forsyth *et al.* (1986), Windle (1991), and Good *et al.* (1993, 1995) compared the US and European airlines and showed that the productivity of European airlines is less than that of their US counterparts (See Chapter 3 for details). Finally, the US airlines are privately owned whereas the European airlines industry has a high degree of state ownership. The European ownership details are explained in the following section.

5.3 Ownership and Recent Privatisation Practices

The European airlines are known as "flag carriers", because they are strongly associated with their country of origin. The majority of airlines are owned by the state. Traditionally the airlines industry experiences a great deal of government intervention. The extent of this intervention however, varies from one country to another. Usually, governments may fully own their airlines or hold a majority stake. Generally the reasons for government involvement in air transport include: national prestige, balance of payments improvements, promotion of tourism, investment in high technology, service to remote communities, and national defence (Taneja, 1976).

Table 5.3 below shows the ownership status of European airlines in 1995. For convenience the airlines can be grouped according to the state ownership stake (OECD, 1988). The first group consists of airlines, which are controlled directly or through public institutions. State involvement is 80% or more in these companies. Among the carriers are, Adria Airways, Aer Lingus, Air France, Air Malta, Alitalia, Balkan, Iberia, Yugoslav Airlines, Olympic Airways, Air Portugal and Turkish Airlines.

The second group is made up of companies, which have between 20% and 50% private participation. These include Lufthansa which experienced partial privatisation in 1995 in which the share of Federal Republic in 1994 declined from 51.42 to 35.68%; in Sabena, the state has a 61.8% participation; SAS, which is 50% publicly owned with 3:2:2 split between the three countries Sweden, Denmark and Norway; Finnair, 60.7%; and Cyprus Airways with 80.46 % state ownership.

Finally, the third group includes of airlines, which are fully private or predominantly private. The state involvement in KLM, Luxair, and Swissair is 38.2%, 23.1%, and 21% respectively. British Airways (BA), British Midland and Icelandair are wholly private companies.

Table 5.3 *The ownership status of AEA airlines in 1995*

Airlines	Country	State %
Adria Airways	Slovenia	100
Aer Lingus	Ireland	100
Air France	France	99.3
Air Malta	Malta	96.4
Alitalia	Italia	86.4
Austrian Airlines	Austria	51.9
Balkan	Bulgaria	100
British Airways	UK	0
British Midland	UK	0
Czech Airlines	Czech Republic	48.99
Cyprus Airways	Cyprus	80.5
Finnair	Finland	60.7
Iberia	Spain	99.8
Iceland Air	Iceland	0
Yugoslav Airlines	Yugoslavia	100
KLM	Netherlands	38.2
Lufthansa	Germany	35.7
Luxair	Luxembourg	23.1
Malev Airlines	Hungary	65
Olympic Airways	Greece	100
Sabena	Belgium	61.8
SAS	Scandinavia	50
Swissair	Switzerland	21
Air Portugal	Portugal	100
Turkish Airlines	Turkey	98.2

Source: Compiled from the AEA Yearbook 1995

It is often claimed that the nature of ownership affects the efficiency of airlines. Additionally this could influence the operational and financial options available to them. The move to privatise airlines is usually justified on these grounds (see chapter 2 for more details). The largest privatisation programme for the state-owned, BA took place in the UK in February 1987. All government shares in the company, amounting to 900 million pounds, were transferred to the private sector. According to Boussofiane *et al.* (1997), BA became more efficient by the measures taken in the post-privatisation period.

Contrary to the UK government's decision to fully privatise the BA, there had been some partial privatisation practices in Europe. The Federal Government of Germany, for example, reduced its share in Lufthansa in 1995 from 51.42% to 35.68%. Moreover, the privatisation phenomenon is highly recommended by the Comité des Sages (1994)[27] to encourage airlines to operate on a fully commercial basis without any government interference. Ultimately, they believe all national carriers should be privatised.

5.4 Mergers, Acquisitions and Commercial Agreements

Another phenomenon, which characterises the recent evolution in the European air transport is consolidation. This may take different forms: the take-over of a smaller airline by a larger one, a merger; acquiring a minority stake in a major airline; and commercial agreements without any equity participation (AEA Yearbook, 1995). Since the end of the 1980s, there has been a considerable increase in commercial co-operations among European airlines. This is probably the result of the liberalisation packages (see 5.5.2 for details on the Third Liberalisation Package), which gradually allowed foreign ownership between the EU carriers.

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[27] Comité des Sages (1994) or 'Committee of Wise Men' was set up in 1994 to prepare a report of recommendations on the future of aviation in the European Union.

5.4.1 Mergers and Acquisitions

The merger between BA and British Caledonian (BCal) in 1987 was the first example and has had profound implications for the European airlines industry. The largest airline of the UK took over the second largest BCal which was established in 1970 to act a 'second force' and contribute to the competition in the UK airlines industry with the recommendations of the 1969 Edward's Report. It was unfortunate that the company fell into serious financial problems and became vulnerable to take-over in the late 1980s. Apart from BA's merger proposal, SAS also announced its willingness to buy a minority share of BCal's equity and assist with the immediate financial needs by cash injection.

Whilst the SAS proposal was rejected owing to the fears of foreign ownership, the UK Monopolies and Merger Commission (MMC) confirmed BA's merger proposal and foresaw the following beneficial outcomes from this merger. First, the union of the two British firms could strengthen the competitive position of BA against the competitive threat from American carriers. Second, the merger could increase the traffic potential and attain financial savings by eliminating the duplication of services. (Wheatcroft, 1988).

Even though the MMC concluded that 'the take-over was not against the public interest' (Vickers and Yarrow, 1988:353), it was widely argued that this merger posed serious threats to competition. The main fears were of the effects of BA's dominance in both Gatwick and Heathrow airports. Finally, the EC intervened and imposed certain safeguards on the merger to maintain sufficient competitive conditions.[28]

A similar merger experience was witnessed in the French airlines industry when the competition was already negligible because of regulation of entry. Only three scheduled carriers were operating in the industry: the state owned Air France, the independent UTA and the domestic airline, Air Inter. Both Air France and UTA owned one-third stakes in Air Inter, but all three served different markets. When there had been some attempts by the UTA to obtain licences to serve some other markets, this was refused by the French government on the grounds that additional route competition would prevent the development of French aviation.

During the time when this matter was taken to the EC for further investigation, Air France announced its willingness to acquire a majority stake in UTA. This could enable Air France to control Air Inter too. Again this matter was investigated by the EC and approved subject to a number of conditions[29]. In 1992, Air France continued to form commercial agreements and bought shares in Sabena and Czech airlines to establish an integrated network between Eastern and Western Europe. In 1994, however, after a request from the Czech government, Air France returned the airline's shares. However, in the early 1990s, Air France penetrated African, Middle East and Far East markets by buying shares in

[28] Pryke (1991) argued that the merger should have been prevented and BCal allowed to merge with the SAS.
[29] According to a study by Dodgson (1994) the consolidation among the three carriers created a monopoly in the French domestic market.

different airlines, i.e. Air Mauritius, Middle East Airlines and Japan Airlines, among others.

More market concentration, however, has developed between European countries and particularly Latin American and US companies. Iberia, for example, bought shares in the two South American companies, Viaso of Venezuela and Aerolineas Argentines of Argentina and established dominant position on the Europe-Latin American route. On the other hand, BA bought 24.6% shares of USAir, which was in financial difficulties. BA also penetrated the Pacific and Asian market by buying 25% of Qantas, the Australian carrier. BA's dynamic concentration policy not only targeted the intercontinental markets but also the European. In 1992, it acquired Brymon European; bought 49% of Deutsche BA; 31% of Air Russia and 49.9% of TAT, of which Air France was forced to sell its 35% stake in TAT by the EC after the merger confirmation.

5.4.2 Partnership Agreements Without Any Equity Participation

Not all agreements involved equity participation. There are partnership arrangements among airlines, which aim to create competition advantages for the partner airlines. Economies of scale can be then achieved by complementing each other's services, particularly in maintenance and marketing. Code sharing agreements, which are highly popular among European airlines, enable airlines to carry different airline brands in the same flight. Moreover, the recent franchising concept involves small carriers in paying a royalty to a larger carrier in order to market its services under the latter's brand name.

Among other examples, in 1995 Lufthansa made code sharing agreements with United, Canadian, Varig, Lauda Air, Business Air, and Luxair; and a marketing alliance with Finnair and Cargolux. British Midland in 1995, had code sharing with American Airlines, United Airlines, Air Canada, Malaysian Airlines, SAS, Austrian Airlines, Alitalia, and Air Portugal. However, some AEA airlines, for example, Adria Airways, Aer Lingus, Air Malta, Balkan, CSA, JAT, Olympic Airways, and Turkish Airlines, are not involved in any partnership agreements at all.

Additionally, there are airline groups in Europe, which co-operate in computer reservation system (CRS) facilities: BA, KLM, Aer Lingus, Air Canada, Air Portugal, Alitalia, Austrian, Olympic, Swissair, United and USAir own a CRS group called Galileo International while Air France, Lufthansa and Iberia lead another CRS group, Amadeus.

Indeed it is evident that the recent trend in liberalisation has boosted consolidation activities in various services and become a significant feature of the European airline industry. Similar practices, however, were highly regulated before the evolutionary liberalisation attempts taken place in European skies. This is detailed in the following section.

5.5 The Evolution of Regulatory Policy in Europe

The regulation of international aviation was initiated with the Paris convention of 1919. It was accepted that states have sovereignty rights over the air space above their territory. This directly involved national governments in the regulation of the industry. Control was mainly handled with a set of *ad hoc* arrangements between nations. The rules on certain economic rights, however, were not set till the 1944 Chicago Conference.

The Conference, involving fifty-two nations, was organised to discuss the possibility of establishing a multilateral agreement in order to develop international air services. Mainly this agreement aimed to deal with three aspects of international transport: the exchange of traffic rights, or 'freedom of the air'; the control of tariffs; and the control of frequencies and capacities (Doganis, 1991:26). The 'freedoms of the air' were defined as:

i. The right to overfly another country's territory;

ii. The right to land in another country for fuel and maintenance, but not to pick or set down passengers;

iii. The right to carry traffic from the home country to the foreign country;

iv. The right to carry traffic from the foreign country to the home country;

v. The right to carry traffic from the foreign country to another third country.

The participant nations were only able to reach agreement in the first two freedoms and no multilateral agreement was reached on the other freedoms. The main reason for this was that the US, whose civil aviation industry was not as severely affected by the World War II as the European countries, would otherwise dominate the market. Therefore, most European states, particularly the UK, did not support the 'open skies' policy proposed by the US. Instead, they wanted to continue to exercise exclusive sovereignty over their space. This policy was only supported by the Netherlands and Sweden who had small domestic markets and needed to benefit from the fifth freedom rights.

The most important outcome of the Conference was the signing of the Convention on the International Civil Aviation. The Chicago Convention later formed the ICAO to provide technical assistance to countries in developing the necessary civil aviation infrastructure.

Over the years, bilateral air services agreements have emerged to regulate all essential elements related to the exchange of air services between nations. Most bilateral agreements involved only the national carriers, from the individual states. The Bermuda agreement signed between the UK and the US in 1946 became a model for many other bilateral agreements. In particular, an agreement would determine the load capacity and frequencies. With restrictive 'pooling agreements', the individual states could share the capacity and the revenue earned from those routes. This led to a regulated duopoly where the participants were usually the government owned national carriers. The governments strictly controlled entry into the industry by refusing to licence competitors. Secure with such agreements, the interests of "flag" carriers were always protected. As a result, competition was eliminated.

In 1945, the IATA was established to regulate fare setting. Rather than having a multilateral agreement, IATA fixed fares and submitted its proposals to governments for approval. IATA tariff procedures were widely accepted in Europe, since the airlines agreed explicitly in the bilateral agreements that they would abide by the procedure imposed by the IATA. This procedure, however, was not supported by the US Civil Aeronautics Board (CAB).

In addition to heavy regulation in international aviation, similar protective attitudes were also evident in domestic aviation. Many states claimed that the rational of regulation was based on public interest considerations. Soon after the Paris convention, regulatory legislation for domestic routes emerged in different parts of the world such as the Air Navigation Act (1920) in Australia, the Civil Aeronautics Act (1938) in the USA and the Civil Aviation Act (1946) in the UK. The regulatory authorities were established with these Acts and governments strictly controlled operations by issuing licenses on the basis of a public need for the extra service (Button and Swann, 1994).

The 1980s, however, witnessed developments in the domestic aviation of individual states in Europe. The UK, for example, was the pioneer in the sense that the Civil Aviation Authority (CAA) gradually removed the tight regulation on entry and relaxed price controls. Moreover, the privatisation of British Airways in 1987 was one of the most important reforms in terms of state withdrawal from airline companies (See Graham, 1994).

Charter operations, on the other hand, were not as tightly regulated as domestic and international services. They were left to the discretion of individual states. The airlines in the charter business are usually prohibited from offering tickets directly to the public, and may only sell tickets as part of a package in which accommodation and the length of stay must be specified. Compared with scheduled operations, the charter operations charge lower prices. These services have increased in response to consumer and tourist pressures. In 1976, for example, the charter share of air traffic from Britain accounted for around 33% of passengers being carried (Barrett, 1987:25). The rapid growth of this sector exerted pressure on the liberalisation of scheduled operations. In the same way, it forced the IATA to restructure its procedures and introduce a more flexible and open tariff setting.

This coincides with the US CAB's attempts to liberalise its bilateral arrangements with European nations. US domestic deregulation was also initiated during this period (see Section 5.5.3). It could also be argued that the US aimed to transform the new liberal philosophy into a heavily regulated international operation. There was a conscious effort to achieve an open skies policy by increasing competition in the trans-Atlantic market. Initially, the US CAB negotiated with the UK, who first opposed the idea of 'open skies' policy (Captain and Sickles, 1997). New bilateral agreements with other nations followed the US-UK agreement. As expected, the entry of new airlines significantly stimulated the level of scheduled traffic. While the share of all European scheduled traffic across Atlantic was about 75% of passengers in 1976, this figure had risen to 94% and 95% by 1981 and 1986 respectively (Button and Swann, 1991:94).

As can be seen, the regulatory system followed a dynamic trend in Europe. Since the beginning of the 1980s there has been considerable pressure for more liberalisation of European aviation market. This pressure mainly comes from different sources: the liberalised bilateral agreements; the EC; and the US domestic airlines deregulation. These are detailed in the following sections.

5.5.1 Liberalised Bilateral Agreements in European Aviation

The intra-European routes, however, were highly regulated and operated with bilateral agreements till the mid-1980s. A number of efforts were directed at relaxing the ongoing system by liberalising the bilaterals. For example, the liberalised UK-Netherlands bilateral agreement of 1984 allowed any airline from either country to carry traffic between them. Besides flexibility in route access, there were varying degrees of liberal attitudes in capacity and tariff constraints (Pelkmans, 1986). This UK-Netherlands agreement was followed by agreements with Germany, Luxembourg, Belgium, Switzerland and the Irish Republic. However, agreements with France, Italy and Spain were limited compared with the UK-Netherlands agreement. The table below summarises the nature of the relaxed agreements with respect to route access, capacity constraint and fare control.

Table 5.4 *Liberalised UK bilaterals with other European countries*

Country	Liberalisation of		
	Route Access	Capacity Constraint	Tariff Constraint
Netherlands (1984)	✓	✓	X
Netherlands (1985)	✓	✓	✓
West Germany	✓	✓	L
Luxembourg	✓	✓	✓
Belgium	✓	✓	✓
Switzerland	✓	✓	L
France	L	L	X
Spain	L	L	X
Italy	L	L	X
Irish Republic	✓	✓	✓

Note: ✓ refers to liberalisation; X refers to non-liberalisation; and L is limited liberalisation [Button, K. (1994)].

The empirical evidence showed that the new system brought significant benefits in fare savings and increased frequency of air services on this route. Barrett (1990) examined the liberalisation effects of the UK-Ireland bilateral agreement of 1986. One of the significant changes occurred on the Dublin-London route showed that liberalisation brought new entrants, e.g. Ryanair and Virgin Atlantic. This increased the price competition without pooling revenues among airlines.

Another comprehensive study, conducted by Abbott and Thompson (1991), investigated the consequences of bilateral liberalisation reforms in European aviation. In particular, the authors examined the effects of the reform with respect to market entry and performance. The findings revealed that the restriction of competition in European aviation disadvantaged the consumers. Finally it was contended that the negative effects on consumers would be substantial unless the restrictions on routes were liberalised.

5.5.2 The Impact of the European Commission

A considerable pressure for the liberalisation in European aviation came from the European Commission (EC) to dictate the extent to which regulatory policy has been relaxed in Europe. The EC is the largest international body in European aviation whose attitudes towards liberalisation have significant implications not only for the EC members but the other states as well. Indeed, the increasing number of liberalised bilateral agreements between the EC airlines and other European carriers necessitated changes in the ongoing system to create a multilateral liberalisation, thus provide an important stimulus towards a freer market within the EC.

It is important to note, however that the position of air transport was never clear in the 1957 Treaty of Rome, which set out to establish economic integration in the European Community. Whilst Article 3 of the Treaty applied to road, rail and inland waterways, the air and sea transport were exempted from the competition rules of the Treaty until a Community-wide policy could be developed. This situation was certainly exploited by some Community members. They eliminated competition with bilateral agreements and protected their national carriers. Moreover most countries continuously subsidised their carriers in different forms of which the most popular form was the direct subsidy[30]. This represents the financial injection into the firm.

The EC had suggested reforms in 1972 to open aviation to competition, but due to the dissenting opinions of individual states, an agreement on this proposal was only reached in 1979 when it published the Civil Aviation Memorandum Number 1. This recommended that airlines introduce various forms of cheap fare; that there was a need to establish new cross-frontier services connecting regional centres within European Community; that a clear policy was essential on competition rules and government subsidies.

After this Memorandum, the debate on air transport in the EC had increased. A report on airfares was published in 1981 concluding that fares were not high compared with the costs, but recommended that procedures for tariff development

[30] There is also indirect subsidy, which represents state aid to develop and maintain infrastructure for aviation.

be improved. Following this report, a Directive for the development of scheduled inter-regional services was issued in 1983. This aimed to dictate common authorisation rules in license granting for the Member States and specify common freedoms for air carriers to apply for interregional services.

In 1984, the EC published the Second Memorandum after consulting with the industry and the users. It aimed to establish a Community framework for air transport, which will be of help to reduce fares and improve the quality of service. Additionally, this Memorandum emphasised the importance of competition, which would increase the productivity, and be beneficial to each party. It is important to note, however that a decisive push on the application of the Treaty's competition came with the 'Nouvelles Frontieres' case in 1986. The European Court ruled on the activities of a French travel agent's who was selling tickets below government approved levels. This decision had been significant to prove that EC had powers in intervening in any fare-setting.

In 1987, the Ministers of Transport of the EC agreed in principle to adopt a more radical approach towards competition and introduced the First Liberalisation Package of measures, which provided for:

- Limited freedom to compete on cheap fares
- Multiple designation[31] on the busier routes, and
- Less restrictive capacity sharing agreements, which entitle either country to operate up to 60% of capacity. (Vincent and Stasinopoulus, 1990)

[31] Multiple designation is granting licenses to more than one airline from each country.

However, this package was only a gradual step to implement liberal policy in Europe. It seemed that conflicts of interest in different regions of Europe did not allow a more liberal regime. For example, the countries in the South which attract tourism opposed any increase in competition since their national carriers were already competing with charter operations. Similarly, the ones in the North saw competition as a threat due to the possibility of the disappearance of their hubs. Simply, any change in the European network might transform SAS into a regional airline. The situation, however, for the Centre countries was mixed. France and Germany did not favour a full liberal regime, but a gradual one. They considered that the intermodal competition coming from well-established railway and motorway networks in their countries were adequate to create a competition with the aviation. On the other hand, the UK and the Benelux countries strongly supported a more liberal regime (Encaoua, 1991). Meanwhile, these countries (first the UK and the Netherlands) liberalised the bilateral agreements which brought an increase in frequency and cheaper fares for users.

In the autumn of 1989, the EC Transport Ministers adopted the Second Package of reforms, which allowed more flexible conditions on setting fares and improving market access. Deep discount fares, for example, were introduced without requiring government approval. The lower limit was reduced from 45% in the 1987 package to 30% of the reference economy fare. Restrictions imposed on capacity shares were gradually removed and aimed to be fully eliminated by January 1993 – the date of the Single Market for European aviation (Stasinopoulos, 1992).

Integrating aviation within the overall framework of the EC policies for the Single Market forced the EC to agree the Third Liberalisation Package with more drastic measures. It was aimed to create a more competitive environment for European aviation. The main features of this package included:

- *Fares*: Airlines could set their own tariffs freely, subject to the safeguards against the predatory pricing or excessive prices.
- *Market Access*: The opening of access to all intra-Community routes will be gradual and completed in 1997. This was an important step for the cabotage[32] rights. Between 1993 and 1997, however, cabotage was only allowed up to 50% of the capacity offered. Any carrier will operate between the airports in another country, but this operation -'consecutive cabotage'- could only be sold no more than 50% of the capacity offered on the international routes.
- *Licensing*: There will not be any discrimination in favour of flag carriers. Any technically and financially sound Community airline can obtain license and fly on any EC route (Stasinopoulos, 1993).

According to Comité des Sages (1994:22), 'the concept of the national carrier no longer fits into the regulatory pattern of the Third Package'. That implies that for the sake of the Single European Aviation, carriers need to be treated as European rather than individual 'flag' carriers. Therefore, the Third Liberalisation Package allowed foreign ownership among Union carriers, which has resulted in an increase in the alliances within EU (See 5.4 for details).

[32] Cabotage rights include the right of an airline to operate domestic flights in other EU countries, e.g. the right of Lufthansa to operate a scheduled service between London and Manchester.

However, this package was highly criticised because of the absence of subsidies policy. Even though subsidies provided for the airlines in financial difficulties have a social basis, again it has been argued by the Comité des Sage (1994) that they may also have competitive distorting effects. Between 1991 and 1996, $11 040 million in subsidies to airlines were approved by the EU. As can be seen from the Table 5.5 below, the airlines, which gained EU's approval for subsidy, were all state-owned. The private airlines such as BA, British Midland, KLM, and SAS, which have not demanded any aid in recent years, may face the problem of unfair competition in European aviation.

Table 5.5 *European Union approved subsidies to European airlines (1991-1996)*

Airline	Subsidy ($ million)	Date
Sabena	1 800	August, 1991
Iberia	1 200	May, 1992
Aer Lingus	250	December, 1993
Air Portugal	1 100	July, 1994
Olympic	2 300	July, 1994
Air France	3 700	July, 1994
Iberia	690	January, 1996

Source: OECD (1997)

It is important to note that it had taken so long to bring European countries to reach a consensus on a multilateral agreement. Triple package of measures to liberalise the market gradually achieved this purpose. January 1993 witnessed the emergence of open skies within Europe after the legislators of the EU applied the principles of a single market to the airlines industry. It was indeed difficult to eliminate the conflicts of interest in an industry traditionally entrenched in national interest with the vast majority of carriers state-owned. In contrast to the evolutionary approach taken by Europe, the deregulation in the United Sates was revolutionary. It was widely believed that the US domestic airlines deregulation has had an impact on the EC liberalisation movement. This is detailed in the following section.

5.5.3 The Impact of US Deregulation

The US was the first, which experienced deregulation in its domestic aviation at the end of the 1970s. It has had profound implications on the policies of many other industries in various countries. In particular, the US experience exerted strong pressures for the liberalisation process in European aviation [for more details, see Forsyth, 1983; Bailey *et al.*, 1985; Kasper, 1988; Button, 1989a, 1989b; and Keeler, 1990].

In the 1970s there had been an increasing consensus that the cost of regulation in the US was high. This had coincided with the time in which the US economy was suffering from high levels of inflation. It was believed that inflation could be reduced through regulatory reforms. Additionally academic studies on the cost of regulation and the introduction of contestable theory gave an added impetus to deregulation in the US domestic airlines (see Chapter 2 for details).

Prior to deregulation, the Civil Aeronautics Board (CAB) in the US controlled entry, exit, routes and fares. Potential entrants were deterred by strict licensing rules. Even the established airlines found it difficult to enter new routes.

Hence, the extensive market regulation led to extreme fares and limited consumer welfare.

Beginning in 1976, however, regulations became more relaxed since CAB allowed the flexibility of fares. Major changes took place in 1978 when CAB authority on fares and routes decreased and eventually ceased to exist at the end of 1982. With the 1978 Deregulation Act, regulation relaxation permitted new, low-cost airlines to enter into the market and compete.

According to the supporters of reform, deregulation in the industry was a complete success. Bailey and Panzar (1985) showed that the removal of restrictions brought both actual and potential competition, increased productivity and reduced fares. The fares decreased in real terms until 1983 despite the rapidly rising cost in the industry.

Another comprehensive study by Morrison and Winston (1986) showed that deregulation benefited both travellers and carriers. According to their estimation in 1983 the savings to passengers and carriers were $6 billion and $2.5 billion respectively. Aggressive competition has forced airlines to decrease their cost in order to be able to increase productivity. Therefore non-price competition decreased to some extent and services were tailored to the needs and financial positions of the consumers. Hence travellers enjoyed low cost travelling in the initial phase.

The carriers, on the other hand, to compete more efficiently, created hub and spokes in many areas. There have been achievements in economies of scale, better organisation and less delay in connections; hence having a wide range of destinations with connecting services at the hub has been advantageous for the airlines in the short run.

Nevertheless, the opponents of the policy contended that deregulation was a public policy failure (Brenner, 1988). Airline cost cutting practices have involved non-union labour, which was lower paid and subjected to more flexible working conditions. One can expect that such cost-cutting exercises and increased passenger volume would increase profitability. According to Meyer and Strong (1992), the industry lost $2 billion between 1980-82.

Furthermore, a number of mergers or disappearances from the industry were witnessed since the 1978. After the merger approval between USAir and Piedmont, the concentration in the industry led eight airlines to control nearly 94% of all domestic traffic in 1987 (Wheatcroft, 1988:190). Additionally, the creation of Frequent Flyer Programmes decreased the chance of competition and proved advantageous to the old airlines. Moreover, complicated fares and an explosion in routes again benefited the major airlines with CRS (Computing Reservation Systems). They have fulfilled a very cost-effective way of informing customers about their own products and receiving information on other airlines. It has been difficult to distinguish predatory pricing from the competitive pricing.

Even though the contestable theory proposed that the potential competition would be sufficient for the firms to price compete regardless of the market, the US deregulation experience showed that the airline markets are much less contestable. Switching any aircraft to different routes by 'hit-and-run' entry may be easy, but the assumption that sunk costs were zero, did not hold. Due to service quality, safety regulation and market opportunities, passengers demanded the incumbents' reliable flights, not the new entrants'. Therefore, building sufficient reputation was represented as sunk costs for the new airlines (Sutton, 1991).

5.6 Conclusion

The European airlines industry is undergoing a stage of critical restructuring. The reform packages were introduced in an effort to put pressure on governments to create a more competitive environment. The Third Liberalisation package, which was in effect from January 1993, has been a serious step into substantial liberalised Europe aviation.

Similar with the expectations from the US experience, a strongly held view is that liberalisation reforms will bring a significant dimension in providing the forces of a truly competitive market that real competition can thrive. Further, this could lower prices and increase consumer benefits, thus enhance productivity in the industry.

Indeed, it is important to learn from the lessons of US experience. Adopting fully the US style deregulation is unlikely for Europe since there are many individual states along with various institutions that have interests in the way liberalisation policy evolves. However, it is expected from all parties to put more effort to establish a long term structure for European airlines which is facing pressures from recent globalisation trends.

One of the lessons of US deregulation showed an increase in mergers and alliances. It is imperative to consider the likely effects of a similar concentration in European aviation whilst creating a more competitive market. Additionally, it is vital to consider the future effects of state ownership, subsidies and the infrastructure constraints on the productivity of the industry.

As a matter of fact, the European airlines industry during its early phase of liberalisation process provides a fascinating case study, which prompts for comparative performance analysis. The next chapter explores the performance over the period 1991-1995. Accordingly, Chapter 7 seeks to examine the determinants of performance in the European airlines industry.

CHAPTER 6. MEASURING THE PERFORMANCE OF EUROPEAN AIRLINES: A NONPARAMETRIC ANALYSIS

6.1 Introduction

Interest in measuring the comparative performance of airline companies has developed considerably in recent years. The deregulation experience of the US airlines in the late 1970s inspired most of the studies. The majority of the research has then focused upon the consequences of the deregulation experience of the US or compared the productivity differences between the deregulated US airlines and European airlines, which operated under heavily regulated environments.

Recently, the European airlines are experiencing substantial competitive pressures due to globalisation, liberalisation and privatisation. It is imperative for the airlines to improve their efficiency relative to their counterparts in order to remain competitive. This study investigates the recent performance record of European airlines to assess the early results of the liberalisation reforms.

The analysis is based on a data set consisting of seventeen airlines over the period 1991-1995. To measure efficiency and productivity, the strength of non-parametric methodologies is used. First, DEA Windows analysis is utilised to capture efficiency changes over time. Secondly, the Malmquist productivity index is used to measure the productivity change and decompose any change into the efficiency and frontier shift effects.

This chapter is organised as follows. The next section introduces the data and discusses the selection of the variables. Section 3 presents the DEA efficiency scores under different scale assumptions. Section 4 and 5 present the empirical findings of

DEA Windows and Malmquist productivity analyses respectively. Finally, Section 6 concludes.

6.2 Data

The panel data consists of annual observations on 17 airlines over the period of 1991 and 1995. The names of the airlines and their countries of origin are as follows: Aer Lingus (Ireland), Air France (France), Air Malta (Malta), Alitalia (Italy), Austrian Airways (Austria), British Airways (United Kingdom), Cyprus Airways (Cyprus), Finnair (Finland), Iberia (Spain), Icelandair (Iceland), KLM (The Netherlands), Lufthansa (Germany), Sabena (Belgium), SAS (Scandinavia), Swissair (Switzerland), Air Portugal (Portugal) and Turkish Airlines (Turkey).

Except for the two privately owned airlines, British Airways and Icelandair, the airlines in the sample are 'flag' carriers with varying degrees of state ownership. Because there would be many non-Community national 'flag' carriers which are also affected by the recent reforms, our sample considers the members of the AEA in which all Community member airlines are included alongside the non-Community ones. Because of data limitations, Adrian, Balkan, British Midland, Czech Airlines, Yugoslav, Luxair, Malev and Olympic Airways are excluded from the sample.

To specify the inputs and outputs, the model by Schefczyk (1993) is adopted. Each of the inputs and outputs in the model reflects the operational characteristics of the airline industry. The inputs are available tonne kilometre (ATK); operating cost; and non-flight assets. The two outputs are revenue passenger kilometre (RPK) and non-passenger revenue. ATK is for the aircraft capacity obtained to include both passenger and non-passenger inputs. Operating cost is obtained by excluding the capital and aircraft costs already reflected in ATK and non-flight assets are included to reflect all assets not already reflected by ATK. These assets are mainly the reservation systems, hotels and other facilities. RPK is used as a proxy for the passenger-flight related output whereas non-passenger revenue reflects all other output that is not passenger-flight related, such as cargo. For all monetary conversions, purchasing power parities by OECD are used.

The data are based on three sources. ATK and RPK are obtained from International Air Transport Association (IATA) World Air Transport Statistics; non-flight assets are from the annual reports of the companies and the rest is from the International Civil Aviation Organisation (ICAO) Financial Data Series. The rapid growth of the European airlines is apparent from Table 6.1, which displays the summary statistics of the data set. There is an increase in the aircraft capacity obtained. Operating costs, however, decrease in the year 1995. Non-flight assets also show a fall in 1994, but reveal a sharp increase in the final year. There is an increasing trend in the passenger revenues whereas non-passenger revenues decrease in the final year. The last feature of the data is that there are enormous variations among the airlines in the sample, which is evidenced by large deviations of the variables. This is because there are very small and very large airlines in the sample.

Table 6.1. *Descriptive statistics for European airlines, 1991-1995*

	ATK	OC	NFA	RPK	NPA
1991					
Mean	3977.4	2260.7	1442.1	16442.4	690.3
Standard deviation	4348.3	2181.8	1185.3	17189.3	690.5
Minimum	131.2	48.6	12.2	1284.2	19.3
Maximum	13005.6	6848.8	3427.4	63190.5	2502.0
1992					
Mean	4382.6	2526.1	1592.8	20375.7	752.9
Standard deviation	4778.3	2557.0	1326.5	21995.6	842.9
Minimum	267.9	51.1	27.3	1284.2	20.5
Maximum	14371.5	7926.3	3801.8	80265.4	2959.9
1993					
Mean	4730.9	2649.8	1698.8	20359.2	766.6
Standard deviation	5228.7	2631.7	1438.7	22008.2	864.3
Minimum	192.3	54.3	25.1	1284.2	21.7
Maximum	15869.1	8224.5	4590.3	80265.4	2941.9
1994					
Mean	5024.6	2816.6	1598.8	21925.1	840.3
Standard deviation	5546.0	2925.7	1312.4	23944.9	988.4
Minimum	417.8	65.9	24.8	2361.1	21.0
Maximum	16989.4	9239.9	3800.5	86395.4	3478.8
1995					
Mean	5384.0	2554.8	2873.2	23575.4	658.5
Standard deviation	5945.5	2574.1	6491.9	25540.1	638.3
Minimum	444.7	71.7	29.8	2555.5	23.9
Maximum	18456.1	9638.8	27781.9	94002.6	2481.6

Notes: ATK; available tonne kilometre; **OC**; operating cost; **NFA**; non-flight assets; **RPK**; revenue passenger kilometre; **NPA**; non-passenger revenue.

6.3 Estimation of DEA Efficiency Scores

In this section, the performance of European airlines is examined in terms of their ability to provide outputs with minimum input consumption. This is an input-based efficiency measurement. The linear programs are solved as described in Section 4.3 [see equations (4.3) and (4.5)]. Table 6.2 compares the efficiency scores under different scale assumptions[33]. These results belong to each year separately. It seems that in each year, under the variable returns to scale technology, a greater number of airlines appear efficient. In 1995, for example, except the three airlines, the entire sample is efficient. It is important to note that DEA efficiency scores obtained from a small sample are sensitive to the difference between the number of DMUs and the sum of inputs and outputs employed. Therefore, too many DMUs may appear efficient as it has happened in this case.

Reducing the number of inputs and outputs or increasing the sample size may not be an answer. This can decrease the conceptual power of any model and collecting extra data may not be possible in many cases. Instead, a DEA Windows analysis is used in order to provide discriminatory results for a small data set (see section 4.5 for details). Additionally, the non-parametric strength of DEA is used in constructing the Malmquist productivity index, which would provide not only the efficiency changes evolving through time, but the sources of changes too.

Hence, this study assumes CRS technology which is consistent with the vast majority of the airline literature (see e.g., White, 1979).

[33] DEA efficiency scores will be of use to construct the Malmquist productivity index.

Table 6.2 Airline efficiency scores[34]

Airlines	1991		1992		1993		1994		1995	
	CRS	**VRS**	**CRS**	**VRS**	**CRS**	**VRS**	**CRS**	**VRS**	**CRS**	**VRS**
Aer Lingus	100	100	100	100	100	100	100	100	100	100
Air France	85.73	93.07	100	100	100	100	100	100	100	100
Air Malta	100	100	100	100	100	100	100	100	100	100
Alitalia	72.94	100	85.20	100	100	100	100	100	97.68	100
Austrian	73.33	74.58	85.80	86.06	94.00	95.48	99.20	100	100	100
British Airways	53.29	100	94.3	100	75.74	100	86.32	100	89.43	100
Cyprus Airways	100	100	100	100	100	100	100	100	100	100
Finnair	86.46	100	100	100	90.74	100	89.88	89.94	100	100
Iberia	46.12	86.33	78.06	82.49	74.53	96.26	88.56	100	83.09	97.96
Iceland Air	63.32	75.39	100	100	82.37	91.98	95.90	100	100	100
KLM	88.72	100	89.01	100	84.94	100	96.59	100	99.57	100
Lufthansa	100	100	100	100	100	100	100	100	69.01	100
Sabena	81.18	84.14	69.42	72.02	63.55	73.90	77.64	82.49	87.20	92.66
SAS	62.42	100	95.29	100	77.81	100	90.28	100	94.92	100
Swissair	91.22	100	99.36	100	100	100	100	100	100	100
Air Portugal	71.83	91.97	93.50	97.27	87.45	100	100	100	100	100
Turkish Airlines	100	100	100	100	69.00	83.48	82.47	82.51	89.38	90.35

Notes: CRS: Constant returns to scale; **VRS:** variable returns to scale

6.4 Estimation results: DEA Windows analysis

The 'windows analysis' approach is used to detect the efficiency variations of 17 airlines covering a 5-year period between 1991 and 1995. From a 5-year period, a window size of three years can be defined. The first window covers the years, 1991-1993. The second one covers 1992-1994 and the third one covers the years, 1993-1995. In each assessment, each airline is treated as a different unit. Therefore, each window provides a total of 51 (3*17) units for assessment.

We report the main findings based on the solutions to the DEA problem given in equation (4.6). The results are tabulated in Table 6.3. In each row, the efficiency

[34] Computations were carried out with Warwick DEA Software.

ratings reflect the performance trend of an airline, which changes within time or within a given window. The efficiency values in each column indicate the relative efficiency of an airline in that year. These may differ according to the comparator set in the overlapping windows. The column 'WM' denotes the average of each window. The column 'EM' indicates the average of the entire period, 9 DEA efficiency scores.

Our first remark is that Air Malta, with an average efficiency score of 98.8% is the most efficient airline over the period 1991 and 1995, though Air Malta's efficiency falls in the last window. On the other hand, Iberia, with an average score of 66.16%, has the lowest efficiency score. Iberia displays inefficient behavior in the first window but the scores improve in the last two windows.

Given the early stages of the liberalised environment, there are airlines, which experience an increase in terms of efficiency in all windows, such as Air France, Austria, Iberia, KLM, and Air Portugal. Our findings show that some airlines experience improvement in the first and second windows, but decrease in their last windows. These are Aer Lingus, Air Malta, British Airways, Cyprus Airways, Finnair, Icelandair, Lufthansa, SAS, and Swissair. However, Turkish Airlines is the only airline in the sample, which experiences a decreasing trend in all windows.

Some major airlines, such as Air France, Lufthansa and Swissair achieve high efficiency scores while British Airways, Alitalia, KLM, SAS and Austria achieve only around 70-85%. These results mostly agree with the earlier work by Good *et al.* (1995) where they identify efficiency and productivity differentials among European and US carriers using DEA over the period 1976-1986. However, it is interesting to note that our study reveals an increase in the efficiency scores for most airlines. This could be the result of regulatory reforms occurred in the 1990s.

Table 6.3 *DEA Windows analysis results*

Airlines	1991	1992	1993	1994	1995	WM	EM
Aer Lingus							
W1	100	100	91.46			97.15	97.42
W2		100	100	95.42		98.47	
W3			100	95.42	94.5	96.64	
Air France							
W1	85.73	96.47	96.49			92.90	95.75
W2		93.97	94.54	100		96.17	
W3			94.57	100	100	98.19	
Air Malta							
W1	100	100	95.34			98.446	98.77
W2		100	100	100		100	
W3			100	100	93.58	97.86	
Alitalia							
W1	72.94	69.28	80.19			74.14	84.15
W2		77.27	88.47	89.96		85.23	
W3			94.8	97.14	87.32	93.09	
Austrian							
W1	73.33	78.89	79.14			77.12	85.25
W2		82.44	82.33	87.82		84.20	
W3			88.64	95.49	99.16	94.43	
British Airways							
W1	53.29	62.73	51.68			55.90	71.28
W2		85	75.74	78.58		79.77	
W3			75.74	78.58	80.2	78.17	
Cyprus Airways							
W1	100	98.55	94.83			97.79	98.51
W2		95.39	97.79	100		97.73	
W3			100	100	100	100.00	
Finnair							
W1	85.83	86.73	84.54			85.70	85.82
W2		92.77	90.37	78.94		87.36	
W3			90.72	78.95	83.54	84.40	
Iberia							
W1	46.12	49.56	51.41			49.03	66.16
W2		70.41	74.53	78.53		74.49	
W3			74.53	78.53	71.85	74.97	
Iceland Air							
W1	63.32	62.82	59.04			61.73	77.31
W2		89.66	82.32	84.64		85.54	

Table 6.3 *continued*

Airlines	1991	1992	1993	1994	1995	WM	EM
W3			82.32	84.64	87.07	84.68	
KLM							
W1	88.72	72.61	78.66			80.00	82.72
W2		79.06	84.62	85.57		83.08	
W3			84.83	85.7	84.75	85.09	
Lufthansa							
W1	100	96.31	95.8			97.37	94.33
W2		100	97.02	100		99.01	
W3			96.86	100	63.01	86.62	
Sabena							
W1	81.18	53.53	50.19			61.63	66.29
W2		64.47	63.55	70.62		66.21	
W3			63.55	70.62	78.91	71.03	
SAS							
W1	62.41	63.91	58.31			61.54	74.61
W2		86.96	77.81	80.76		81.84	
W3			77.81	82.44	81.11	80.45	
Swissair							
W1	91.22	90.63	96			92.62	94.99
W2		99.35	100	92.52		97.29	
W3			100	92.63	92.57	95.07	
Air Portugal							
W1	71.79	70.51	70			70.77	83.66
W2		86.47	84.68	87.06		86.07	
W3			86.94	100	95.52	94.15	
Turkish Airlines							
W1	100	88.88	51.84			80.24	78.9
W2		100	66.85	72.23		79.69	
W3			68.54	80.21	81.55	76.77	

Notes: **WM**, the average of each window; **EM**, the average of the entire period.

6.5 Estimation of Malmquist Productivity Indices[35]

In this section we report the main findings based on the solutions to the Malmquist productivity index given in the equation (4.11). The problem is solved for each airline in all adjacent periods from 1991 to 1995. We note that the Malmquist

[35] The computations were carried out with OnFront software.

index is less than one if there is productivity decline. If there is productivity growth, the Malmquist index exceeds one. If, however, there is no change in productivity, the Malmquist index equals one.

Table 6.4 *Relative efficiency change*

Airlines	1991/92	1992/93	1993/94	1994/95	Mean	Change%
Aer Lingus	1	1	1	1	1	0
Air France	1.17	1	1	1	1.0425	4.25
Air Malta	1	1	1	1	1	0
Alitalia	1.17	1.17	1	0.98	1.08	8
Austrian	1.17	1.1	1.06	1.01	1.085	8.5
British Airways	1.77	0.8	1.14	1.04	1.1875	18.75
Cyprus Airways	1	1	1	1	1	0
Finnair	1.16	0.91	0.99	1.11	1.0425	4.25
Iberia	1.69	0.95	1.19	0.94	1.1925	19.25
Iceland Air	1.58	0.82	1.16	1.04	1.15	15
KLM	1	0.95	1.14	1.03	1.03	3
Lufthansa	1	1	1	0.69	0.9225	-7.75
Sabena	0.86	0.91	1.22	1.12	1.0275	2.75
SAS	1.53	0.82	1.16	1.05	1.14	14
Swissair	1.09	1.01	1	1	1.025	2.5
Air Portugal	1.3	0.94	1.14	1	1.095	9.5
Turkish Airlines	1	0.69	1.2	1.08	0.9925	-0.75
Geometric Mean	1.179	0.938	1.079	1.000		

The results reported in Table 6.4 represent the MC, changes in efficiency, from the equation (4.9). Three airlines (Aer Lingus, Air Malta and Cyprus Airways) experience no change in efficiency in all time periods. These airlines are all very small. Austrian Airlines is the only airline, which shows efficiency improvements in all periods. In the rest of the sample, we find periods with efficiency increase as well as periods with efficiency decrease. For the sample as a whole, three periods show average improvement in efficiency and one period shows average decline. Only three airlines experience efficiency improvements in that decline period. Perhaps, most of the airlines could not adapt to the increased competition at the beginning, but increase their efficiencies at the later stages. We note that variation in efficiency occurs due to liberalisation. There is pressure on all companies to become efficient on average, but also there is increased scope for the most efficient to respond to market incentives and leap ahead.

Table 6.5 *Frontier shift effect*

Airlines	1991/92	1992/93	1993/94	1994/95	Mean	Change%
Aer Lingus	0.9	0.92	0.89	0.85	0.89	-11
Air France	0.95	0.97	1.11	0.88	0.9775	-2.25
Air Malta	0.8	1.07	1.04	0.93	0.96	-4
Alitalia	0.85	0.97	1.02	0.96	0.95	-5
Austrian	0.93	0.91	1.02	0.97	0.9575	-4.25
British Airways	0.66	1.11	0.9	0.97	0.91	-9
Cyprus Airways	0.69	1.04	1.1	0.88	0.9275	-7.25
Finnair	0.85	1.08	0.85	1.01	0.9475	-5.25
Iberia	0.63	1.11	0.89	0.99	0.905	-9.5
Iceland Air	0.65	1.12	0.88	0.98	0.9075	-9.25
KLM	0.86	1.04	0.89	0.97	0.94	-6
Lufthansa	0.95	0.96	1.04	0.88	0.9575	-4.25
Sabena	0.85	1.05	0.91	1	0.9525	-4.75
SAS	0.7	1.09	0.91	0.94	0.91	-9
Swissair	0.91	1.01	0.94	1	0.965	-3.5
Air Portugal	0.8	1.04	0.99	0.97	0.95	-5
Turkish Airlines	0.69	0.88	0.96	0.96	0.8725	-12.75
Geometric Mean	0.797	1.019	0.958	0.948		

Table 6.5 displays the calculated technical progress or regress in the airlines frontier from time period t to t+1. This corresponds to MF, frontier shift effect, in equation (4.10). Our results show on average that there are three periods with regress and one period with progress. Between 1992-1993, around 65% of the airlines in the sample show technical progress. This is the period when European airlines found themselves in a phase of transition between a highly regulated civil aviation and free

competition. They were, therefore, forced to implement radical programmes for institutional restructuring.

Table 6.6 *Malmquist productivity change*

Airlines	1991/92	1992/93	1993/94	1994/95	Mean	Change%
Aer Lingus	0.9	0.92	0.89	0.85	0.89	-11
Air France	1.11	0.97	1.11	0.88	1.0175	1.75
Air Malta	0.8	1.07	1.04	0.93	0.96	-4
Alitalia	0.99	1.14	1.02	0.93	1.02	2
Austrian	1.09	1	1.07	0.97	1.0325	3.25
British Airways	1.16	0.89	1.03	1.01	1.0225	2.25
Cyprus Airways	0.69	1.04	1.1	0.88	0.9275	-7.25
Finnair	0.98	0.98	0.84	1.12	0.98	-2
Iberia	1.07	1.06	1.05	0.93	1.0275	2.75
Iceland Air	1.03	0.92	1.03	1.02	1	0
KLM	0.87	0.99	1.01	1	0.9675	-3.25
Lufthansa	0.95	0.96	1.04	0.61	0.89	-11
Sabena	0.73	0.96	1.11	1.12	0.98	-2
SAS	1.07	0.89	1.06	0.99	1.0025	0.25
Swissair	0.99	1.02	0.94	1	0.9875	-1.25
Air Portugal	1.04	0.97	1.14	0.97	1.03	3
Turkish Airlines	0.69	0.61	1.15	1.04	0.8725	-12.75
Geometric Mean	0.939	0.957	1.034	0.948		

Table 6.6 displays calculated productivity changes in airlines, as represented by the Malmquist input productivity index in equation (4.11), which is the product of the efficiency and technical change components discussed above. Our results indicate considerable variation across airlines and time. European airlines experience mostly productivity regress during 1991 and 1995. There is only one period with productivity growth and there are three periods with productivity losses. Productivity decline is notable between 1991 and 1993, the period when the third liberalisation package was introduced. This continues with productivity growth in 1993-1994. There is no airline in the sample, which shows progress in all periods.

A close inspection of Tables 6.4-6.6 indicates that the source of productivity growth in this period mainly stems from the increase in technical efficiencies, that is the convergence towards efficiency or catching up effect. Of 14 airlines, 9 achieve productivity growth due to an increase in their technical efficiencies whereas the source of productivity gain in the rest of the sample is the result of improvement in the performance of best practice airlines, that is the technical change or frontier shift effect. The remaining periods exhibit productivity decline. The source of productivity decline in 1991-92 and 1994-95 is explained by a deterioration of the performance of best practice airlines, whereas in 1992-93, the decline occurs due to the divergence from best practices on the part of the remaining airlines.

In order to provide a clearer view of all the estimations, we report in columns (5) and (6) of Tables 6.4-6.6, the mean and average annual rates of growth for the entire period respectively. Our first remark is that small airlines experience negative growth rates within the period. These are Aer Lingus, Air Malta, Cyprus Airways and Icelandair. Probably, they find it difficult to adapt themselves to the changing competitive Euro environment. Besides these small airlines, there are larger airlines in the sample, which achieve negative growth rates like KLM, Lufthansa, Finnair, Sabena, Swissair, and Turkish Airlines.

With the exception of Lufthansa, the rate of productivity in these airlines, however, improved as liberalisation has proceeded. It is interesting to note that they fail to achieve productivity growth due to their inability to achieve technological progress. This might reflect difficulties in raising capital from the private capital market. The capital market riskiness (β) may have increased following liberalisation.

Another noticeable group of airlines includes Air France, Alitalia, Austrian Airlines, British Airways, Iberia and Air Portugal. These experience positive average annual growth rates. Their success is mainly attributed to their improvement in technical efficiencies. In comparing the results obtained from the Windows analysis and the DEA based Malmquist index, we note that by and large, the major trends experienced by these successful airlines are consistent across the methods. For example, both methods identify substantial efficiency improvements and positive growth rates for these airlines.

Further, these findings are consistent with the institutional and organisational restructuring which took place at airline level over the study period. The common purpose of such developments was to reduce costs and raise productivity. For example, the new management in Air France aimed to rebuild the company with a 'Plan'. This included a major restructuring programme to decentralise the decision-making power to operational levels. In addition, Air France signed an agreement with unions in March, 1994 to reduce personnel expenses. Similarly, Austrian Airlines experienced an organisational restructuring to achieve more efficient decision-making procedures. Moreover, with the new collective bargaining agreement they aimed to improve the personnel cost structure by lowering the salary schedules. Iberia's new management, which took office in 1993, reduced costs with a Cost Reduction Programme. Alitalia, on the other hand, reviewed the Company's organisational structure and established a Sales and Marketing Unit to improve the efficiency in Alitalia's marketing processes. Air Portugal approved an Economic and Financial Restructuring Strategic Plan (PESEF) for organisational and structural alterations. British Airways is the only private airline, which recorded positive growth rates. The company was privatised in 1987. There has been continuous investment in computerisation and modernisation of the fleet. At the same time, with the alterations in marketing approach, British Airways became more customer-oriented.

If we compare the results for the rest of the sample, we find that the two methodologies provide different results. While small airlines share the highest efficiency scores in Windows analysis, they achieve negative growth rates with Malmquist analysis. It is evident that the liberalisation policies adopted have considerable impact on small airlines, which are also disadvantaged with small home markets. Small airlines may find it difficult to keep their market share under the pressures of increased competition.

6.6 Conclusion

The objective of this study has been to analyze the performance of European airlines during the early phase of the liberalisation process. Our analysis has been based on a data set consisting of seventeen airlines over the period 1991-1995. To accomplish our task we utilised non-parametric methodologies: firstly, DEA windows analysis to capture efficiency changes over time, secondly, the Malmquist productivity index to measure the productivity change and decompose any change into the efficiency and frontier shift effects. We believe that this is the first use of Windows and Malmquist productivity analyses together in the context of airline performance measurement.

Our results obtained from Windows analysis reveal an increasing trend in the efficiency scores for most of the airlines. This could be explained by the impact of regulatory reforms in the early 1990s. Nevertheless, Malmquist indices of productivity change show a decline in the first two periods, but some evidence of turnaround in 1993-1994, probably with the introduction of the third liberalisation package. However, we are aware that the study period is rather short for a definitive appraisal of the consequences of liberalisation.

Regardless of which method is used, some successful larger airlines show similar trends. Moreover, these findings are consistent with the developments, which occurred in their institutional and organisational restructuring. Small airlines, on the other hand, share the highest efficiency scores in windows analysis, but fail to achieve positive growth rates with the Malmquist approach. Given these findings, it seems appropriate for European airlines to attach priority to institutional and organisational restructuring. These are vital if the European airlines are to reduce cost problems and become more competitive in the liberalised Euro skies.

CHAPTER 7. THE DETERMINANTS OF PERFORMANCE FOR THE EUROPEAN AIRLINES: AN APPLICATION OF TOBIT ANALYSIS

7.1 Introduction

The previous empirical chapter analysed the results of the estimation of efficiency and the productivity changes over time for 17 European airlines. In this chapter, we go on to the second stage of our analysis and explore the determinants of inefficiency for the same set of airlines. To identify these variables, we utilise the DEA efficiency scores, which were obtained by using the DEA windows analysis, then these scores are transformed to be the dependent variables in the Tobit model (see section 4.7 for details).

Recalling the studies reviewed in Chapter 3, it seems that there has been little research, which aims to explain inefficiency in the European airlines industry by employing frontier techniques. Schefczyk (1993) used regression methods for international airlines to determine the relationship between the DEA efficiency scores and some strategic variables, e.g. focus of the airline, load factors, etc. Nevertheless, the vast amount of literature is based on non-frontier techniques. These studies mainly compare the US and non-US airlines and examine the significance of structural and operating characteristics on performance.

The recent methodological advancements, however, make it feasible to go further and blend a variety of techniques to measure technical efficiency and to identify the sources of inefficiency. A commonly held view in previous studies is that the use of DEA with Tobit model can provide results which guide the essential policies to enhance performance (see Oum and Yu, 1994). To our knowledge, this is the first time that the combination of DEA windows and Tobit analyses has been used in the airline efficiency literature. The empirical results on the sources of inefficiency that will be obtained from this chapter may be of use for formulating policies for the European airlines industry, which is seeking to improve its performance whilst passing through a critical restructuring.

This chapter is organised as follows. The following section of this chapter presents five categories of performance determinants in the literature. Section 3 identifies potential determinants of airline efficiency – the variables that could be associated with the European airline efficiency. The data for the empirical application is explained in Section 4. The results are reported in Section 5. Finally, Section 6 concludes.

7.2 Determinants of Performance

The determinants of performance can be classified under five broad headings (Caves, 1992; and Mayes *et al.* 1994). First, lack of competition is believed to induce inefficiency. Three measures are used to estimate the effects of competitive conditions on inefficiency: firm concentration; openness of the market; and the rate of contestability. Second, managerial and organisational factors may influence the activities of any firm. These factors include the ownership structure and the extent to which the organisation is unionised, among others. Third, the structural heterogeneity between organisations can lead to structural efficiency differences. This may include heterogeneity in production processes. Fourth, dynamic factors are thought to foster efficiency. These include R&D facilities, innovations and market growth. Finally, public policy may influence the incentives to improve efficiency. Government regulations as well as the subsidies are policies, which could adversely influence the productive efficiency of activities.

It is important to note that these determinants of technical efficiency are not clear in reflecting the extent of inefficiency in each industry and may not be regarded as technical inefficiency in the strict sense of Farrell (Mayes *et al.* 1994). Thus the theoretical foundation for explaining technical efficiency may be imprecise relative to the methodologies for measuring it. However, as it was emphasized in Button and Weyman-Jones (1994:100) it is essential 'to go beyond [performance] measurement ...for a much more systematic study of the causes of inefficiency'. This could assist in developing policies towards improving performance while exploring the determinants of inefficiency.

7.3 Potential Determinants of European Airlines Performance

The potential explanatory variables for this analysis are determined according to the frame set in Section 7.2. It is worthwhile to note that the relevant variables are selected by data availability.

7.3.1 Competition

First, the main hypothesis for competitive conditions is that there is less scope for inefficiency in a competitive environment. However, bilaterally imposed restrictions in the European airlines industry could severely limit the competitive behavior and increase the level of air transport prices, and, thus, inefficiency in the industry (see, for example, Sawers, 1987). Some pressures to change this regulatory framework were initiated at the beginning of 1980s with liberalised bilateral agreements.

The evidence indicates that the liberalisation can provide substantial benefits to consumers where liberalisation has been followed by significant entry. Contrary to what is proposed by the contestable theory, evidence shows that actual competition on a route is more effective than potential competition in securing these benefits (Abbott and Thompson, 1991). Even though there have been new entries into the industry, given the limitations wherein economies of density restrict the number of airlines on a certain route (Pryke, 1991), there has been a tendency observed in Europe towards concentration.

Some notable examples are the mergers between the British Airways and British Caledonian in 1988 and between Air France, UTA and Air Inter in 1990. Most of the other European airlines are also engaged with strategic alliances in and out of Europe. The impact of concentration on performance is *a priori* unclear. On the one hand, there were fears that such alliances could act as monopoly and prevent the entry of potential competitors. On the other hand, it has been argued that they may promote and accelerate the restructuring process which could lead significant cost savings (see Comité des Sages, 1994). The concentration variable (DUMCON) is included into the model by using a dummy, taking the value of unity when there is any strategic alliance among airlines.

7.3.2 Managerial and Organisational Factors

Managerial and organisational factors can affect efficiency. The effect of ownership structure, for example has been extensively discussed by economists. The literature of property rights pointed out the costs of state ownership (Alchian, 1965). European airlines are mostly owned by the state. It is usually claimed that the state ownership of airlines is more prone to government interference, which can weaken the market-oriented approach to decision-making (OECD, 1997). Therefore, they are blamed for the inefficiency in the industry.

In the late 1980s there has been a privatisation movement. For example, the national carriers of the UK and the Netherlands were sold to the public. Whilst the government has fully privatised the company, the Netherlands government reduced its share to 38.2% in the KLM. According to Rapp and Vellas (1992), sixteen countries in Europe were involved in privatisation, either by full privatisation or by a policy for reducing the government shares. The ownership status (OWN) is available for each airline in the sample, and is defined as the percentage of state ownership.

Since there is no consensus among the empirical evidence on the superiority of private firms' performance, it is safer to assume that it is *a priori* unclear how state ownership affects efficiency (see Chapter 2 for details). Due to the unavailability of data, there will not be any explanatory variable, which could account for the unionisation in the firms.

7.3.3 Heterogeneity

The heterogeneity in the production process is postulated to be lower when the proportion of output produced in the principle product industry is greater (Mayes *et al.,* 1994). This is called specialisation. The degree of specialisation in airlines operations is thought to affect the demand patterns, thereby increasing the airline efficiency. Airlines may specialise on scheduled, charter and cargo flights. Each call for different product and marketing facilities. The relationship between specialisation and airlines efficiency is, however, a neglected research area due to the problem of quantifying the influence (Morrell and Taneja, 1979). The available information is incorporated by defining the three markets: the percentages of scheduled, charter, and cargo flights in total traffic. However, the highest proportion of output produced by all firms is in the scheduled operations. This is included in the model as the percentage of scheduled flights flown (SCHED) in kilometres in total traffic.

As an alternative to the specialisation variable (SCHED), the heterogeneity can be accounted for by considering the spatial disparities, which may occur through demand. This can be defined by the proportion of scheduled destinations concentrated in geographical operation areas. The available information is incorporated by defining three areas: the proportion of destination within Europe, international and within any country. The first two Europe (EUR) and international (INT), are the principal operation areas, hence included in the model.

Furthermore, it seems useful to include spatial, quality and temporal characteristics of the services to support the traditionally used output aggregates (Kersten, 1996). Whilst there are data limitations on the temporal characteristics, spatial characteristics of the network can be accounted for by a number of variables. First, the average stage length (STAG) is one of the most popular measures. This may influence the route pattern, and thus efficiency. It is computed by dividing total aircraft-kilometres performed by aircraft departures. Stage length is mostly used in explaining the airlines operating costs. However, the evidence suggests that its influence on production or profitability is unclear (see for example Caves *et al.,* 1981; Tretheway, 1984).

Second, it is possible to interprete the changes introduced by airlines in response to deregulation by incorporating the route network density (ROUT) into the model (Distexhe and Perelman, 1994). This variable concerns the intensity of traffic flows and is computed as the average number of aircraft departures per 100,000 kilometre. An immediate consequence of the deregulation is the restructuring of airline route networks and the emergence of hubs (Bailey *et al.,* 1985). European airlines evolve in the direction of low-density networks either as a result of mergers and takeovers or with the introduction of wide-body planes. The impact of route density on performance could be negative (Morrell and Taneja, 1979).

Finally, the measure of service quality should be considered whenever possible. The load factor (LOAD) is a popular measure and often used as a proxy for service competition (Good *et al.*, 1995). It is computed as the percentage of total capacity available for passengers, freight and mail which is actually sold and utilised. There is evidence that the load factor has a positive effect on performance (Caves *et al.* 1981, 1983).

7.3.4 Dynamic Factors

Dynamic factors can play a significant role in an industry's efficiency. However, the data on R&D facilities and innovation is not always available. Thus, such factors are not incorporated into the model.

7.3.5 Public Policy

The effects of government regulation and subsidies need to be considered for the European airlines. Until the 1980s air transport was heavily protected by national and international regulations where major institutional changes recently liberalised the sector. With the US deregulation in 1978, which removed rate and route regulations, certain reforms were also introduced in Europe to provide flexibility in pricing, capacity sharing and market access. The third liberalisation package introduced in 1993 was the most decisive and designed to move from protecting existing airlines to enhancing efficiency and responding to consumer interests.

However, with the disappearance of traditional forms of regulatory practices, the importance of state aids for the state owned carriers also increased (Comité des Sages, 1994). On one hand, state aids may discriminate in favour of the state owned airlines, thereby severely contribute to overcapacity and uneconomic pricing. On the other hand, state aids may be imperative in alleviating an airline situation while passing through the restructuring process. The effects of liberalisation and subsidies policies are incorporated into the model by using dummies.

The impact of liberalisation is represented by the dummy, DUMYE. This takes the value of zero for the year, 1993 when the third liberalisation was introduced. The following years, 1994 and 1995 are represented with the values of unity. It is believed that the impact in the first year will not be as strong as in the following years. Further, the subsidised airlines between 1993 and 1995 (DUMSUB) are represented by a unity value and zero otherwise.

7.4 Data

This empirical chapter employs the same sample of 17 airlines used in chapter 6. These are collected for the years 1993, 1994 and 1995. The total number of observations is 51. Table 7.1 below presents the descriptive statistics for the inefficiency score and the potential explanatory variables outlined in the previous section.

As mentioned before the DEA inefficiency score is computed by the equation 4.6 and employed as a dependent variable in the Tobit analysis. The data on the independent variables is based on the following sources. DUMCON, OWN, EUR and INT are obtained from the Association of European Airlines (AEA) Yearbooks; LOAD is from the AEA Statistical Appendices; ROUT, STAG, and SCHED are derived from the IATA World Air Transport Statistics; and DUMSUB is from Sixth Survey on State Aids published by the EC.

Table 7.1 *Descriptive statistics for Tobit variables*

	Mean	Std.Dev.	Minimum	Maximum
INEFF	0.215539	0.220429	0	1.03957
LOAD	0.630098	0.070597	0.46	0.741
OW	0.645076	0.343151	0	1
EUR	0.51589	0.134643	0.320346	0.83871
INTER	0.337138	0.173229	0.088235	0.611765
ROUT	86.2077	29.4765	30.1275	172.717
STAGE	1291.92	454.857	578.98	3319.22
SCHED	0.920691	0.080011	0.567185	1
DUMCON	0.588235	0.49705	0	1
DUMSUB	0.235294	0.428403	0	1
DUMYE	0.666667	0.476095	0	1

7.5 Explaining Inefficiency of European Airlines: Tobit Results

A preliminary analysis reveals that there is multicollinearity (r = 0.86) between route network density (ROUT) and average stage length (STAG)[36]. It could be argued that these two may measure the same phenomenon since the stage length can influence the route pattern. Therefore they are not included into the model together, but incorporated in different models. Also, the specialisation variables (EUR), (INT) and (SCHED) can be employed interchangeably.

The results for the Tobit estimation[37] are summarised in models 1 to 4 in Tables 7.2-7.5. It is important to note that the dependent variables in all models are the inefficiency, which were obtained by transforming the DEA efficiency scores. Thus the sign of the coefficients are reversed – a *positive* coefficient implies an *inefficiency increase* whereas a *negative* coefficient means an association with *inefficiency decline* or *increased efficiency.* Since the estimated coefficients of the Tobit models do not provide the marginal effects, they are computed by the equation (4.14) for each model. The results of the regression are significant at 95% level or higher and the overall variation explained in the models 1-4 are 0.37, 0.38, 0.38 and 0.39 respectively.

All coefficient signs in model 1-4 are in close agreement. However, only the year dummy (DUMYE) appears significant in all models. The overall load factor, state ownership and concentration dummy along with the year dummy are significant in models 1 and 3. In those models where scheduled operations are used

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[36] Appendix shows a matrix of correlations among the explanatory variables.
[37] The Tobit estimates were computed using LIMDEP.

as specialisation variable, none of the above variables (except the year dummy) appear significant.

The sign of the coefficient for overall load factor is as expected. Increasing the overall load factor can increase the efficiency. Indeed, the new regulations created a more competitive airline industry in Europe, which fostered service quality. This indicates that airlines with higher load factors tend to attain a higher efficiency.

The percentage of state ownership has a statistically significant negative coefficient. This finding suggests that state ownership can not be associated with the efficiency decline. It is however evident that in the 1990s most of the airlines, whether private or public, are challenged by the globalisation of economic activities. In order to survive in the dynamic aviation market, both public and private airlines tend to operate on a more commercial basis, rather than with non-economic political objectives.

On the other hand, the concentration dummy has statistically significant positive coefficient, which may indicate that increasing number of mergers and alliances may increase the inefficiency. Even though the global competitiveness of the European airlines industry is greatly supported, the overall potential advantages of such arrangements may results in significant dominant positions, which lead inefficiency in the industry.

Likewise, the subsidies dummy has a statistically significant positive coefficient. This result may reveal that increasing subsidies can increase the inefficiency. It is important to note that subsidies may have competitive distorting effects. If airlines are ensured that they will be protected any time when they face financial problem, they will have less incentive in cutting their costs and improving the efficiency. Due to lack of information, our analysis did not distinguish amongst the types of subsidies and on which terms they were provided.

The year dummy is negative and statistically significant, showing the positive effects of the third liberalisation package on efficiency. It is also important to note that this result is consistent with the measured Malmquist efficiency change in Chapter 6, which is 6 % and shows an upward trend. One can conclude that reduced subsidies and greater market liberalisation can encourage efficiency in the European airlines industry.

Looking at the marginal effects, the best thing that could be done to improve efficiency is to attract higher load factors. It is evident however that the third liberalisation package, brought an increase in discount-fare traffic, thus resulted in higher load factors in the industry. Throughout this period, the increase in load factors substituted wide-bodied aircraft for narrow-bodied planes to realise the economies of scale of the larger jets.

Table 7.2 *Estimation results: Tobit model 1*

Variables	Coefficients	t-ratio	Marginal
Constant	1.54896	3.85825	1.36700
Overall load factor	-1.4239	-2.64695	-1.25663
State ownership	-0.20227	-2.12499	-0.17851
European flights	-0.62215	-1.79995	-0.54906
International flights	-0.30713	-0.6846	-0.27105
Route network density	0.00078	0.51112	0.00069
Concentration dummy	0.18867	2.23845	0.16651
Subsidies dummy	0.15318	1.97521	0.13519
Year dummy	-0.15546	-2.82294	-0.13719
Sigma	0.17521	9.91838	
R^2	0.3747		
Log-lik	17.2327		

Table 7.3 *Estimation results: Tobit model 2*

Variables	Coefficients	t-ratio	Marginal
Constant	0.11935	0.19485	0.10562
Overall load factor	-0.98601	-1.86648	-0.87260
State ownership	-0.09297	-0.89643	-0.08227
Route network density	0.00076	0.86168	0.00067
Scheduled flights	0.7923	1.83077	0.70117
Concentration dummy	0.12237	1.70276	0.10830
Subsidies dummy	0.07762	0.96066	0.06869
Year dummy	-0.17032	-3.09923	-0.15072
Sigma	0.17489	9.88057	
R^2	0.38498		
Log-lik	17.6558		

Table 7.4 *Estimation results: Tobit model 3*

Variables	Coefficients	t-ratio	Marginal
Constant	1.66674	4.42681	1.46784
Overall load factor	-1.41687	-2.82381	-1.24779
State ownership	-0.20133	-2.16305	-0.17730
European flights	-0.50955	-1.46799	-0.44874
International flights	-0.13798	-0.34129	-0.12151
Stage length	-0.00012	-1.1498	-0.00010
Concentration dummy	0.16093	1.95551	0.14172
Subsidies dummy	0.14655	1.9116	0.12906
Year dummy	-0.15203	-2.80923	-0.13388
Sigma	0.174066	9.92418	
R^2	0.3753		
Log-lik	17.2592		

Table 7.5 *Estimation results: Tobit model 4*

Variables	Coefficients	t-ratio	Marginal
Constant	0.340714	0.543977	0.30140
Overall load factor	-0.94939	-1.81288	-0.839866
State ownership	-0.09173	-0.89117	-0.0811517
Stage length	-9.44E-05	-1.42575	-0.0000834
Scheduled flights	0.727546	1.67265	0.64361
Concentration dummy	0.120407	1.69031	0.10651
Subsidies dummy	0.077112	0.963573	0.0682157
Year dummy	-0.16819	-3.07896	-0.1487911
Sigma	0.173638	9.89335	
R^2	0.3870		
Log-lik	17.7412		

7.6 Conclusion

This chapter examined the determinants of efficiency in the European airlines industry. First we used a general framework for explaining the determinants of firms' performance. Accordingly, some of the determinants for the European airlines were specified. As was mentioned in the introduction, this study may provide insights for the policy debates.

The empirical findings confirm the detrimental effects of concentration and subsidy policies. Airlines confronting competition may seek to exploit economies of scope and of density. Therefore they look favourably to the alliances and mergers. However, it seems evident that concentration can impede competition, results in excessively high fares and inefficiency. Subsidies also drive inefficiency by providing 'unlevel playing field' in European aviation. In recent years, it has been strongly argued by the EC that all state aids for the state-owned carriers be eliminated except in very rare circumstances.

Moreover, the empirical findings reveal that the state ownership does not provide an impediment for being efficient. When airlines operate on commercial basis in which this excludes political objectives, being privately or publicly owned does not matter. Further, in order to remain competitive and efficient, the European airlines need to maintain their service quality – increase the load factors.

This analysis, however, is the first attempt in the airline efficiency literature. Therefore additional studies are imperative to confirm or falsify the detected determinants in this study.

CHAPTER 8. CONCLUSION

This thesis aimed to conduct an empirical analysis, using the most recent methodological advancements to investigate the recent performance record and assess the determinants of performance in the European airlines industry. It was of great interest to examine the efficiency and productivity growth of European airlines in their early stages of the liberalisation process. The lack of empirical studies, which focus solely on the analysis of European airlines, motivated this thesis. To conduct our analysis, we used new data from the period between 1991 and 1995. In this period, the European airlines industry witnessed substantial changes in pricing, capacity sharing and market access. Moreover, privatisation experiences changed the traditional structure of the airlines industry where major airlines were all owned by the states. The co-existence of both public and private firms in a more liberalised market provided a good opportunity to test the ownership effects as well. In this chapter, we summarise the contents and findings of all chapters included in the thesis and present an overall conclusion.

In Chapter 2 we surveyed the theoretical literature regarding the possible ownership and regulation effects on performance. The interrelated strands of literature were briefly reviewed under three headings: theories on property rights, public choice and regulation. In general, these theories suggested the superiority of private firms over public firms. A common view was that, in the absence of clearly defined incentives, public sector management tended to pursue their own goals which could be detrimental to internal efficiency. This argument was however open to several objections which were discussed in the chapter. We argued that existing theories did not provide a general case for private ownership.

Rather we noted that this was a question which should be dealt with by an empirical analysis.

Previous empirical studies focussing on the effects of ownership, regulation and other operational factors on airline performance were reviewed in Chapter 3. They were classified under seven headings: ratio analyses, multivariate analysis, value added analysis, unit costs and labour productivity analyses, total factor productivity analyses, parametric and non-parametric analysis. These studies mainly compared the US airlines with the European airlines. The evidence suggested that US airlines performed better than the European airlines owing to differences in operating characteristics. This implied that the operating environment does matter in determining efficiency differences. We noted that ownership was not the only factor in determining the efficiency of airlines and concluded that along with ownership, the importance of various issues, i.e. regulatory environment, subsidies and operational characteristics need to be considered. Moreover, this extensive literature review on empirical studies provided the opportunity to find out the right methodology for the empirical applications in the thesis. Additionally, the variables, the type and period of the sample data, aims and findings were all noted for each study. Having identified the strengths and weaknesses of each methodology, we followed the DEA methodology which had the strengths of non-parametric methods.

In Chapter 4, we detailed the DEA as well as the other methodologies employed in the thesis. These were the Malmquist productivity index and the Tobit model. The DEA windows analysis was used to capture efficiency changes over time. Because of the inability of this method to measure any technical change and productivity change, the Malmquist productivity index was constructed by using the DEA to measure the productivity change in the industry. The index provided to decompose any change into efficiency and technical change. Finally we followed the Tobit analysis in presenting the procedure to investigate the potential determinants of inefficiency. In the censored regression Tobit model, the transformed efficiency scores obtained through the DEA windows analysis were used as dependent variables.

Chapter 5 provided an extensive analysis of the European airlines industry. The chapter began with the discussion on the characteristics of the industry and followed with the recent privatisation and consolidation practices. Further, a section on the evolution of regulatory policies identified the role of liberalised bilateral agreements, the impact of the EC and the influence of the US domestic airlines deregulation. The state ownership, subsidies and consolidation attempts were all characteristics of the industry. It was evident that there was no single market in Europe due to the existence of many sovereign states with various institutions that had different interests in the way liberalisation develops. This implied the difficulty to create a fully liberalised Single Aviation Market. This chapter has been of use in exploring and learning more about the industry before the empirical applications were conducted.

In the first empirical analysis in Chapter 6, initially we examined the relative technical efficiency (input-based) of seventeen airlines over the period of 1991-1995 under different scale assumptions. The analysis was conducted using the DEA. The results showed that many airlines appeared efficient under the VRS technology. We noted that efficiency scores obtained from a small sample were sensitive to the sample size and the sum of input and outputs employed. However, reducing the number of input or output was not a feasible option as it could decrease the conceptual power of the model. Given the limitations of data collection from small airline companies, increasing the sample size might not also be an answer as well. Instead, a DEA windows analysis was used in order to increase the sample through periods and provide discriminatory results. This analysis detected the efficiency variations of the same data set in a window size of three years. The results revealed an increasing trend in the efficiency scores for most of the airlines which could imply the impact of regulatory reforms. Finally, the Malmquist productivity index was formed to compute the productivity change and the sources of this change. The results showed a decline in the first two periods, but an increase in 1993-1994. This could be an indication of the effects arising from the third liberalisation package. Whilst the results of this analysis showed that any method provided similar trends for some larger airlines, with windows analysis small airlines shared the highest efficiency scores, but could not achieve positive growth rates with the Malmquist approach. We noted that their success in achieving high growth rates were also consistent with the institutional and organisational restructuring taken place at the companies during the liberalisation process. In each analysis, we assumed the CRS technology which was consistent with general airline literature.

In Chapter 7, we extended our initial analysis in order to explain efficiency differences. The analysis was conducted using the Tobit model. The efficiency scores computed by the windows analysis were used and then transformed to be the dependent variables in the second stage Tobit model. The independent variables were selected according to the availability from the determinants of performance classified under five broad headings: competition, managerial and organisational factors, heterogeneity, dynamic factors and public policy. Given the existence of multicollinearity between some variables, we accommodated them in four different models. The results indicated that the year dummy which was used to capture the third liberalisation package appeared significant in all models whereas the overall load factor, state ownership and concentration dummy were significant in models 1 and 3. In the models where scheduled operations were used as the specialisation variable, none of the above variables appeared significant. Overall the results obtained in this chapter showed no significant role for state ownership, which implied that ownership is not an impediment for being efficient. The globalisation pressures challenged both private and public airlines to focus more on their commercial activities and thus increased the efficiency concerns. On the other hand, decline in efficiency was explained with significant concentration and subsidy policies. Also, the marginal effects indicated the importance of load factors to improve efficiency.

Before drawing a final conclusion, it is important to note the limitations. Firstly, the study period is rather short for a definitive appraisal of the consequences of European liberalisation reforms. Longer time spans are essential for this purpose. Secondly, the increase in sample size will increase the discriminatory power of the DEA efficiency results. Thirdly, using the DEA with Tobit was only the first attempt in airline efficiency literature. Therefore additional studies are required to confirm or falsify the detected determinants.

Nevertheless, the results are quite stimulating. They can be used to guide the essential policies to enhance performance in the European airlines industry. Is ownership an important determinant of performance? Our evidence suggests change in ownership (privatisation) need not be the primary consideration for European airlines industry. Even though many governments are responding to the competitive challenges with privatisation plans, privatisation is not the way to become more efficient. Given the right incentive, governments can still allow their flag carriers to operate like privately owned airlines. As long as a competitive environment is introduced with the liberalisation reforms, those having the ability to face the intense competition can survive. Obviously, the subsidy policy can deter the fair competition, thus the incentives of public airlines to reduce their costs and become more efficient. Alternatively, significant dominant positions arising from various consolidation activities may impede the desired competition and thus decrease the efficiency.

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Appendix 1 Data Limitations

Fax messages and letters were sent to all AEA airlines in 1995. Some airlines did not respond at all or could not provide information on NFA. Therefore, only 17 airlines were included in the sample due to data limitations.

1. Adria Airways	did not respond.
2. Aer Lingus	included.
3. Air France	included.
4. Air Malta	included.
5. Alitalia	included.
6. Austrian Airlines	included.
7. Balkan	did not respond.
8. British Airways	included.
9. British Midland	insufficient data on NFA.
10. Czech Airlines	insufficient data on NFA.
11. Cyprus Airways	included.
12. Finnair	included.
13. Iberia	included.
14. Iceland Air	included.
15. Yugoslav Airlines	did not respond.
16. KLM	included.
17. Lufthansa	included.
18. Luxair	insufficient data on NFA.
19. Malev Airlines	did not respond.
20. Olympic Airways	insufficient data on NFA.
21. Sabena	included.
22. SAS	included.
23. Swissair	included.
24. Air Portugal	included.
25. Turkish Airlines	included.

Appendix 2a DEA Efficiency Scores (CRS)

Table of efficiencies (radial)

100.00	AERLIN91	85.73	AIRFRAN91	72.94	ALITAL91
73.33	AUST91	53.29	BRITISH91	100.00	CYPRUS91
86.46	FINNAIR91	46.12	IBERIA91	63.32	ICE91
88.72	KLM91	100.00	LUFT91	100.00	MALTA91
71.83	PORTUG91	81.18	SABENA91	62.42	SAS91
91.22	SWISS91	100.00	TURKISH91		

Table of efficiencies (radial)

100.00	AERLIN92	100.00	AIRFRAN92	85.20	ALITAL92
85.80	AUST92	94.30	BRITISH92	100.00	CYPRUS92
100.00	FINNAIR92	78.06	IBERIA92	100.00	ICE92
89.01	KLM92	100.00	LUFT92	100.00	MALTA92
93.50	PORTUG92	69.48	SABENA92	95.29	SAS92
99.36	SWISS92	100.00	TURKISH92		

Table of efficiencies (radial)

100.00	AERLIN93	100.00	AIRFRAN93	100.00	ALITAL93
94.00	AUST93	75.74	BRITISH93	100.00	CYPRUS93
90.74	FINNAIR93	74.53	IBERIA93	82.37	ICE93
84.94	KLM93	100.00	LUFT93	100.00	MALTA93
87.45	PORTUG93	63.55	SABENA93	77.81	SAS93
100.00	SWISS93	69.00	TURKISH93		

Table of efficiencies (radial)

100.00	AERLIN94	100.00	AIRFRAN94	100.00	ALITAL94
99.20	AUST94	86.32	BRITISH94	100.00	CYPRUS94
89.88	FINNAIR94	88.56	IBERIA94	95.90	ICE94
96.59	KLM94	100.00	LUFT94	100.00	MALTA94
100.00	PORTUG94	77.64	SABENA94	90.28	SAS94
100.00	SWISS94	82.47	TURKISH94		

Table of efficiencies (radial)

100.00	AERLIN95	100.00	AIRFRAN95	97.68	ALITAL95
100.00	AUST95	89.43	BRITISH95	100.00	CYPRUS95
100.00	FINNAIR95	83.09	IBERIA95	100.00	ICE95
99.57	KLM95	69.01	LUFT95	100.00	MALTA95
100.00	PORTUG95	87.20	SABENA95	94.92	SAS95
100.00	SWISS95	89.38	TURKISH95		

Appendix 2b DEA Efficiency Scores (VRS)

Variable returns to scale used
Table of efficiencies (radial)

100.00	AERLIN91	93.07	AIRFRAN91	100.00	ALITAL91
74.58	AUST91	100.00	BRITISH91	100.00	CYPRUS91
100.00	FINNAIR91	86.33	IBERIA91	75.39	ICE91
100.00	KLM91	100.00	LUFT91	100.00	MALTA91
91.97	PORTUG91	84.14	SABENA91	100.00	SAS91
100.00	SWISS91	100.00	TURKISH91		

Table of efficiencies (radial)

100.00	AERLIN92	100.00	AIRFRAN92	100.00	ALITAL92
86.06	AUST92	100.00	BRITISH92	100.00	CYPRUS92
100.00	FINNAIR92	82.49	IBERIA92	100.00	ICE92
100.00	KLM92	100.00	LUFT92	100.00	MALTA92
97.27	PORTUG92	72.02	SABENA92	100.00	SAS92
100.00	SWISS92	100.00	TURKISH92		

Table of efficiencies (radial)

100.00	AERLIN93	100.00	AIRFRAN93	100.00	ALITAL93
95.48	AUST93	100.00	BRITISH93	100.00	CYPRUS93
100.00	FINNAIR93	96.26	IBERIA93	91.98	ICE93
100.00	KLM93	100.00	LUFT93	100.00	MALTA93
100.00	PORTUG93	73.90	SABENA93	100.00	SAS93
100.00	SWISS93	83.48	TURKISH93		

Table of efficiencies (radial)

100.00	AERLIN94	100.00	AIRFRAN94	100.00	ALITAL94
100.00	AUST94	100.00	BRITISH94	100.00	CYPRUS94
89.94	FINNAIR94	100.00	IBERIA94	100.00	ICE94
100.00	KLM94	100.00	LUFT94	100.00	MALTA94
100.00	PORTUG94	82.49	SABENA94	100.00	SAS94
100.00	SWISS94	82.51	TURKISH94		

Table of efficiencies (radial)

100.00	AERLIN95	100.00	AIRFRAN95	100.00	ALITAL95
100.00	AUST95	100.00	BRITISH95	100.00	CYPRUS95
100.00	FINNAIR95	97.96	IBERIA95	100.00	ICE95
100.00	KLM95	100.00	LUFT95	100.00	MALTA95
100.00	PORTUG95	92.66	SABENA95	100.00	SAS95
100.00	SWISS95	90.35	TURKISH95		

Appendix 3 DEA Windows Analysis Results

Table of efficiencies (radial)

100.00	AERLIN91	100.00	AERLIN92	91.46	AERLIN93
85.73	AIRFRAN91	96.47	AIRFRAN92	96.49	AIRFRAN93
72.94	ALITAL91	69.28	ALITAL92	80.19	ALITAL93
73.33	AUST91	78.89	AUST92	79.14	AUST93
53.29	BRITISH91	62.73	BRITISH92	51.68	BRITISH93
100.00	CYPRUS91	98.55	CYPRUS92	94.83	CYPRUS93
85.83	FINNAIR91	86.73	FINNAIR92	84.54	FINNAIR93
46.12	IBERIA91	49.56	IBERIA92	51.41	IBERIA93
63.32	ICE91	62.82	ICE92	59.04	ICE93
88.72	KLM91	72.61	KLM92	78.66	KLM93
100.00	LUFT91	96.31	LUFT92	95.80	LUFT93
100.00	MALTA91	100.00	MALTA92	95.34	MALTA93
71.79	PORTUG91	70.51	PORTUG92	70.00	PORTUG93
81.18	SABENA91	53.53	SABENA92	50.19	SABENA93
62.41	SAS91	63.91	SAS92	58.31	SAS93
91.22	SWISS91	90.63	SWISS92	96.00	SWISS93
100.00	TURKISH91	88.88	TURKISH92	51.84	TURKISH93

Table of efficiencies (radial)

100.00	AERLIN92	100.00	AERLIN93	95.42	AERLIN94
93.97	AIRFRAN92	94.54	AIRFRAN93	100.00	AIRFRAN94
77.27	ALITAL92	88.47	ALITAL93	89.96	ALITAL94
82.44	AUST92	82.33	AUST93	87.82	AUST94
85.00	BRITISH92	75.74	BRITISH93	78.58	BRITISH94
95.39	CYPRUS92	97.79	CYPRUS93	100.00	CYPRUS94
92.77	FINNAIR92	90.37	FINNAIR93	78.94	FINNAIR94
70.41	IBERIA92	74.53	IBERIA93	78.53	IBERIA94
89.66	ICE92	82.32	ICE93	84.64	ICE94
79.06	KLM92	84.62	KLM93	85.57	KLM94
100.00	LUFT92	97.02	LUFT93	100.00	LUFT94
100.00	MALTA92	100.00	MALTA93	100.00	MALTA94
86.47	PORTUG92	84.68	PORTUG93	87.06	PORTUG94
64.47	SABENA92	63.55	SABENA93	70.62	SABENA94
86.96	SAS92	77.81	SAS93	80.76	SAS94
99.35	SWISS92	100.00	SWISS93	92.52	SWISS94
100.00	TURKISH92	66.85	TURKISH93	72.23	TURKISH94

Table of efficiencies (radial)

100.00	AERLIN93	95.42	AERLIN94	94.50	AERLIN95
94.57	AIRFRAN93	100.00	AIRFRAN94	100.00	AIRFRAN95
94.80	ALITAL93	97.14	ALITAL94	87.32	ALITAL95
88.64	AUST93	95.49	AUST94	99.16	AUST95
75.74	BRITISH93	78.58	BRITISH94	80.20	BRITISH95
100.00	CYPRUS93	100.00	CYPRUS94	100.00	CYPRUS95
90.72	FINNAIR93	78.95	FINNAIR94	83.54	FINNAIR95
74.53	IBERIA93	78.53	IBERIA94	71.85	IBERIA95
82.32	ICE93	84.64	ICE94	87.07	ICE95
84.83	KLM93	85.70	KLM94	84.75	KLM95
96.86	LUFT93	100.00	LUFT94	63.01	LUFT95
100.00	MALTA93	100.00	MALTA94	93.58	MALTA95
86.94	PORTUG93	100.00	PORTUG94	95.52	PORTUG95
63.55	SABENA93	70.62	SABENA94	78.91	SABENA95
77.81	SAS93	82.44	SAS94	81.11	SAS95
100.00	SWISS93	92.63	SWISS94	92.57	SWISS95
68.54	TURKISH93	80.21	TURKISH94	81.55	TURKISH95

Appendix 4 Malmquist Productivity Results

1991\1992	(x1,x2,x3,y1,y2)						
Aer Lingus	0.90	1.00	0.90	1.00	1.00	1.24	1.00
Air France	1.11	1.17	0.95	0.86	0.96	0.92	1.00
Air Malta	0.80	1.00	0.80	1.00	1.06	1.65	1.00
Alitalia	0.99	1.17	0.85	0.73	0.69	0.82	0.85
Austrian	1.09	1.17	0.93	0.73	0.79	0.78	0.86
British Airways	1.16	1.77	0.66	0.53	0.63	0.82	0.94
Cyprus Airways	0.69	1.00	0.69	1.00	0.99	2.06	1.00
Finnair	0.98	1.16	0.85	0.86	0.87	1.05	1.00
Iberia	1.07	1.69	0.63	0.46	0.50	0.73	0.78
Iceland Air	1.03	1.58	0.65	0.63	0.63	0.94	1.00
KLM	0.87	1.00	0.86	0.89	0.73	0.97	0.89
Lufthansa	0.95	1.00	0.95	1.00	0.96	1.07	1.00
Sabena	0.73	0.86	0.85	0.81	0.54	0.86	0.69
SAS	1.07	1.53	0.70	0.62	0.64	0.86	0.95
Swissair	0.99	1.09	0.91	0.91	0.91	1.00	0.99
Air Portugal TAP	1.04	1.30	0.80	0.72	0.71	0.85	0.94
Turkish Airlines	0.69	1.00	0.69	1.00	0.89	1.87	1.00
1992\1993	(x1,x2,x3,y1,y2)						
Aer Lingus	0.92	1.00	0.92	1.00	1.02	1.20	1.00
Air France	0.97	1.00	0.97	1.00	1.02	1.09	1.00
Air Malta	1.07	1.00	1.07	1.00	1.25	1.09	1.00
Alitalia	1.14	1.17	0.97	0.85	0.93	0.84	1.00
Austrian	1.00	1.10	0.91	0.86	0.85	0.94	0.94
British Airways	0.89	0.80	1.11	0.94	0.84	0.85	0.76
Cyprus Airways	1.04	1.00	1.04	1.00	1.13	1.04	1.00
Finnair	0.98	0.91	1.08	1.00	0.99	0.93	0.91
Iberia	1.06	0.95	1.11	0.78	0.83	0.70	0.75
Iceland Air	0.92	0.82	1.12	1.00	0.92	0.90	0.82
KLM	0.99	0.95	1.04	0.89	0.85	0.82	0.85
Lufthansa	0.96	1.00	0.96	1.00	1.01	1.10	1.00
Sabena	0.96	0.91	1.05	0.69	0.69	0.68	0.64
SAS	0.89	0.82	1.09	0.95	0.85	0.87	0.78
Swissair	1.02	1.01	1.01	0.99	1.05	1.01	1.00
Air Portugal TAP	0.97	0.94	1.04	0.94	0.91	0.90	0.87
Turkish Airlines	0.61	0.69	0.88	1.00	0.73	1.38	0.69
1993\1994	(x1,x2,x3,y1,y2)						
Aer Lingus	0.89	1.00	0.89	1.00	0.95	1.21	1.00
Air France	1.11	1.00	1.11	1.00	1.17	0.96	1.00
Air Malta	1.04	1.00	1.04	1.00	1.45	1.33	1.00
Alitalia	1.02	1.00	1.02	1.00	1.02	0.98	1.00
Austrian	1.07	1.06	1.02	0.94	0.99	0.91	0.99
British Airways	1.03	1.14	0.90	0.76	0.79	0.86	0.86
Cyprus Airways	1.10	1.00	1.10	1.00	1.22	1.00	1.00
Finnair	0.84	0.99	0.85	0.91	0.79	1.10	0.90
Iberia	1.05	1.19	0.89	0.75	0.79	0.84	0.89
Iceland Air	1.03	1.16	0.88	0.82	0.85	0.93	0.96
KLM	1.01	1.14	0.89	0.85	0.86	0.95	0.97
Lufthansa	1.04	1.00	1.04	1.00	1.05	0.97	1.00
Sabena	1.11	1.22	0.91	0.64	0.71	0.69	0.78
SAS	1.06	1.16	0.91	0.78	0.83	0.86	0.90
Swissair	0.94	1.00	0.94	1.00	0.93	1.06	1.00
Air Portugal TAP	1.14	1.14	0.99	0.87	1.06	0.94	1.00
Turkish Airlines	1.15	1.20	0.96	0.69	0.84	0.76	0.82
1994\1995	(x1,x2,x3,y1,y2)						
Aer Lingus	0.85	1.00	0.85	1.00	1.02	1.43	1.00

Appendix 4 Malmquist Productivity Results

	[illegible]	[illegible]	EC	TC	F11	F12	F21	F22
56	Air France	0.88	1.00	0.88	1.00	1.09	1.42	1.00
57	Air Malta	0.93	1.00	0.93	1.00	0.94	1.09	1.00
58	Alitalia	0.93	0.98	0.96	1.00	0.92	1.03	0.98
59	Austrian	0.97	1.01	0.97	0.99	1.04	1.10	1.00
60	British Airways	1.01	1.04	0.97	0.86	0.86	0.89	0.89
61	Cyprus Airways	0.88	1.00	0.88	1.00	1.05	1.35	1.00
62	Finnair	1.12	1.11	1.01	0.90	1.01	0.89	1.00
63	Iberia	0.93	0.94	0.99	0.89	0.81	0.89	0.83
64	Iceland Air	1.02	1.04	0.98	0.96	0.99	0.98	1.00
65	KLM	1.00	1.03	0.97	0.97	0.93	0.96	1.00
66	Lufthansa	0.61	0.69	0.88	1.00	0.69	1.29	0.69
67	Sabena	1.12	1.12	1.00	0.78	0.88	0.79	0.87
68	SAS	0.99	1.05	0.94	0.90	0.89	0.96	0.95
69	Swissair	1.00	1.00	1.00	1.00	1.01	1.02	1.00
70	Air Portugal TAP	0.97	1.00	0.97	1.00	1.00	1.06	1.00
71	Turkish Airlines	1.04	1.08	0.96	0.82	0.86	0.86	0.89

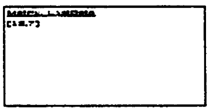
Appendix 5 Correlation Matrix

```
--> RESET
--> READ;file="C:\My Documents\TOBLIM1.xls";format=xls;names$
--> DSTAT;Rhs=INEFF,LOAD,OW,EUR,INTER,DOM,ROUT,STAGE,SCH,DUMCON,DUMSUB,DUYEAR
    ;Output=2$
```

Descriptive Statistics

All results based on nonmissing observations.

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases
INEFF	.215539407	.220428823	.000000000	1.03956761	51
LOAD	.630098039	.705969560E-01	.460000000	.741000000	51
OW	.645076471	.343150848	.000000000	1.00000000	51
EUR	.515889635	.134643017	.320346320	.838709677	51
INTER	.337138202	.173228810	.882352941E-01	.611764706	51
DOM	.146972163	.107695403	.191082803E-01	.382352941	51
ROUT	86.2076874	29.4765273	30.1275290	172.717431	51
STAGE	1291.92130	454.856916	578.980359	3319.22342	51
SCH	.920691104	.800110246E-01	.567185148	1.00000000	51
DUMCON	.588235294	.497050122	.000000000	1.00000000	51
DUMSUB	.235294118	.428403328	.000000000	1.00000000	51
DUYEAR	.666666667	.476095229	.000000000	1.00000000	51



Correlation Matrix for Listed Variables

	INEFF	LOAD	OW	EUR	INTER	DOM	ROUT	STAGE
INEFF	1.00000	-.15454	-.18224	-.16866	.07155	.09577	.10050	-.21456
LOAD	-.15454	1.00000	-.25522	-.29013	.45314	-.36614	.07407	-.02389
OW	-.18224	-.25522	1.00000	.08286	-.09772	.05359	.06681	.05458
EUR	-.16866	-.29013	.08286	1.00000	-.78328	.00970	.26419	-.01556
INTER	.07155	.45314	-.09772	-.78328	1.00000	-.62923	-.52302	.30859
DOM	.09577	-.36614	.05359	.00970	-.62923	1.00000	.51099	-.47691
ROUT	.10050	.07407	.06681	.26419	-.52302	.51099	1.00000	-.86526
STAGE	-.21456	-.02389	.05458	-.01556	.30859	-.47691	-.86526	1.00000

STAGE

	INEFF	LOAD	OW	EUR	INTER	DOM	ROUT	
SCH	.40133	.06952	–.42800	–.31835	.29956	–.08384	.08145	–.24920
DUMCON	.26582	.46626	–.32048	–.45462	.61712	–.42428	–.01386	–.09915
DUMSUB	–.04116	.30937	.41972	.05099	.03270	–.11635	.21646	–.11119
DUYEAR	–.38196	.17117	–.00979	–.02336	–.00804	.04214	–.05780	.08323

	SCH	DUMCON	DUMSUB	DUYEAR
SCH	1.00000	.47952	–.04838	.09120
DUMCON	.47952	1.00000	–.09945	.00000
DUMSUB	–.04838	–.09945	1.00000	.00000
DUYEAR	.09120	.00000	.00000	1.00000

Appendix 6a Tobit Analysis: Model 1

```
TOBIT;Lhs=INEFF;Rhs=ONE,LOAD,OW,EUR,INTER,ROUT,DUMCON,DUMSUB,DUYEAR;Margin$
```

```
+-----------------------------------------------------------------------+
| Limited Dependent Variable Model - CENSORED   Regression              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = INEFF     Mean=    .2155394067     , S.D.=    .2204288234 |
| Model size: Observations =        51, Parameters =   9, Deg.Fr.=   42 |
| Residuals:  Sum of squares= 1.519155668     , Std.Dev.=        .19019 |
| Fit:        R-squared=  .374690, Adjusted R-squared =          .25558 |
| Model test: F[  8,      42] =    3.15,    Prob value =         .00702 |
| Diagnostic: Log-L =      17.2327, Restricted(b=0) Log-L =      5.2603 |
|             LogAmemiyaPrCrt.=   -3.157, Akaike Info. Crt.=      -.323 |
+-----------------------------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	1.485490255	.43401279	3.423	.0006	
LOAD	-1.286880396	.57291465	-2.246	.0247	.63009804
OW	-.1703371394	.10076779	-1.690	.0910	.64507647
EUR	-.5307589814	.37107770	-1.430	.1526	.51588963
INTER	-.3771688104	.47383929	-.796	.4260	.33713820
ROUT	.6968732262E-04	.15672349E-02	.044	.9645	86.207687
DUMCON	.1929270028	.89860621E-01	2.147	.0318	.58823529
DUMSUB	.1364091601	.83600859E-01	1.632	.1027	.23529412
DUYEAR	-.1497432157	.59599617E-01	-2.512	.0120	.66666667

Normal exit from iterations. Exit status=0.

```
+---------------------------------------------+
| Limited Dependent Variable Model - CENSORED |
| Maximum Likelihood Estimates                |
| Dependent variable                 INEFF    |
| Weighting variable                   ONE    |
| Number of observations                51    |
| Iterations completed                   4    |
| Log likelihood function         14.89901    |
| Threshold values for the model:             |
| Lower=      .0000      Upper=+infinity      |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Primary Index Equation for Model				
Constant	1.548961906	.40146756	3.858	.0001	
LOAD	-1.423896138	.53793938	-2.647	.0081	.63009804
OW	-.2022656024	.95184337E-01	-2.125	.0336	.64507647
EUR	-.6221447496	.34564467	-1.800	.0719	.51588963
INTER	-.3071319558	.44863259	-.685	.4936	.33713820
ROUT	.7880334178E-03	.15417518E-02	.511	.6093	86.207687
DUMCON	.1886779269	.84289358E-01	2.238	.0252	.58823529
DUMSUB	.1531859886	.77554142E-01	1.975	.0482	.23529412
DUYEAR	-.1554556020	.55068747E-01	-2.823	.0048	.66666667
	Disturbance standard deviation				
Sigma	.1752193812	.17666125E-01	9.918	.0000	

Appendix 6b Tobit Analysis: Model 2

```
--> TOBIT;Lhs=INEFF;Rhs=ONE,LOAD,OW,ROUT,SCH,DUMCON,DUMSUB,DUYEAR;Margin$

+-----------------------------------------------------------------------+
| Limited Dependent Variable Model - CENSORED   Regression              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = INEFF     Mean=   .2155394067    , S.D.=    .2204288234   |
| Model size: Observations =       51, Parameters =   8, Deg.Fr.=    43 |
| Residuals:  Sum of squares= 1.494159509     , Std.Dev.=        .18641 |
| Fit:        R-squared=  .384979, Adjusted R-squared =           .28486 |
| Model test: F[  7,      43] =     3.85,    Prob value =         .00249 |
| Diagnostic: Log-L =      17.6558, Restricted(b=0) Log-L =       5.2603 |
|             LogAmemiyaPrCrt.=   -3.214, Akaike Info. Crt.=       -.379 |
+-----------------------------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	.1182086597	.64344321	.184	.8542	
LOAD	-.9423197749	.56091191	-1.680	.0930	.63009804
OW	-.7624929184E-01	.10986122	-.694	.4877	.64507647
ROUT	.4700303116E-03	.92508977E-03	.508	.6114	86.207687
SCH	.7929682161	.45218502	1.754	.0795	.92069110
DUMCON	.1081803148	.75722156E-01	1.429	.1531	.58823529
DUMSUB	.6514243666E-01	.85669590E-01	.760	.4470	.23529412
DUYEAR	-.1639363595	.58384607E-01	-2.808	.0050	.66666667

Normal exit from iterations. Exit status=0.

```
+---------------------------------------------+
| Limited Dependent Variable Model - CENSORED |
| Maximum Likelihood Estimates                |
| Dependent variable                INEFF     |
| Weighting variable                  ONE     |
| Number of observations               51     |
| Iterations completed                  4     |
| Log likelihood function        14.48531     |
| Threshold values for the model:             |
| Lower=      .0000      Upper=+infinity      |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Primary Index Equation for Model				
Constant	.1193501332	.61252047	.195	.8455	
LOAD	-.9860108173	.52827237	-1.866	.0620	.63009804
OW	-.9297223008E-01	.10371348	-.896	.3700	.64507647
ROUT	.7616514696E-03	.88391148E-03	.862	.3889	86.207687
SCH	.7922996152	.43276819	1.831	.0671	.92069110
DUMCON	.1223767694	.71869492E-01	1.703	.0886	.58823529
DUMSUB	.7762613809E-01	.80804218E-01	.961	.3367	.23529412
DUYEAR	-.1703173764	.54954658E-01	-3.099	.0019	.66666667
	Disturbance standard deviation				
Sigma	.1748938926	.17700785E-01	9.881	.0000	

```
+-----------------------------------------+
| Partial derivatives of expected val. with |
```

Appendix 6c Tobit Analysis: Model 3

```
--> TOBIT;Lhs=INEFF;Rhs=ONE,LOAD,OW,EUR,INTER,STAGE,DUMCON,DUMSUB,DUYEAR
    ;Margin$

+-----------------------------------------------------------------------+
| Limited Dependent Variable Model - CENSORED   Regression              |
| Ordinary     least squares regression    Weighting variable = none    |
| Dep. var. = INEFF    Mean=   .2155394067    , S.D.=   .2204288234     |
| Model size: Observations =       51, Parameters =   9, Deg.Fr.=   42  |
| Residuals:  Sum of squares= 1.517578214    , Std.Dev.=        .19009  |
| Fit:        R-squared=  .375339, Adjusted R-squared =         .25636  |
| Model test: F[  8,      42] =    3.15,    Prob value =        .00690  |
| Diagnostic: Log-L =     17.2592, Restricted(b=0) Log-L =      5.2603  |
|             LogAmemiyaPrCrt.=   -3.158, Akaike Info. Crt.=     -.324  |
+-----------------------------------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant  1.486497588      .39307109        3.782   .0002
 LOAD     -1.286709080      .53755932       -2.394   .0167   .63009804
 OW       -.1688700812      .98911997E-01   -1.707   .0878   .64507647
 EUR      -.4989260183      .37514919       -1.330   .1835   .51588963
 INTER    -.3394552456      .39004678        -.870   .3841   .33713820
 STAGE    -.1704587556E-04  .79792856E-04    -.214   .8308  1291.9213
 DUMCON    .1871753264      .83958633E-01    2.229   .0258   .58823529
 DUMSUB    .1332602242      .83307357E-01    1.600   .1097   .23529412
 DUYEAR   -.1483104822      .58920789E-01   -2.517   .0118   .66666667

Normal exit from iterations. Exit status=0.

              +---------------------------------------------+
              | Limited Dependent Variable Model - CENSORED |
              | Maximum Likelihood Estimates                |
              | Dependent variable                INEFF     |
              | Weighting variable                  ONE     |
              | Number of observations               51     |
              | Iterations completed                  5     |
              | Log likelihood function        15.53050     |
              | Threshold values for the model:             |
              | Lower=      .0000      Upper=+infinity      |
              +---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
          Primary Index Equation for Model
 Constant  1.666738168      .37650958        4.427   .0000
 LOAD     -1.416872576      .50175958       -2.824   .0047   .63009804
 OW       -.2013277859      .93076014E-01   -2.163   .0305   .64507647
 EUR      -.5095534740      .34710956       -1.468   .1421   .51588963
 INTER    -.1379844519      .40430363        -.341   .7329   .33713820
 STAGE    -.1218268282E-03  .10595441E-03   -1.150   .2502  1291.9213
 DUMCON    .1609317208      .82296423E-01    1.956   .0505   .58823529
 DUMSUB    .1465526797      .76665051E-01    1.912   .0559   .23529412
 DUYEAR   -.1520270507      .54117059E-01   -2.809   .0050   .66666667
         Disturbance standard deviation
 Sigma     .1740660930      .17539598E-01    9.924   .0000
```

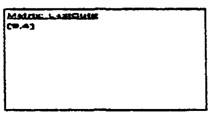
Appendix 6d Tobit Analysis: Model 4

```
--> TOBIT;Lhs=INEFF;Rhs=ONE,LOAD,OW,STAGE,SCH,DUMCON,DUMSUB,DUYEAR;Margin$

+-----------------------------------------------------------------------------+
| Limited Dependent Variable Model - CENSORED   Regression                    |
| Ordinary    least squares regression    Weighting variable = none           |
| Dep. var. = INEFF     Mean=    .2155394067    , S.D.=    .2204288234        |
| Model size: Observations =       51, Parameters =   8, Deg.Fr.=        43   |
| Residuals:  Sum of squares= 1.489164413     , Std.Dev.=          .18610     |
| Fit:        R-squared=  .387035, Adjusted R-squared =            .28725     |
| Model test: F[  7,      43] =     3.88,     Prob value =          .00235     |
| Diagnostic: Log-L =       17.7412, Restricted(b=0) Log-L =        5.2603    |
|             LogAmemiyaPrCrt.=    -3.217, Akaike Info. Crt.=         -.382   |
+-----------------------------------------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant  .2245880823      .66218662          .339   .7345
 LOAD     -.9232985318      .55895050        -1.652   .0986  .63009804
 OW       -.7403663298E-01  .10957949         -.676   .4993  .64507647
 STAGE    -.3849824141E-04  .60624698E-04     -.635   .5254  1291.9213
 SCH       .7612177345      .45786081         1.663   .0964  .92069110
 DUMCON    .1059989703      .75408703E-01     1.406   .1598  .58823529
 DUMSUB    .6534577477E-01  .85271641E-01      .766   .4435  .23529412
 DUYEAR   -.1625374521      .58403198E-01    -2.783   .0054  .66666667

Normal exit from iterations. Exit status=0.

              +---------------------------------------------+
              | Limited Dependent Variable Model - CENSORED |
              | Maximum Likelihood Estimates                |
              | Dependent variable                 INEFF    |
              | Weighting variable                   ONE    |
              | Number of observations                51    |
              | Iterations completed                   4    |
              | Log likelihood function         15.18054    |
              | Threshold values for the model:             |
              | Lower=      .0000     Upper=+infinity       |
              +---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
          Primary Index Equation for Model
 Constant  .3407136132      .62633797          .544   .5865
 LOAD     -.9493903674      .52369061        -1.813   .0698  .63009804
 OW       -.9173436961E-01  .10293746         -.891   .3728  .64507647
 STAGE    -.9436497656E-04  .66186411E-04    -1.426   .1539  1291.9213
 SCH       .7275464161      .43496646         1.673   .0944  .92069110
 DUMCON    .1204068566      .71233758E-01     1.690   .0910  .58823529
 DUMSUB    .7711147200E-01  .80026573E-01      .964   .3353  .23529412
 DUYEAR   -.1681943542      .54627064E-01    -3.079   .0021  .66666667
         Disturbance standard deviation
 Sigma     .1736377369      .17550955E-01     9.893   .0000
```



```
+---------------------------------------------+
| Partial derivatives of expected val. with |
```