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***Capital productivity and investment:
their role in profitable airline operations***

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Abstract

The aim of the research was to develop and apply improved measures of capital productivity using published airline data, and to evaluate the role of capital investment and productivity in overall airline performance. As well as contributing to total factor productivity, capital productivity is a partial measure, and the investment upon which it is based should improve the productivity of other inputs to the production process, in particular labour and fuel.

Productivity ratios require outputs and inputs to be combined and indexed. Index numbers have been developed using weights that are consistent with the underlying economic theory, and also meet various tests (such as reversal and products). Airline passenger, cargo and incidentals were combined using a number of such index number approaches. Capital inputs were estimated using annual lease equivalents which when discounted to the present over the expected future economic lives of the assets resulted gave either balance sheet values adjusted to a common year's prices, or the total of the market values of individual assets (aircraft).

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As with any list, there is always a danger that important contributors have been omitted, and I apologise for any oversight in this respect. And, as always, any errors and omissions remain

Capital productivity and investment: their role in profitable airline operations

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Capital productivity and investment: their role in profitable airline operations

1 Introduction and objectives

1.1 Airlines as investments and investors

Capital investment involves giving up part of current consumption expenditure in order to provide a return or increased consumption in future periods. For a rationally motivated firm, such as an airline, this involves one or more of the following:

- Investing in real tangible assets such as aircraft/equipment, buildings or land
- Investing in intangible assets such as airport slots, research or training
- Investing in financial assets

The last type of investment gives the firm purchasing the financial asset a claim on the assets of other firms, and thus a return in future periods based on another firm's (or government's) assets. Conversely, when a firm sells financial assets, it promises to provide the holder of the assets a return over a given period (or with ordinary share capital, an unlimited period). It would thus need to invest in real capital or other financial assets to be able to deliver these returns.

Assets, whether tangible or intangible, usually need to be combined with other inputs such as labour in order to provide a good or service and generate a return. However, some assets, for example property or land, may produce a financial return by themselves from expectations about their future use and value. Aircraft, the major asset owned by airlines, fit this category, leading to their evaluation by banks and financial institutions both as physical capital able to generate returns from services, and also financial capital which may appreciate in value.

Airlines use their own capital and labour to provide air services¹, together with inputs from suppliers of airport and en route air navigation facilities, oil companies, IT, handling and catering firms and other suppliers. Some of these inputs were in the past

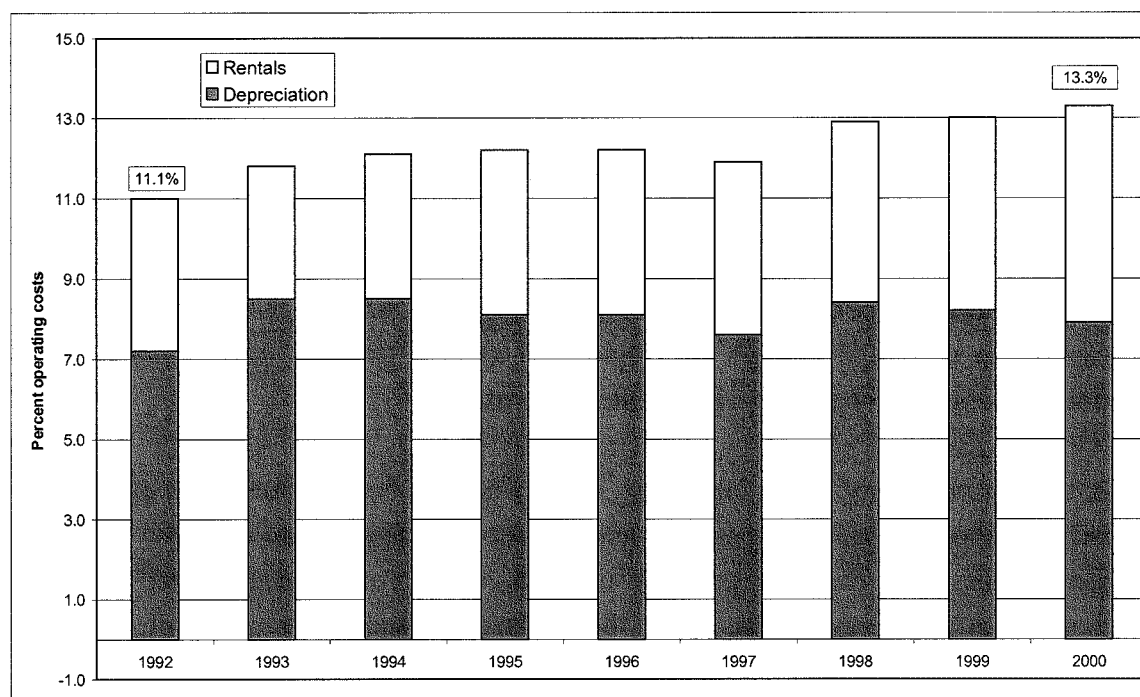
¹ They may also be exploiting route and traffic rights granted by governments; without these intangible assets, air services would not be possible.

supplied by the airlines themselves, but there has been a trend towards outsourcing these to large global specialists in recent years.²

1.2 The importance of capital to airlines

The airline industry has often been described as capital intensive, although this is somewhat misleading, since labour costs account for up to 35-40% of total costs for some airlines. The capital intensive label is probably derived from the fact that airlines operate aircraft costing as much as \$150 million each. These aircraft, together with spares and related flight equipment, account for a very large proportion of an airlines' fixed assets.

Figure 1.1: Importance of capital costs for IATA international services



Source: *Airline Economic Results and Prospects, 1999-2000, IATA December 2001*

Figure 1.1 shows that capital costs have been increasing gradually as a percentage of total costs over the past decade, although some of this increase has come a transfer of interest from 'financial' to 'operating' expenses. It should be noted that capital costs is defined here as 'flight equipment' and excludes ground equipment. The graph also excludes interest on debt (apart from the interest implicit in aircraft rentals, an increasing part of the total), which was 2.5% of total operating costs in 1999, and 2.0% in 2000 (this was net of interest received on deposits). Thus total capital costs

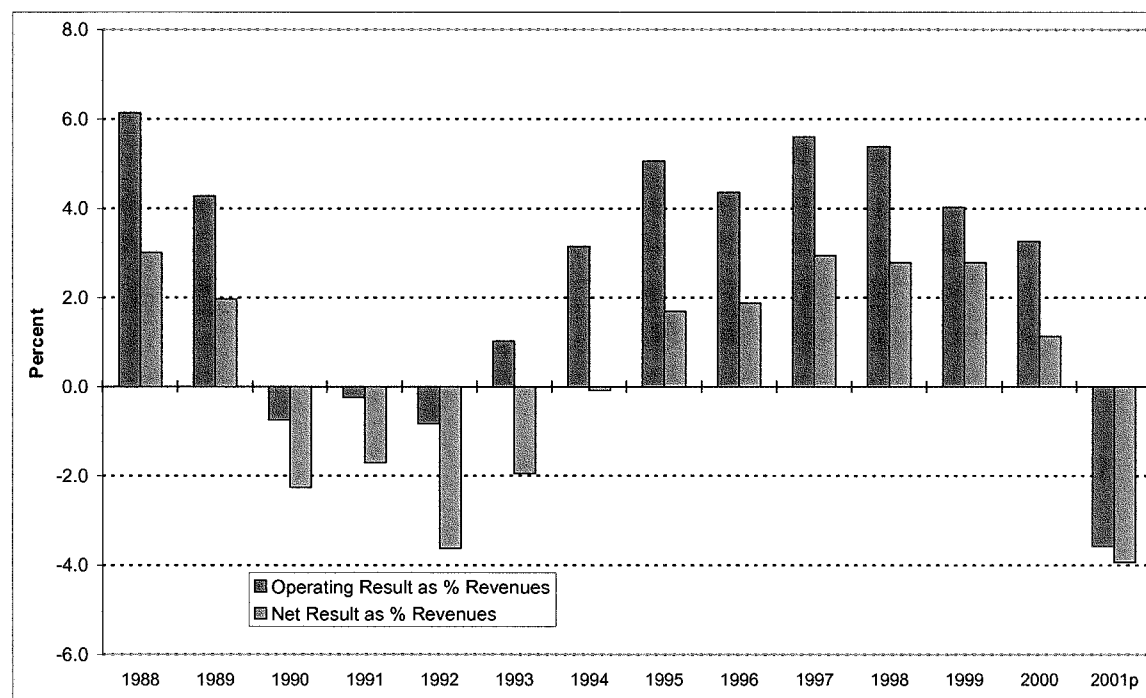
² For example handling companies like GlobeGround, and catering specialists like SkyChefs

(including interest paid) would be well above 15% of total. This compares with the significantly higher labour cost share referred to above.

Figures from ICAO, which include airlines providing most of the world's scheduled air services, show that between 1989 and 2000, the total balance sheet value of flight equipment (after depreciation) increased at a rate of 7.7% a year (or 7.0% a year before depreciation). The long-term debt that the airlines took on to finance their fleet increased over the same period by 6.6% a year to reach US\$130 billion, and it has since 2000 advanced significantly.

An alternative, and better way of looking at capital intensity is to examine capital's share in value added. Industry data are not published in this form, but for BA capital's share in gross value added (defined as the costs of labour, depreciation, rentals and interest paid) increased from 29% in 1985/86 to 37% in 2000/01. This compares with estimates for the UK as a whole averaging 31% between 1996 and 1999 (Gust and Marquez, 2000, p.669).

Figure 1.2: ICAO scheduled airline financial results, 1988-2001



Source: ICAO Financial Statistics

Whatever measure is used, the airline industry has invested very large sums of money with the assumed expectation that this investment will generate a return that will exceed its average cost of capital. In most airlines, investment appraisal techniques

are applied that demonstrate to boards of directors that the capital investment is justified. The outcome in accounting terms has been disappointing as Figure 1.2 shows: over the past 14 years, the operating margin has averaged only 2.6%, out of which interest payments have had to be paid. This raises many questions as to whether the investment (mostly in aircraft) has lived up to expectations technologically, whether the investment has led to the more efficient use of labour and other inputs to the process of providing services, and whether the capital itself has been used productively. This research, which investigates the return on investment in *economic* rather than accounting terms, focuses on the last of these questions but will also consider the role of investment in labour productivity (labour being the single most important input).

In addition to airline investments, a considerable proportion of the resources needed to operate air services are bought from other firms, namely airports, ATC providers, handlers, caterers and IT specialists. Airports themselves are very capital intensive, while some of the activities taking place at the airport such as handling and catering are more labour intensive than the airlines. Engine and avionics equipment overhaul is probably more capital intensive than airlines.

While much attention has recently been applied to labour, there are signs that the airline industry is becoming more capital intensive. In aircraft maintenance, expensive test and monitoring equipment is replacing more labour intensive component repair, while at airports self-service check-in and ticketing machines are becoming more common. In the air, two pilot operations are already the norm. The need for fuel efficiency has increased the attraction of new technology aircraft, especially in a period of low interest rates.

1.3 Investment and capital productivity

Capital and investment have an impact on total factor productivity, through their impact on the amount of labour, fuel and other inputs needed to operate air services. This can be divided into economies of scale and technical efficiency, which in practice are difficult to separate. The application of technology also brings quality changes, such as a more reliable, punctual, quieter or smoother flight, which can easily be missed in productivity evaluation.

The decision to invest by airlines is important both to the future financial success of the firms themselves, but also to society as a whole through future wealth creation

(and increasingly through environmental sustainability). Simple models of investment decisions assume that capital can be bought and sold in any quantity and becomes productive immediately upon purchase. Furthermore, it is assumed that there are no costs involved in the sale and purchase of capital goods or in the productive implementation of new capital (Nickell, 1978).

Thus, airlines could fine-tune their aircraft and related assets according to demand, and long-term investment decisions would not have to be made. These simplifying assumptions are clearly far from realistic for the airline industry, where long lead times are evident in capital asset delivery, capital is not homogeneous, and there are significant costs in adding or subtracting aircraft to/from a fleet.

Given the importance of aircraft to an airline's success, much research has been undertaken in the area of technical aircraft efficiency, and some analysis has taken place of aircraft utilisation. However, little work has been published on the relationship between technical efficiency and the intensity of aircraft use on the one hand, and the cost of aircraft and related finance on the other. Some studies have examined total factor productivity, and by implication capital productivity. But most previous studies focus on labour productivity, partly because of trends in the 1970s and 1980s towards overmanning and labour inefficiency, and partly because simple measures can be used with readily available data.

Capital productivity underlies one of the crucial decisions faced by start-up airlines in the US and elsewhere: whether to operate new aircraft intensively or choose to fly older aircraft less intensively. It is also a major factor in determining rates of return on investment. Finance is a critical constraint for this type of airline (both in availability and cost), and the output generated by each dollar of capital input will be important in its subsequent success or failure.

In the US, many of the recent new entrant airlines have chosen old aircraft that could be acquired very cheaply (eg ValuJet, Kiwi etc), although JetBlue began its exceptionally well-funded life with new A320s. Another more established airline, Southwest, which has recently expanded into markets previously dominated by major carriers, operates relatively new aircraft very intensively. In Europe, EasyJet initially chose older aircraft (B737-200/300), as did Ryanair with even older B737-200s, but both soon invested in new aircraft; charter new entrants generally choose new equipment.

Capital or aircraft productivity growth has been a key driver of overall airline productivity and efficiency gains over the past 30 years. The largest productivity gains came from the transition from piston-engined aircraft to jets in the 1960s. Further gains came from the replacement of the longer-haul Boeing 707s and Douglas DC8s with DC10s and Lockheed Tristars and later the Boeing 747. However, these gains were largely offset by the extra price that had to be paid for the additional revenue generating capability of the bigger jets (Gordon, 1990).

The most recent transition has been from four-engined (B747) and three-engined (DC10 and L1011) jets to twin-jets on medium and long-haul sectors. This has produced efficiency increases in terms of fuel, maintenance and crewing costs at a reasonable price: the development costs of these jets had already been recovered to a large extent from short/medium haul operations.

Another more recent development has been the replacement of turbo-prop aircraft with more capital-intensive regional jets on shorter haul sectors. The jets delivered speed and a better quality of service at a price which was affordable for those airlines with a reasonable mix of higher yielding business traffic.

1.4 Thesis aims and objectives

From the above discussion it is evident that capital investment and productivity is important both in wealth creation, and as a driver for further profitable growth in the airline industry. It will also be demonstrated that there has been little research in this area with application to the airline industry. This research into airline capital productivity and investment is thus intended to improve understanding in this important field, and achieve the four following aims:

1. Develop measures of capital productivity that can be calculated using published data
2. Examine trends in investment and capital productivity over time
3. Compare capital productivity between airlines by region and type of operator
4. Identify the key factors which determine capital productivity, and assess its role in labour and total factor productivity

As well as contributing to total factor productivity, capital productivity is a partial measure, and investment improves the productivity of other inputs to the production

process, in particular labour and fuel. This means that capital productivity cannot be studied in isolation, and so two further questions arise:

- A. What has been the record of airline investment in the past, and how does the cost of capital and productivity contribute to airline profitability?
- B. Are there any significant differences in capital productivity, investment and capital intensity amongst airlines, and what are the reasons for this?

The first question needs to be addressed with reference to the returns from capital investment, and will involve the analyses of both British Airways (BA) and a cross-section of airlines.

The returns on capital invested have been described as very poor in comparison with other industries. This return, however, has in part been bolstered by the fact that the capital asset (aircraft) has at least maintained its value over time. Investors have been attracted by this feature of the asset, as much as by the asset's ability to generate adequate profits over its economic life. The value of the asset has been conserved by strict regulatory rules (internationally enforced), and very thorough maintenance and overhaul procedures (far in excess of those applied to, for example, motor cars). The asset also had the advantage of being mobile, and could be used in most countries around the world with, in general, modest modifications to satisfy local aviation authorities.

Return on capital needs to be calculated over a given period of time, and this raises a related question of how well airlines perform over longer periods of time. Airline output cannot be stored in common with other service industries, and this makes it difficult to react to short-term cyclical downturns. The degree to which BA have managed to adapt supply to demand, and to anticipate cyclical swings will also be examined.

In order to answer the second question, the research will look at a cross-section of airlines, which includes airlines in developed and developing countries, and established as well as start-up airlines. The relative prices of capital, labour and fuel should play a role in the rate of investment, and differences in these prices across airlines might be expected to lead to different levels of capital investment.

There has been a significant amount of co-operation in the airline industry in the past. This has involved standardisation of equipment, documentation and procedures. For example, a standard interchangeable ticket was developed through IATA, and joint

computer systems were developed in such areas as lost baggage and container tracing, and stolen air tickets. In some cases, the desirability for standards and the problems associated with reaching a consensus have perhaps led to the late introduction of badly needed technology. One example of this is self-service check-in, and another is electronic tickets.

Computer Reservation Systems (CRS) also received significant amounts of airline investment, but subsequent improvements slowed due to the need to work with existing legacy systems. Similarly, the technological advances incorporated in newer aircraft slowed, although they continued to generate cost savings, especially through their need for less labour and fuel inputs.

In summary, this research advances knowledge and understanding on the topic through:

- Developing more appropriate measures of both airline outputs and capital inputs
- Taking into account the quality of airline output
- Providing an analysis of the link between capital investment, productivity and financial return
- Provide guidelines for investors and stakeholders in the industry

1.5 Research methodology and scope

The approach to the research will be one of application of economic theory, and statistical and financial analysis, to published airline data. This will involve index numbers, as well as econometric modelling. Such techniques will be applied to one major international airline, British Airways (BA), which has been subject to competition in many of its international and all of its domestic markets (at least in the past ten year period).

A selection of airlines for the cross-section analysis will include those based in each major world region, and also established and more recently formed airlines:

North America:

American Airlines

Delta Air Lines

Northwest Airlines

United Airlines

Europe:

Air France
British Airways
KLM
Lufthansa

Asia:

Cathay Pacific Airways
Japan Airlines
Singapore Airlines
Thai Airways International

This analysis will be for 1999/2000, a year which followed a number of profitable years, and which did not include any special factors such as 9/11 or the Asian financial crisis.

There is a substantial amount of data available on airline costs and finance, published by ICAO, IATA and the airlines themselves in annual reports and accounts. This is not always in the form required, and also presents problems of comparability because of differing financial years, accounting standards or unrealistic exchange rates. However, it was an important objective to make the necessary adjustments and complete the research without recourse to specific surveys of airlines or requests for additional information. This would make this research more useful to other researchers into airline performance and also more relevant to industry analysts.

1.6 Thesis structure

The first stage in the research is to review previous studies and to discuss the application of economic theory to productivity in general, and the airline industry in particular. This is done in more general terms in Chapter 2, looking at the various approaches taken to productivity studies, in particular index number theory and econometrical modelling. Chapter 3 will focus on outputs in air transport, and will examine the definitions and measurements used in previous studies. Chapter 4 will deal with definitions of capital stocks and flows in relation to airlines and Chapter 5 will cover similar ground to Chapter 3, but for inputs, in particular capital.

In Chapter 6, all other non-capital inputs will be introduced, especially labour, together with their importance in total output and their relationship with capital

invested in the airline. Recent examples of the calculation of capital inputs on an economic rather than accounting basis will be presented in Chapter 7. The measures developed in Chapters 3 and 5 will then be applied to a detailed examination of BA's performance between 1984 and 2001 follows in Chapter 8. This 17-year period starts before privatisation, and spans almost two economic cycles. Much of the underlying economic theory applied in this thesis relies on long-term equilibrium relationships and thus cannot easily accommodate cyclical downturns or upswings. It is thus 'preferable to examine productivity growth over longer periods of time' (OECD, 2001a, paragraph 199, p119).

A cross-section analysis of a selection of airlines will then be evaluated in Chapter 9, before the final chapter summarises and draws conclusions from the research.

2 Background to productivity

The starting point for any study of productivity is to examine the relevant economic theory, and the approaches taken in previous studies. This will be addressed in the first section of this chapter, applying the underlying concepts to the airline industry wherever possible. This leads on to the techniques used in previous studies in the next section, which divide into non-parametric approaches, especially index numbers, and econometric studies. The chapter concludes with the preferred way forward for this research.

2.1 Basic concepts

The starting point for any numerical analysis of productivity is the theory of the firm. This considers a production process whereby inputs or factors of production are converted into saleable output.

The theory of the firm is still firmly based on classical economic theory, which relies on assumptions of perfect competition in both output and input markets, in order to allow the examination of resource allocation and pricing, which are based on profit maximisation and cost minimising behaviour. This assumes that all firms are price takers, with no possibility to influence price or pass on cost increases. The theory has been adapted to take into account oligopolistic markets and product differentiation, but much of the work on productivity relies on many of the earlier classical assumptions.

The convenient unit of measurement and comparison is the firm, which even in earlier times rarely produced one product. Diversification led to distortions, with firms moving into a number of different businesses, some of which were even operating in different industries. This is true of airlines where a number of firms incorporate a range of businesses from airlines to hotels, catering companies, duty-free shopping and tour operators.

The focus of this thesis is the airline production process, which involves the transfer of passengers and freight from ground transport modes to aircraft, a flight to the destination airport, where another transfer takes place to ground transport. Airlines

sometimes also operate ground transport services for passengers³ or freight ('door-to-door').

Airline production is generally defined as the offer of seats and cargo capacity over a network of city pair routes, according to a published timetable.⁴ A certain part of this production or output is generally not sold, due lack of demand, revenue management policy, last minute cancellations or no-shows. The airport transfer process is included in airline production in terms of check-in, baggage handling and gate boarding. Airlines can combine inputs in varying quantities to produce output of varying quality. Their production 'function' relates the combinations of inputs required to produce a given output, according to a given technology. Under competitive conditions, it is assumed that managers employ all inputs efficiently. Technology has been described as 'the currently known ways of converting resources into outputs desired by the economy' (Griliches, 1987). Airlines are able to acquire this knowledge or develop it internally.

Airlines need to invest in (or rent) aircraft and other capital equipment to provide air services, and they have the option of acquiring older technology that requires more labour, fuel and other inputs, or buying the latest technology incorporating labour saving devices and fuel-efficient engines. Some features of the new aircraft can be retrofitted on older aircraft, for example seat-back videos, engine hush-kits and bad weather navigation systems.

For any given technology, there will be a relationship between the quantities of each input needed to produce output. Factor substitution between inputs will occur in the way described above, depending on their relative prices, but these will only define a different way of producing the same level of output. The production function defines the relationship between inputs and output and the maximum amount of output that can be produced with different combinations of inputs:

$$Q = f(K, L, M, \dots) \dots\dots\dots (2.1)$$

Q is the output in a defined period, K is the corresponding capital input, L the labour input, and M the material inputs (which will be described in more detail in Chapter 6). Clearly, there could be other inputs, such as fuel, airport and other services. A

³ eg Virgin Atlantic and Thai Airways with their limousines, the former for premium passengers on a complimentary basis, the latter for those who wish to pay for more comfortable travel to the centre of Bangkok.

⁴ Charter airlines do not normally publish their timetable, but sell output to one or more tour operators.

commonly used form is the Cobb-Douglas production function, shown here with the two major inputs only:

$$Q = A \cdot K^a \cdot L^b \dots\dots\dots (2.2)$$

A is a positive constant measuring neutral technical change, and a and b are positive constants reflecting the elasticities of output with respect to the two inputs. Technical progress could be neutral in its effect on capital and labour inputs (Hicks neutral in equation 2.2), or it could shift the production function in such a way that the same output could be produced with either less labour or less capital (Nicholson, 1985, p.256). In practice it is difficult to separate out the impact of technology embodied in the measure of each input and the separate technical progress term (A). The application of technical progress to capital may be relatively slow, where capital equipment has a long life and bolting new technology on to existing capital is difficult or expensive. For aircraft, it does sometimes take place (eg retrofitting of new engines to meet noise regulations), but usually awaits the introduction of new models.

Constant returns to scale are a characteristic of a particular case of the Cobb-Douglas function, when $a + b = 1$. Equation 2.2 has been quite widely used in productivity studies in its logarithmic form:

$$\ln Q = \ln A + a \ln K + (1 - a) \ln L \dots\dots\dots(2.3)$$

Output can only be increased by using more inputs, or with a change in technology or method of organisation of production (A in equations 2.2 and 2.3 above) such that existing inputs are used more efficiently. The latter effect could also be achieved by increasing returns to scale, where the effect of specialisation or learning will allow a greater output to be produced with the same level of inputs.

Measures of productivity indicate how much output is produced on average by the various inputs or factors of production. This can be done for each input in turn, holding the others constant. This is known as *partial* factor productivity, its level being defined as the ratio between output and the input of one factor of production:

$$\begin{aligned} \text{Labour productivity} &= Y / L \\ \text{Capital productivity} &= Y / K \\ \text{Material productivity} &= Y / M \end{aligned}$$

The *growth* in capital productivity (or other partial ratios) is given by the difference between the growth in output (y) and the growth in capital input (k), or other inputs (m ...).

Productivity analysis is concerned with changes in outputs and inputs, and thus in how production functions behave. Without physical measures of inputs and outputs, it is difficult to measure productivity in absolute terms, and thus changes in productivity are measured over time or indexed on one firm or country. It is important to define productivity ratios and the weights attached to its constituent parts in a way that is consistent with assumptions on the shape of the production function. This is not known and the elasticities in equation 2.2 are not observable (both can be estimated using econometric techniques). Solow (in Hulten, 2001, p.7) started with the production function and showed the theoretical link with productivity ratios (or index numbers). This allowed the measurement of technical efficiency for given values of Q, K and L, without knowledge of the way output changed for all values of Q, K and L.

Total factor productivity (TFP) or multifactor productivity (MFP) is derived from equation 2.2 and given by the following:

$$TFP = (Y/K)^a \cdot (Y/L)^b \text{ or } Y / [(Y/K)^a \cdot (Y/L)^b] \dots\dots\dots(2.4)$$

With constant returns, $a + b = 1$, and b can be re-written as $(1 - a)$, as per equation 2.3 above.

Growth in TFP or MFP is estimated as the difference between output growth and the growth of factor inputs. It can be expressed as the difference between the growth of output and the weighted average growth of capital, labour and other inputs (using lower case for growth rates):

$$\text{Growth in TFP or tfp} = y - (w_l.l + w_k.k + w_m.m \dots) \dots\dots\dots (2.5)$$

w_l, w_k etc are the respective factor weights. The marginal contributions of each factor should be used as weights, but these depend on the production function (equation 2.2 above), which is not known. It is normally assumed that these marginal contributions are proportional to the share of production that they receive in compensation (ie employee or capital cost share of total value added).

Equation 2.5 can also be re-written as an expression of output growth less the growth in inputs:

$$y = \text{tfp} + (w_l.l + w_k.k + w_m.m \dots) \dots\dots\dots(2.6)$$

One problem is the number of factors of production which are considered separately. It may have been a reasonable simplification in the analysis of the old industries (such as steel) to take only land, labour, capital and materials. The latter were raw materials purchased at market prices, to which value was added using land, labour and machines. Only labour and capital are considered for productivity study in relation to national accounts, since other inputs are outputs from other firms using capital and labour and so on. But at the firm level all inputs should be included in relation to gross output where possible, or capital and labour to output net of other inputs (value added).

Efficient firms are those that can produce a certain output with lower input volumes than other firms, or produce a greater output with the same inputs. The definition and measurement of inputs and outputs will be discussed in relation to airlines in the next three chapters. Capital productivity relates output to one input (capital), and is distinguished from return on capital by considering physical inputs and outputs (or their proxies), whereas return compares financial income generated from capital with the stock of amount of capital available.

In comparing output quantities, whether determined using physical measures or deflated revenues, it is important to try to adjust for any quality changes. This is because the purpose of the measure is to track changes (or compare differences) in technology and efficiency in both production and distribution of a good or service. Including quality changes would mean not comparing like with like. This will be addressed later, both with respect to physical measures, and also the use of price indices (see Gust and Marquez, 2000, for the problem as it relates to national accounts).

Capital inputs are important both at the level of the overall economy (national accounts, taxation etc), and also at the firm level. The latter includes studies on production and industrial growth (of which productivity analysis is part), as well as environmental economics. There have been many studies published on the role of capital in national accounts (see OECD, 2001a), and a number on the measurement of capital and technical change at the micro-economic level (see Robinson, 1954, and OECD, 2001a). The latter have focused on economic depreciation in general, with

empirical evidence from certain industries (see Hulten and Wykoff, 1981). Most of them stress the need for further research in this area.⁵

Some researchers distinguish capital from labour inputs in that the latter are an input only, while capital is an input and an output.⁶ By this they mean that, after capital has been used to provide output, there remains a stock to use for subsequent periods. However, this is true only insofar as it is very difficult to measure the stock of human capital. In fact, both capital and labour produce a flow of services from a stock, but the latter is measured for accounting purposes for capital but not for labour.

A number of different single factor (partial) and multifactor productivity measures or ratios that can be evaluated for the two principal inputs:

- Labour productivity (using both gross output or value added)
- Capital productivity (using both gross output or value added)
- Total factor productivity with all inputs (gross output)
- Total factor productivity with only capital and labour inputs (value added)

These are useful in their different ways, and have both advantages and drawbacks. Capital productivity, which is the focus of this thesis, has the advantage of showing how efficient a firm is in producing added value or output from their investment in capital, but capital is only employed together with other factors, and their impact cannot be eliminated without further study.

There have been numerous studies that have evaluated partial productivity measures for airlines, and many of these have also considered total productivity in terms of aggregate measures such as operating cost per ATK. These have been well summarised in relation to air transport (Windle and Dresner, 1992, p.436, and Forsythe et al, 1986, p.65). An earlier study examined airline managerial efficiency using data for 16 European scheduled airlines, regressing labour productivity against five explanatory variables (Pearson, 1976). One of the variables included in the model was aircraft productivity, defined as average aircraft utilisation. Another equation explained unit costs in terms of four explanatory variables including labour but not capital productivity. Managerial efficiency was then measured by each airline's standardised residuals from the two models. Apart from the lack of rigorous statistical testing of the regression models, this work failed to address marketing

⁵ see Hulten & Wykoff (1996), conclusions

⁶ *ibid*, p.1

efficiency, revenues or quality of output, although these weaknesses was pointed out by the author.

Another earlier study focused entirely on labour productivity, examining partial measures for the various airline staff categories for 10 European and North American airlines (McKinsey, 1977). The study concluded that North American carriers had much higher labour productivity in all staff categories, *because of their generally greater size and network density*. This was one of the few studies that adjusted the data for contracting out and contracting in, by converting third part amounts paid or received into man-years.

The previous weakness of the omission of marketing efficiency in the Pearson productivity study was rectified in a study of 26 airlines from Europe, North America and the Asia/Pacific regions (Doganis et al, 1995, later updated as Morrell et al, 2000). However, lack of data prevented any adjustments to be made for third party work. The study allows a useful time series and cross-sectional comparison of the world's major airlines, both across and within regions, and includes some disaggregate labour productivity measures such as pilot productivity.

2.2 Techniques for productivity measurement

Productivity can be the ratio of two physical quantities, or proxies for quantities that are calculated by deflating either revenue output by a suitable price index or input values by a suitable cost index. They could also be a combination of physical output and deflated inputs, or vice versa.

There are two basic approaches to productivity:

- Non-parametric methods (eg index numbers)
- Econometric evaluation

The first compares ratios of inputs and outputs directly. The most commonly used of these is index numbers, although other approaches, such as Data Envelope Analysis (DEA), are increasingly applied to the study of air transport efficiency. With these approaches, assumptions are sometimes made about the shape of part of the production function, but no attempt is made to estimate points along it.

On the other hand, the second type of approach examines the statistical contribution of various factors to changes in efficiency, and attempts to estimate the parameters of the variables that explain changes in output using econometric techniques. This is often referred to as a parametric approach, which estimates all points along a production function.

These two approaches will be described in more detail in the next two sections, together with their advantages and disadvantages.

2.2.1 Index number approach

Productivity studies involve the study of both changes in productivity over time (time series) and variations across firms, sectors or economies (cross-sectional data). These can be combined in the examination of a number of firms over time (panel data). The index number approach measures ratios of outputs to inputs directly for comparison over time and/or across firms. However, each observation is compared to one particular observation, whether for one airline and one time period in the sample, or one time period.

Because both inputs and outputs involve heterogeneous quantities that cannot be added directly, weights are required to convert each quantity into an amount that can be combined together to arrive at both denominator and numerator of the productivity ratio. This applies both to combining labour and capital inputs, and also to combining different types of capital input (eg different aircraft types).

The problem with index numbers arises both through the choice of weights used and in the process of aggregation. Weights change, especially over time, and the fact that the weights are input prices or values leads to changes in factor or input mix, and thus can be a cause of change, rather than merely a result of the process.

It is generally agreed that it is better to compare time series ratios through the indexation of adjacent year values (1990, 1992, 1993 1994 and 1995), rather than directly, say, the 1990 value with the 1995 value. This is because the weights are adjusted gradually. This is the way many countries construct their consumer price index, and is called ‘chaining’ (see OECD, 2001a for a summary of index number theory and application).

There are two different approaches to index numbers: the axiomatic and economic theory approaches (Hill, 1998, 125-127). The first treats all the quantities and prices

being compared as independent variables, and seeks to ensure that the index meets various tests. Some appear fairly obvious such as the requirement that if prices in the current year are increased or prices in the base year reduced, then the index increases. Others are less obvious such as the product test, which is the need for the product of the price and the quantity indices to be the same as the expenditure index. This last axiom is important when dealing with economic ratios.

The economic theory approach to index numbers removes the independence assumption of quantity and price, since the two will clearly be related. As mentioned above, this causes an interaction between the quantities being indexed and the weights. This approach tries to find an index formulation that will best allow for such relationships, and conform to how consumers or producers might react (as discussed in Section 2.1 above).

Where two adjacent years are compared, the base year weights ($W_{k,t-1}$) can be applied to both current year (P_t) and base year prices ($P_{k,t-1}$). This is called a Laspeyres index (LI):

$$LI = \frac{\sum_k P_{k,t} \cdot W_{k,t-1}}{\sum_k P_{k,t-1} \cdot W_{k,t-1}} \dots\dots\dots(2.7)$$

or

$$LI = \sum_k W_{k,t-1} \cdot \frac{P_{k,t}}{P_{k,t-1}}$$

This is often the approach taken in calculating the consumer price index, with the weights of a basket of k items equal to the values of the item consumed in the base year. Thus W in equation 2.7 would be in value ($P \cdot Q$) terms, but quantity weights (Q) could also be used. The first formulation is more usual, but it should be noted that the second calculation produces a slightly different result. The Paasche index (PI) uses the current year weights:

$$PI = \frac{\sum_k P_{k,t} \cdot W_{k,t}}{\sum_k P_{k,t-1} \cdot W_{k,t}} \dots\dots\dots(2.8)$$

$$\text{or} \quad PI = \sum_k W_{k,t} \cdot \frac{P_{k,t}}{P_{k,t-1}}$$

Laspeyres tends to overstate the change in the composite price index shown in equation 2.7 and Paasche index in equation 2.8 to understate it (see Hill, 1988, for a discussion of the application of these two indices and chain-linking). The Fisher ‘ideal’ index responds to this by taking the geometric mean of the indices stated in equations 2.7 and 2.8.

There has been considerable discussion in the economic literature about the appropriate index formulation to use. Neither the Laspeyres index nor the Paasche index is appropriate because they imply fixed inputs and no substitution between inputs. This does not accord with the behaviour of the firm. The selected index should be linked to the underlying economic concepts, which in addition to input substitution would include cost minimisation or revenue maximisation for given costs (Balk, 1998).

The Törnqvist index was one of a number of variations on the Fisher index, which were described as ‘superlative’. This was because they were thought to match closely empirically determined production functions (and consumer preferences). The Törnqvist index (TI) is a weighted geometric average of the two values. It is still a bilateral index in the same way as the Laspeyres and Paasche indices, in that it compares two values (i and j of the kth item⁷).

$$\ln TI = \sum_k \frac{W_{k,i} + W_{k,j}}{2} \ln \frac{P_{k,i}}{P_{k,j}} \dots\dots\dots (2.9)$$

In order to allow for cross-section analysis (for example multi-country comparisons), the index was converted to a multilateral index (MI) by taking harmonic and geometric means across the whole sample, whether time series or cross-section data, or both (Caves et al, 1982).

The weighting for the Translog multilateral index is given by the following formula.

$$\ln MI = \sum \frac{W_{k,i} + \bar{W}_k}{2} \ln \frac{P_{k,i}}{\bar{P}_k} - \sum \frac{W_{k,j} + \bar{W}_k}{2} \ln \frac{P_{k,j}}{\bar{P}_k} \dots\dots\dots (2.10)$$

⁷ They could equally be observations in period t and (t-1) of the kth item, as shown in the Laspeyres and Paasche examples.

This is similar to the Törnqvist index, but compares the weight of an observation with the arithmetical mean of the sample ($\bar{W}_k$) and the quantity with the geometrical mean of the sample ($\bar{P}_k$). Equation 1.10 could be re-written to express the change or difference in MFP between I and j , if price were replaced by outputs in the first term and by inputs in the second term.

Table 2.1 shows a simple theoretical example of the calculation of a price index of aircraft lease rates using the various approaches discussed above. The aircraft price index uses as weights the share of the lease cost of each aircraft type in the total lease cost of all types (Oum and Yu, 1998, p.66, also use these weights). The different outcomes arise from the different way of combining these weights in each of the indices.

Table 2.1: Aircraft price index calculations

	B747-400	B737-400	A320	Total fleet
<i>Period 1:</i>				
No. of aircraft	5	12	15	32
Lease rate (\$/m)	850	330	370	
Cost share	0.31	0.29	0.40	1.00
Cost (\$)	4,250	3,960	5,550	13,760
<i>Period 2:</i>				
No. of aircraft	5	15	25	45
Lease rate (\$/m)	800	350	460	
Cost share	0.19	0.25	0.55	1.00
Cost (\$)	4,000	5,250	11,500	20,750
<i>Price index in period 1:</i>				100.00
<i>Price index in period 2:</i>				
Laspeyres index (Equation 2.7)				105.25
Paasche index (Eq.2.8)				111.01
Fisher index				107.61
Törnqvist index (Eq.2.9)				105.39
Multilateral index (Eq.2.10)				108.03

Source: Author's calculations

As suggested above, the Paasche index tends to produce a higher index, and the Laspeyres a lower one, and the Fisher is the geometrical mean of the two.⁸ In the example, the Törnqvist bilateral index lies just above the Laspeyres and the Multilateral translog index just above the Fisher index. Both lie between the

⁸ This should also tend to be true for a quantity index.

Laspeyres and the Paasche, which provide the upper and lower bounds to the true index (Hill, 1988, p.131).

If both fleets and lease experience small changes (for example for adjacent periods or years), then the difference between the indices becomes quite small. The differences between the indices is not great for comparisons on relatively short periods or similar airlines, and probably dwarfed by the potential bias in the measurement of the capital quantities and weights to be included in the index. Some sort of mean of weights across the entire sample would seem desirable, and the translog multilateral provides that as well as making cross-sectional and panel comparisons easier to undertake than chain-linked bilateral ones (Caves et al, 1982). The translog indices also approximate better to the underlying production function based on the normal assumptions on the behaviour of firms.

2.2.2 Econometric studies of productivity

One of the drawbacks of the index number approach is that it cannot identify sources of productivity growth. Growth in productivity that arises through economies of scale cannot be distinguished from advances through increased technical efficiency and knowledge (Oum et al, 1992). Index numbers merely allow comparisons between firms and over time.

Econometric or statistical approaches attempt to model the firm's production function from observations of inputs and outputs, and identify productivity change as shifts in the function. In practice, physical input and output quantities may be difficult to collect, but this problem is common to both index number and parametric methods. Cost functions are generally easier to model, using more readily available data, but require an assumption of cost minimisation on the part of the firm. In practice, many airlines seek to expand their network and increase frequency to gain market share. Cost minimisation is then a secondary objective, especially for a business segment focused airline.

Both cost and productivity models face problems with model specification, endogeneity of output variables, and multicollinearity of input variables. Where two independent variables are highly correlated with each other, their estimation will be subject to considerable error (see Black, 1982, for a discussion of this and other problems with econometric models).

Brunning (1991) developed a stochastic frontier cost model for 73 airlines using data for 1987. He used a Cobb-Douglas log-linear cost function relating total operating costs to a number of variables including RTKs, and the prices of capital labour and fuel. The relative inefficiency of each airline was estimated against an 'efficient' frontier, and each of these were then explained by specific operating environmental factors. He concluded that values of total error for each airline may have resulted in the estimates of inefficiency being under- or over-reported, and that this may have been the cause of some unexpected results in the regression analysis.

Good et al (1993) also examined productivity via a cost rather than a production function, and include output and network characteristics in the model, in addition to the standard inputs of capital, labour and materials. However, none of the former was statistically significant, and thus the attempt to account for operating environment in productivity variations failed. Both this paper and a more recent one (Jha and Sahni, 1992) use the 'within' estimation procedure which transforms the data into deviations from individual means and then applies ordinary least squares technique to the transformed data. This has two disadvantages: the parameters in the original equation cannot be estimated, and variations across individual airlines are ignored.

2.3 The preferred approach

The foregoing discussion has shown that there are numerous problems whatever the approach taken to estimating airline productivity. Non-parametric approaches have been developed using the considerable work undertaken on index numbers, but these require additional analyses to eliminate output and network factors that account for significant differences across airlines. The DEA approach suffers from the possibility that measurement error in one observation may depress the frontier, and thus exaggerate the results from other observations (Ng and Seabright, 2001, p.595)

Parametric approaches, whether using stochastic frontier, OLS or more complex techniques, need considerably more observations, and are often plagued by statistical problems that result in biased results. Attempts to correct these problems can lead to losing sight of the original parameters and thus the ability to understand the process. Problems of data availability make direct estimates of production (rather than cost) functions impossible.

Almost all studies have used either cross-sectional or panel data for airlines. This presents considerable complexity of output mix and network features that are not

present when examining one airline over time. For this reason, the approach here is to combine a time series analysis of one international airline, British Airways (BA), with a cross-sectional analysis of BA with a number of competing international airlines. The time series analysis applies index number theory to measuring productivity, allowing improved measures of capital flow to be developed, followed by correction where necessary for any output or network changes. The cross-sectional analysis then applies the same approach and similar methods of measurement to other major international airlines.

3 Measurement of airline outputs

3.1 Definition of airline output

Airline output can be defined in physical or money terms. Total factor productivity measures require the combination of the various types and dimensions of output into one measure. Partial productivity measures may consider only one type of output, but then this leads to more complex problems of allocation of inputs.

Physical units most often used in aggregate measures are available tonne-kms (ATKs) or revenue tonne-kms (RTKs). The first describes production or capacity, and is relevant to those inputs such as flight operations whose effort is related to this, while the second is a measure of traffic, of greater relevance to sales and handling personnel. Overall, the second is to be preferred over the first, since it is the ability of the airline to convert inputs into sold capacity that is of interest. Those ATKs not sold cannot be stored for later sale, as in the case of manufacturing industries.

Monetary measures of output include total revenue, and gross or net value added. These measures combine the major types of airline output:

- Passenger services (scheduled and charter)
- Air cargo services

These two (or three) products generally account for between 75% and 95% of airline output, where the airline is separated out from its diversified group (eg the former Swissair from SAir Group). There remains, however, a sizeable group of activities that the airline performs for other companies, and which are not directly related to the core business of their own air transport operations.

These other activities for third parties are easily incorporated into the monetary measures, at least in terms of gross or net revenues. It is not possible to combine them with ATK or RTK measures, without modification.

A second significant problem is the quality of outputs, and how this can be measured so as to avoid distortions in productivity analysis. This is addressed in the next section.

Each of the various types of output will be discussed in turn, both in terms of quantity and quality. In each case, their treatment in previous studies will also be assessed. This will be followed by a discussion of monetary based measures, before concluding as to

the preferred approach to be used in the airline comparisons. Before that, however, preferences for physical as opposed to monetary measures will be examined from previous studies.

McKinsey Global Institute (1996) have a preference for physical measures, but this is not always feasible due to both the difficulty of adding units of a variety of types of asset (eg machines and buildings), and also because of quality differences. They used value added deflated by Purchasing Power Parities (PPPs) for their case studies of the retail and automotive industries, and physical measures for telecoms (call minutes) and electric utilities (kilowatt hours). Value added was defined as factory-gate gross output less purchases of materials and energy. Gross output (also in money terms) was also considered.

Appendix A summarises the previous measures that have been used in air transport cost and productivity studies. Most use physical measures of output, which are then combined in index form with revenue weights. The majority take passenger-kms (or -miles) and freight tonne-kms, with only two using some form of capacity rather than traffic⁹. Incidental revenue output, which is not reported as a physical measure, is generally deflated by PPP exchange rates. The physical measure indices are then combined using the multilateral translog procedure discussed in the previous chapter, with revenue shares as weights.

Two of the earlier studies listed have used some sort of revenue output, whether value added or revenues. However, a revenue approach does give the proper weight in output to those airlines that are targeting high yield or business travellers. This type of traffic requires more inputs to service, and traffic measures of output do not adequately capture this. The revenue weights applied to traffic measures merely get the balance right across the main categories of output, but not within the passenger service output.

This problem of output mix was addressed in two of the traffic output studies: Caves et al (1981) separated passenger traffic into first, coach and charter; Encaoua (1991) split traffic into normal and promotional fares, but data on this is not published by carrier (and the author did not indicate its source).

One recent study (Forsythe, 2001) used both RPKs and deflated revenues for output with very different results. The author thought that the RPK measure 'probably gives a more accurate picture', but went on to say that RPKs did not reflect the lower quality

⁹ Ehrlich et al (1994) used actual rather than capacity output, since the former represented purchased capacity, but suggested that capacity output may 'serve as a better measure of long-run production levels'.

service (less convenience, smaller seat pitch and more ticket restrictions) enjoyed by discount fare passengers. This type of traffic had expanded considerably over the period considered, resulting in the revenue output productivity ratio growing much less rapidly than the traffic based one.

However, a more significant problem admitted by Forsythe was the choice of price deflator, which was the Australian national statistics index of air fares. This relied heavily on full economy fares, whereas there was a marked shift over the period examined to discount fares. Swierenga and Crandall (1982) avoided this problem by taking an index of average airline revenue per ton mile as the deflator. However, almost all of the period covered by this study was characterised by strict CAB price regulation, where price changes were permitted only in relation to cost changes.

Some of the studies adjust output changes for changes in load factor or sector length, especially in cross-section comparisons. This can be applied to the numerator and denominator separately, or in regressing explanatory variables against productivity ratios.

3.2 Output - air passenger transport

Passenger services can be split into scheduled and charter services. The former can be broadly defined as being individually ticketed and sold direct to the general public without packaging into a holiday or tour. Charter services on the other hand are still largely sold on a wholesale basis to tour operators, who need them to market inclusive holidays. Charters may involve selling the whole plane's capacity to one tour operator, or to a number of different operators. The tour operators will sell seats to the public and assume the risk if the seats are not sold.

While the measures of output of the two appear similar (ATK, RTK, seat-km or passenger-km), there are important quality differences between the two. These are, in fact, an extreme example of the quality differences that will also exist between various scheduled service airlines.

Even on identical routes, for example London/New York, and using identical types of aircraft (B747), will it be possible for significant variations in output quantity and quality exist:

British Airways: 12 first class, 30 business class and 240 Y class = 385 seats

Continental Airlines: 40 business class and 350 Y class = 420 seats

Quality changes are not reflected in changes in tonne-kms. For example, an airline can increase ATKs and RTKs by changing from a two class service to one class. This, however, increases seating density and results in a lower quality product.

Looking at the above example in more detail, it can be seen that air passenger transport comprises a number of elements:

- Seat of varying width and pitch
- Free baggage allowance (checked and carry-on)
- Drinks, meals, reading material, gifts
- Frequent flyer points or miles
- In-flight entertainment systems, lap-top connection and phones
- Airport lounge access (on departure and sometimes arrival)
- Rapid or telephone check-in and immigration/security checks (fast track)
- Ground transport home/airport (occasionally)

All of these will increase in quality and availability with class of service, with higher ticket prices and revenues matched by increased inputs of capital (seat pitch) or airport inputs (business/first class lounges). If passenger-kms or seat-kms are used as a measure of output, quality variations will not be reflected in output and inputs will incorporate resources needed to deliver quality improvements. This will lead to distortions in productivity measures.

This problem can be partly addressed by aggregating traffic or capacity by class of travel (eg first, business and economy). Such figures are not published, but could be obtained direct from airlines. But this would still leave the problem of quality differences across airlines for the same class of service. One airline might offer long-haul seats in their economy class cabin at a 34" pitch, another at 32". Furthermore, analyses of one airline might reveal significant changes in seat pitch over time: BA introduced their flat beds in their first class cabin in the mid-1990s, with the result that the number of seats in their first class cabin on B747-400s declined from 18 to 14.¹⁰

¹⁰ Flight International, 27 October 1995, p.12

Adjustments would thus need to be made for these variations using seating densities in common aircraft types. This can be done by adjusting seat-km data for each airline by a ratio of actual seats installed in each aircraft type compared to a maximum allowed by the aircraft certification authorities. This standard is generally shown in aircraft manufacturers' brochures and published in Flight International's Commercial Aircraft Guide, for example:

Boeing 737-200 124 seats at 30" pitch

Often, the limiting factor is emergency exits, and, in the example above, new safety requirements led to a reduction in maximum permitted seats from 130 to 124.

The seats in this configuration would then be compared with the actual seats offered by each airline on each aircraft type, and an overall ratio computed as the ratio for each aircraft type weighted by aircraft block hours flown during the year:¹¹

$$\text{Comfort index} = \frac{\sum_k \text{SM}_{k,t} \cdot W_{k,t}}{\sum_k \text{SA}_{k,t} \cdot W_{k,t}} \dots\dots\dots (3.1)$$

Where: $\text{SA}_{k,t}$ is the actual number of seats for aircraft type k in period t , $\text{SM}_{k,t}$ is the maximum number of seats for aircraft type k in period t , and $W_{k,t}$ is the number of hours (or kilometres) flown by type k in period t .

The passenger-kms or passenger RTKs used in the output index would then be increased or reduced according to this ratio.

None of the previous studies made this type of adjustment to output measures in their productivity comparisons. For some studies, a relatively similar set of airlines was compared, such as US domestic carriers, so that the distortion may have been small (eg Swierenga and Crandall). Others combined domestic and international, short-haul and long-haul airlines, and consequently distortions would have been larger (eg Oum and Yu, 1995, Good and Rhodes, 1991).

It is estimated that British Airways could have operated their 1997/98 network with 42.6% more seat-hours in all economy configuration than they did with their actual seat configurations. American Airlines would have produced 34.1% more seat-hours in the same year, and thus BA's operations could be described as around 6% higher quality

¹¹ Aircraft kms would be better, but data for this by aircraft type is not generally published.

(measured only in terms of seat pitch) than American's. Results from one recent study showed Total Factor Productivity for American Airlines 25% above that of British Airways in 1993, before adjusting for factors beyond managerial control such as 'operating and market conditions' (Oum and Yu, 1995). These were stage length, total output (size) and the percentages of output accounted for by cargo, charters and services to third parties (but not output quality). After these adjustments, the residual TFP for American in 1993 was 12% higher than for British Airways, half of which might be accounted for by the above quality difference..

A number of studies combined scheduled and charter passenger (and other) outputs into an index, using revenue shares as weights (eg Oum and Yu, 1995, Windle, 1991). This acknowledges the higher quality product offered by scheduled services versus charters, but does not measure quality differences across the various classes of scheduled service.

Similarly, one study used the percentage of output offered on charter flights as a proxy for quality differences, and used this percentage as an explanatory variable in regression models of airline productivity (Gillen et al, 1990).

Sickles et al (2002, p.139) argue that capacity output as defined by available tonne-kms 'provides an important measure of service quality. A carrier offering a lot of flights (and consequently having a large capacity output) will be more likely to have a seat available when a passenger wants it'. However, this would depend on the airline's revenue management system, and even full fare passengers could find no seat available at the last minute if a carrier with large capacity output had already filled all seats at lower fares. It could be argued that airlines with low average load factor are likely to have better seat availability, but this is just one dimension of service quality, which is any case valued highly by only one market segment (business travellers).

A second problem is one of the free baggage allowance, and the weights used for both this and the average passenger weight in converting both passenger-kms and seat-kms into RTKs (which is obviously essential in the physical measure approach to output).

Airlines use various weight allowances to convert passenger-kms to passenger tonne-kms. For example, American Airlines use an average figure of 90 kg, Cathay and Singapore use 95 kg and Air France and Lufthansa use 100 kg. These would need to be standardised on, say, 95 kg, since it is unlikely that Lufthansa's passengers are on average heavier and/or take more baggage than those travelling on British Airways, at least not by as much as 10 kg. Only one of the previous studies that used RTKs as their output measure even considered these differences: Sickles et al (2002, p.140) state that

they have assumed that an average passenger and associated baggage weigh 100 kilograms, but do not investigate which airlines do use this conversion factor or adjust the output of those that do not.

Bowen et al (1992) undertook a more comprehensive, albeit partly subjective, approach to the quality of passenger services. They arrived at 19 factors to be included in their quality rating:

1. Average age of fleet
2. Number of aircraft
3. On-time performance
4. Load factor
5. Pilot deviations
6. Number of accidents
7. Frequent flyer awards
8. Flight problems
9. Oversales
10. Mishandled baggage
11. Fares
12. Customer service
13. Refunds
14. Ticketing/boarding
15. Advertising
16. Credit
17. Other consumer complaints
18. Financial stability
19. Average seat-mile cost

The factors had to be either available from the airline or of relevance to consumers when judging the quality of airline service. Interestingly, the above list makes no mention of seat quality or in-flight service, and airport lounges have not been covered in the survey. Weights were assigned from a survey of 65 industry experts, as well as from airline statistical sources, to produce an index number for each US airline. While this index was updated in subsequent years, it would not be appropriate in the context of this thesis.

Ozment and Morash (1998) considered airline output quality in their examination of productivity: three objective measures were used, and three subjective ones. The objective ones were the percentage of late arrivals, percentage of mishandled baggage

and percentage of cancelled flights. The subjective ones were flight, baggage and combined complaints per 100 passengers. Data for these variables was available from the US Department of Transportation for US airlines only.

These variables are more focused than the 19 used by Bowen referred to above. However, they suffer from two problems:

- They do not address important features of the product (not captured in published output data), which vary considerably by class of service or ticket type, and which require substantial differences in resources to provide them
- Some of them concern productivity or efficiency in suppliers to the airlines, namely airport or baggage handling companies or air traffic service providers

Another survey of airline quality is carried by Zagat¹² of around 12,000 people who have taken at least four flights in the past year. Airlines are rated by comfort, service and food according to a scale from 0 to 30. Airline costliness is indicated by four descriptors: inexpensive, moderate, expensive and very expensive. These subjective ratings for comfort were compared with objective measures of seat pitch in comparison to an all economy configuration (this is described above and applied in 8.1).

Table 3.1: Airline comfort evaluation: survey vs actual data

	Zagat Comfort	All-Y seats vs actual (%)	Estimated Comfort*
Singapore	26	55.5	24
Cathay	24	55.1	24
JAL	23	47.1	21
Thai	22	48.5	22
Lufthansa	21	46.1	21
KLM	21	48.5	22
BA	20	48.8	22
Air France	19	37.9	18
United	18	39.7	19
Delta	18	37.0	18
American	17	34.7	17
Northwest	16	27.1	15

* estimated from relationship between % difference between all economy seating and actual average configuration for each airline (third column) and Zagat score (adjusted R^2 of 0.85)

Source: Zagat survey 2001, airline annual reports, JP Fleets, and author

¹² See www.zagat.com; latest survey is for 2001.

Table 3.1 shows that there was a reasonably strong correlation between the Zagat comfort scores and the percentage difference between an equivalent all-economy seat configuration and each airline's actual configuration.

The Zagat scores were taken from their 2001 survey, and may therefore have been for 2000, or at least been based on travel that had taken place over the previous 12-18 months. The seat density data was based on the years 1999 and 2000 (some financial year data straddled the two years). It can be seen that two Asian airlines scored two higher than the model predicted (Singapore and JAL), presumably because of the elements of service that were not measured, whereas BA was the only airline to score two below the predicted value. The second Zagat rating for 'service' gave Singapore Airlines and JAL 28 and 25 respectively, two above their comfort scores. BA also earned a service rating two above their comfort rating.

The Zagat survey provides some support for using seat pitch to adjust airline output to take account of only one, albeit important, dimension of quality of service. The second quality measure, service, is also closely correlated with comfort.

Other elements of service that can be measures are regularity and punctuality. The former is defined as the percentage of scheduled flights that are actually flown or completed. For BA this did not change significantly over the past 14 years, ranging from 98.0% in 1997/98 to 99.5% in 1994/95. This would not be a good delineator of service quality between major airlines, since the number of flight cancellations is very low and does not vary much, and those flights cancelled for commercial reasons are excluded.

Punctuality is defined in various ways, but BA publishes data on the percentage of flights departing within 15 minutes of schedule. This varies within and across airlines, and for BA it has ranged from 72% in 1988/89 to 85% in 1993/94. However, not many airlines report such data.

3.3 Output - air cargo transport

Air cargo is carried on both passenger and cargo flights. With the former, it is usually confined to the lower deck, but may in some cases be on the main deck of the aircraft, together with passengers (on so-called 'combi' aircraft). The lower deck capacity available for cargo is not a fixed volume or weight, but is rather dependent on:

- The amount of checked passenger baggage
- The sector distance to be operated (and thus fuel required)
- Aircraft performance variables, such as temperature and runway length

The measure of air cargo output is usually tonnes or tonne-kms, but could also be volume or even number of shipments. Assuming that tonnes are used, there are still problems in airline comparisons. For origin or destination cargo, airlines offer special low tariffs for consolidators who deliver the cargo in ready-to-ship containers. This means that the airline does not need to build the individual shipments into container loads, the only handling required being the loading of the containers on to the aircraft. Thus, this type of cargo needs very little inputs, but also earns less revenue.

At the other extreme, frozen goods need special airport terminal storage facilities, both at origin and destination airport. Animals such as racehorses also need special treatment both on the ground and in the air. These types of cargo are charged more to cover the additional handling costs, commensurate with the additional inputs required for its transport.

Both examples highlight the distortions that would be evident with RTK or ATK measures of output, where an airline's traffic mix differed significantly from the average. For example, the inclusion of an airline such as El Al in any comparison, would mean an above average of fresh fruit and vegetables and chilled or frozen produce in their total cargo traffic.

One major shortcoming of previous studies was the absence of any differentiation of product or output quality of the sort discussed above. Air cargo quality might also vary between airlines in terms of priority, but data is not available to make any adjustments for either of these variations. Furthermore, eliminating specialists like El Al and integrators such as Fedex from the sample of airlines compared lessened the likelihood of distortion.

3.4 Output - incidental services

Airline inputs might be employed in producing ATKs for other airlines, through third party work. It would be difficult to estimate the part of capital and labour employed in this work in order to separate out these inputs and outputs from airline productivity comparisons. Similarly, ATKs could be produced with very few inputs of capital and labour by contracting out many functions.

This problem can be solved in two different ways. First, third party revenues can be converted into equivalent RTKs by applying the average yields for each airline's scheduled and charter air services. This treats these services to third parties as if they were airline outputs. ICAO financial statistical reporting guidelines ask airlines to divide incidental revenues into two amounts: air transportation and other:

Air transportation (gross revenues):

- Revenue from passengers paying less than 25% of the normal applicable fare (those paying more than 25% are included in passenger revenues)
- Commissions received from sale of tickets on other carriers
- Fees from no-shows or cancellations
- Chartering or wet-leasing of aircraft to other carriers
- Revenues from capacity equalisation agreements (revenue pools)
- Revenues from the sale of capacity to other carriers, on aircraft operated by the reporting carrier (eg under block space agreements)

*Other incidental revenues from services provided to third parties
(gross revenues net of related expenses):*

- Handling services (ramp, passenger and cargo)
- Technical and maintenance services
- Surface transport
- Catering services
- Property services
- Package holiday sales

British Airways reported total revenues from incidental services of £751 million in 1996/97¹³. This included aircraft maintenance, package holidays and 'other airline services'. However, the British Airways return to the ICAO Financial Statistics for 1996 showed no 'other' incidental revenues, since they had been combined with the air transportation incidentals into one figure.¹⁴ Thus gross revenues and gross revenues net of all related expenses had been reported as one figure. This illustrates the problem with using ICAO as a sole source, which many of the previous academic airline productivity studies appear to have done. Only two of the airlines in the cross-sectional analysis of

¹³ These have grown by an average annual rate of 8.9% over the past 14 years.

¹⁴ This was also the case for most US airlines and some of the other European airlines. Asian airlines generally provide separate figures.

Chapter 9 reported a split between air transport and other incidental revenues: Japan Airlines earned 40% from air transport related, and Singapore Airlines 74%.

It also highlights the care needed in selecting comparable airline legal entities: choosing a diversified holding company such as Lufthansa Group would include a very significant share of incidental revenues in turnover; choosing an airline operating company, such as BA, would give a much narrower focus.

Table 3.2 excludes inter-company billing, and shows that Lufthansa Group obtained 24% of its gross revenues from non-air traffic related services to others. Not many other airlines would be this diversified, and require the unbundling of airline service inputs and outputs as required for Lufthansa.

Table 3.2: Lufthansa Group revenues in 2001

	€m
Lufthansa Passenger (Air passenger services)	10,183
Lufthansa Cargo (air cargo)	2,422
Lufthansa Technik (Maintenance, overhaul and repair)	1,541
LSG Skycheffs (Catering)	2,067
Lufthansa Systems (IT services)	126
GlobeGround and other (handling and other services)	352
Total	16,690

Source: *Lufthansa Annual Report, 2001*

The conversion of incidental revenues to RTKs using average yields would make sense for the first category of incidental revenues, but not for the second. A more appropriate treatment might be to convert the revenues to a quantity using an appropriate PPP price index. This might be one based on air fares and rates (see below) for the first category and a more general GDP one for the second category (if the split is known).

Once the incidental ‘quantities’ have been estimated, they can then be combined with passenger and cargo tonne-kms by combining each component into an index using the translog multilateral procedure. This uses revenue shares of each type of output as weights.

The use of revenue shares as index weights is valid if both constant returns to scale apply and if the prices of outputs are proportional to their marginal costs. Many studies have confirmed that the first condition is satisfied, while the second appears to have been validated, at least for the US, using a two output cost function.

3.5 Output - monetary measures

Productivity comparisons are designed to measure efficiency in terms of quantities of inputs and outputs or their equivalents. Airline outputs were defined directly in quantity terms in the earlier part of this chapter. The major problems encountered with these were the difficulty in quantifying non-air traffic related amounts so that they can be added to the traffic data, and the problem with quality.

Monetary measures of output such as total revenue, and gross or net value added, avoid the first problem (incidentals) and take into account changes in output mix, but not quality changes for which consumers are prepared to pay a premium (this is reflected in the deflator).

Using gross output (revenues), the price deflator should be an index of fares actually paid by passengers. In this way, if prices or yields declined, the volume output would increase, regardless of the cause of the fall in prices. If prices declined because of a change in output mix, then this correctly tracked the likely volume increase. However, if average prices fell because of the fear of flying (as occurred in 1991 and 2001), then volume would not increase, the lower prices offered by all airlines necessary to return volumes at least to their original level. An economic downturn would have the same impact.

If value added is used for the measure of output, it is necessary to apply double deflation to account for both revenue output price changes and the prices of intermediate goods that are deducted from it (OECD, 2001b). Leaving aside the appropriate index number formulation, the input price index should be a producer price index, and the deflated output index should be adjusted a second time to reflect the changes in these input prices.

The conversion of monetary outputs (revenues) to quantities, which can be used in productivity comparisons, is initially relatively simple for time series. An index of revenues is 'deflated' by a suitable output price index to give an indirect quantity index, with any price changes removed. The price index should reflect the changes from one period to the next of prices. If airline output is aggregated (passengers and cargo), then this could be the average yield obtained from all airline services. For time-series, this has the effect of converting revenues back to RTKs, or physical quantities. However, passengers, cargo and incidental revenues could be treated separately, and later combined using a suitable method of weighting.

For comparisons across airlines, the conversion of revenues to quantities requires an index that removes the relative price changes in the country where each airline is based. A suitable exchange rate must be chosen to give a fair comparison across airlines and countries. Morrell and Taneja (1979) used reported or market rates of exchange between the currency of the home country of the airline and the US dollar. However, a better approach would need to avoid possible distortions when particular currencies are significantly over- or undervalued.¹⁵ This is achieved by using Purchasing Power Parity (PPP) exchange rates that equates the price for a typical output in one country with an identical output in another. Published PPP exchange rates unfortunately do not do this: they are based on typical baskets of goods and services, rather than typical airline services. However, an airline PPP could be constructed by taking the local currency ratio of air fares for an average trip length and average fare class.

This latter approach was taken in a comparison of the automotive industry, with a PPP calculated for cars using factory prices for identical models (McKinsey Global Institute, 1996). The same study used the OECD PPP for household consumption for its retail industry case study, which approximated to a retail services PPP.

3.6 Output - conclusions

Both physical and revenue based measures of output have their advantages and disadvantages. Traffic, rather than capacity, should be used for physical measures, especially where similar types of airline are being compared. When seat factors differ significantly between carriers (for example between regional airlines on the one hand, and low cost or charter airlines on the other), capacity measures may be appropriate, or adjustments made to reflect the quality of output.

Revenue based measures require careful consideration of exchange rate and relative price issues, and should use PPP exchange rates and deflators that reflect industry price changes rather than those for the economy as a whole.

The analysis of BA over time will examine both revenue output (gross and net revenues) and physical measures in order to draw some conclusions. A similar approach will be taken with the cross-section analysis in the following chapter.

¹⁵ In 2002, the South African Rand was an example of an under-valued currency, and the Australian dollar of an over-valued one.

4 Definition of airline capital inputs

Airlines require inputs of capital, labour, materials and services provided by others in order to offer flights and associated booking, ground and other services. Some inputs, such as airport and air traffic control services purchased from others are themselves the product of capital, labour and materials managed by other agencies. Capital inputs will be discussed in terms of definition, measurement and treatment in previous productivity studies in this chapter, followed by the various ways to measure capital in the next one. The definition and measurement of all non-capital inputs will then be addressed in Chapter 6.

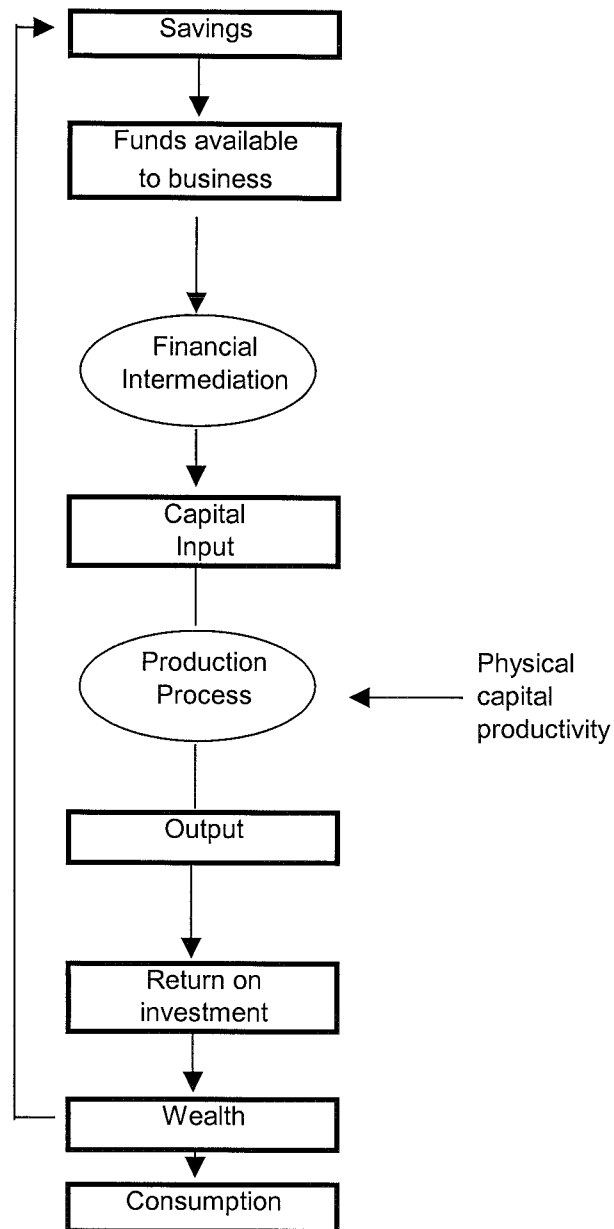
4.1 Tangible capital assets

The measurement and definition of capital is more complex than labour, which is discussed in Section 6.1. Its definition rests on the idea of diverting resources from current to future consumption. This leads to the consideration of any input that is not consumed in the production process during an initial time period being available for consumption at a later period.

From the perspective of an individual consumer (or family unit), money not spent on consuming current goods and services can be saved, and such savings will initially be in the form of financial capital, for example invested in a bank or other savings institution. The funds could then be lent to other consumers for credit purchases, or they could be lent to producers for fixed capital formation. They could also be invested directly into production units or firms, such that they would own a share of both physical and financial capital.

From the firm's perspective, capital formation will depend both on any surplus funds generated from the sales in the current and previous periods, together with the savings that have been channelled to them via financial intermediation (see Figure 4.1). Capital is thus seen as a 'storage device for savings' (McKinsey Global Institute, 1996, p.3).

Figure 4.1: Wealth creation and capital investment



Source: McKinsey Global Institute, 1996, modified by author

As with other inputs capital has a physical or volume dimension and a price, and it is this that provides the means of rationing a scarce resource and provide an incentive for savers to invest. Firms produce surpluses that they can return to shareholders through share buy-backs or dividends, and this capital also has a price or opportunity cost. For many state-owned airlines that rarely produce surpluses, debt finance is the only path open to them to continue to invest in new and updated physical assets.

Capital assets are treated in management accounts as:

- Tangible (fixed or investments)
- Intangible

Tangible assets are the physical assets or investments in aircraft and other vehicles together with related spare parts, plant, equipment and land. Investments are financial holdings in other companies, where the percentage of ownership is usually less than 50% (ie less than a controlling interest), and thus the assets have not been consolidated in the balance sheet under consideration. Investments will be discussed in this section, since they are claims on physical assets, albeit controlled by other firms. However, limited resources are required by the investing firm to manage such claims, such that their inclusion is unnecessary for measures of productivity.

Intangible assets are non-tangible investments with no claim on a physical asset, where the money has been spent in something that will add value in the longer term. This type of capital is more difficult to quantify, since there is no physical piece of equipment to count, but it is a very real, and increasingly important, part of the capital invested in companies, especially service industries such as air transport. It will therefore be discussed more fully in the next section.

Two questions now arise, namely:

- How can capital be distinguished from a material input?
- How much capital has actually been consumed over a given period of time?

The first question concerns the useful life of the asset or piece of equipment. Aircraft and related spare parts are obviously capital items. Airlines also have two further categories of equipment, namely rotables or repairables (capital) and consumables (materials such as gaskets, turbines or compressor blades). The first are relatively short life items which can be repaired, such as a pump or fuel control. The second are not. Aircraft tyres may fall into the consumables category, although some airlines would re-use these after re-treading (and thus include them in repairables). In balance sheet terms, the first are usually included in fixed assets, the second under current assets. The example of aircraft tyres illustrates the problem of what to include under capital, but the accounting definition provides a practical approach. Thus inventories that are shown as current assets (including items such as office supplies) might better be treated as non-capital material inputs.

The second question considers the stock of capital assets producing a flow or consumption of capital over its useful life. This flow is more appropriate to use as an input of capital, but depreciation is likely to be misleading as a proxy for this, since depreciation allowances are often much greater than the decline in an asset's output producing capacity (Kendrick, 1991).

Much of the earlier literature considered capital input at the aggregate level of the economy, but many of the conceptual problems also apply at the firm level (see treatment of capital in previous studies in Appendix B. In some cases, capital stock was used, where an annual flow of services was preferred (Solow, 1957). The same paper, however, stressed that capital in use rather than 'capital in place' should be used, although annual capital utilisation data at the aggregate level was not available. The author also talks of the 'profound difficulties that stand in the way of giving any precise meaning to the quantity of capital', going so far as to state that 'the capital time series is one that will really drive the purist mad' (Solow, 1957, p.314).

Solow's original model assumed that technology was a separate variable that, together with capital and labour, explained changes in output. However, it became clear that this treatment did not allow for the fact that much of the technical change was embodied in new capital investment, or an increase in the quantity of capital in his model. This idea of capital and technology being closely tied together means that capital measurement needs to take account of vintages of capital equipment. A shift in the amount of capital employed from older to newer equipment and technology can result in an increase in capital intensity, although capital productivity might remain unchanged through the reduction in productivity of older equipment due to obsolescence (Baily and Schulze, 1990).

This is evident in the air transport industry, where replacing older Boeing 727-100 aircraft with the new technology Boeing 737-300s leads to lower labour requirements in terms of 2 versus 3 pilots, and reduced maintenance labour. Capital productivity, however, is unlikely to be much changed, since range and seating capacity are similar.

The McKinsey researchers defined capital input as the flow of services generated from a given stock of capital, rather than the stock itself. This they measured by identifying each type and age of asset, and dividing the cost by the useful life in years. In some cases they also added financing costs to the original purchase cost of the investment goods. Output was measured where possible in physical units (eg kilowatt hours for electric utilities), and value added for industries with more heterogeneous outputs.

Inputs and outputs were denominated in local currencies, and converted into a common currency by using purchasing power parities (PPPs) exchange rates.

International differences in capital productivity have been very little studied, according to a recent study (McKinsey Global Institute, 1996), and *'even less is known about what causes capital productivity differences'*. This study's main objective was to identify reasons for capital productivity differences between Germany, Japan and the United States. It followed on from earlier research into labour productivity and employment performance. The study combined a top-down macro analysis with a micro study of five industries: automobiles, food processing, retailing, telecommunications and electric utilities.

The 1996 McKinsey study highlighted the need to consider monetary values of various capital assets (because of the difficulty in adding physical units of diverse and heterogeneous assets), but converted these to comparable physical units by deflating expenditure-based estimates by the investment goods PPP.

McKinsey considered the flow of service from an asset to be the payments that would be made as if the asset were leased. This would therefore include both depreciation and interest payments. This approach they used for some industries, and for others they divided the capital stock by the useful life for each type of asset, and aggregated these costs to arrive at the total flow of capital services. Many airlines lease a significant part of their fleet and there is an implicit interest cost included in their monthly or quarterly lease payments. In any case, in economic terms interest is a real cost of investing in capital, whether charged directly or through the opportunity cost of interest foregone.

Many previous researchers have estimated capital stock using the perpetual inventory method (McKinsey Global Institute, 1996, Oum and Yu, 1995 and 1998). This infers the capital stock from the gross fixed capital formation expenditures and presumed depreciation schedules for each type of asset.

Many authors agree on the inclusion of both depreciation and interest in any measure of capital consumption (see Deakin and Seward, p.26). Some go further to suggest that both dividends and retained earnings should also be included, on the basis that, if the return on loan capital investment (eg interest) is considered, so should the return on equity capital (Kendrick and Creamer, 1961).

One study converted capital (defined in some way) into equivalent man-years of labour, so that labour and capital could be combined to obtain total factor inputs in equivalent

labour terms (Smith and Beeching, 1948). This approach conveniently avoids many of the problems associated with the measurement of capital, but labour can only produce capital goods with other capital goods (Robinson, 1954), and interesting aspects of capital productivity were ignored.

Another study distinguished between the cost of flight equipment and ground property and equipment (Oum and Yu, 1995). An index of flight equipment input quantity was constructed by multiplying the annual lease cost by the number of each aircraft in the fleet (grouped in categories), and then weighting the result by the lease price or cost of each aircraft category. The price index weighting was performed using the translog multilateral index procedure. The real stock of ground property and equipment was estimated using the perpetual inventory method. The annual cost was then computed by multiplying this real stock by a service price. The latter was estimated using the method proposed by Christensen and Jorgenson (1969). This accounts for interest, depreciation, corporate income and property taxes and capital gains. The flight equipment and ground property indices were then combined into one index, again using the translog procedure.

Some previous studies have used published lease costs as an economic cost of capital. This has been used both as a weight to form an index of capital quantity input, and as a price deflator. The use in the production of an index only works with aircraft, and not with ground equipment, since the latter are too heterogeneous to be treated in this way. Indeed, the basis for combining numbers of aircraft into an index using cost weights is justified by the assumption that their quantitative and qualitative contribution to output is proportional to their lease cost. This assumption requires closer scrutiny, first by examining the published lease costs or prices.

The only consistent series of lease costs by aircraft type is published by Avmark.¹⁶ These prices are for five year operating leases, and give a range from the oldest good-condition, half-life aircraft to newer versions in a similar condition. They add in a footnote that actual (lease) rates are variable, depending on lessee's credit, duration of lease, tax considerations and residual value assumptions. They might also have added demand for the particular aircraft type or the market situation (Barrington, 1998, p.59), since there is a tendency for lessors to keep their aircraft flying and generating some cash during recessionary periods. This will be examined further in Section 5.6.

¹⁶ These have been published in the Avmark Aviation Economist since 1990.

4.2 Intangible capital assets

So far, the discussion of capital investment has been limited to physical capital. This is recorded in the airline's balance sheet, although the net book value is generally derived from historical costs less an estimate for accumulated depreciation. Other forms of capital, or intangible assets, can also appear on the balance sheet, but usually only when such assets have been acquired, for example through a purchase of airport slots or the payment for goodwill in the take-over of another company.

Intangible assets are capital investments that, in the same way as tangible, produce a flow of income or benefit over a given period of time. In the airline industry they can be subdivided into:

- Route rights
- Airport slots
- Research and development (for example in yield management systems)
- Training
- Brands, goodwill and alliance agreements

All these enhance an airline's ability to increase output from a given amount of physical and human capital. Some can be associated more closely with certain inputs, especially training and labour inputs. Physical capital increasingly incorporates a considerable amount of software, which could be considered as the product of research and development and labour.

Attempting to value intangible assets and place them on the balance sheet is fraught with difficulties. An alternative approach is to compare a company's total market value with the book value of its equity. This avoids having to value specific intangible assets. This difference in market to book value can then be attributed to various forms of intangible asset (Edvinsson and Malone, 1997). The authors distinguish between human capital and structural capital, the latter further subdivided into:

- Value of loyal customers
- Patents
- Copyrights
- Other product ideas, business processes etc

This work was originally developed for the Swedish company, Skandia, and it resulted in the publication of an intellectual capital supplement to their 1994 Annual Report.

However, the company is in the insurance and financial services sector, and so different indicators were developed to those that might be appropriate to the air transport industry.

4.2.1 *The valuation of route or traffic rights*

An airline's intangible assets would include mainly its route/traffic rights, and the rights to take-off and landing slots at congested airports. They might also include items such as brand value, and management and staff experience and training.

Scheduled airlines operate international air services using traffic rights granted to them by governments. The majority of these rights are still negotiated bilaterally between two countries, with each country designating one or more carriers to take advantage of the traffic rights that the designating states have negotiated.

The negotiation of these rights was originally pursued according to a *quid pro quo* approach, with countries exchanging routes of comparable value. This was later to become the doctrine of an *equal exchange of economic benefits*, which dominates most bilateral negotiations today. For one country to negotiate effectively with another, it needs to evaluate a complex web of options, which would encompass fifth and even sixth freedom rights in addition to third and fourth freedoms (Doganis, 1991). It would also need to consider the so-called *soft rights*, including such areas as transfers of foreign exchange, and the opening of sales offices, as well as increasingly code-sharing and ground handling.

Most governments view these traffic rights as government property, and if an airline ceases to operate or goes into liquidation they revert to the state. For example, the UK's Civil Aviation Authority considered the possible sale or franchising of route rights prior to the privatisation of British Airways, but took the following view (CAA, 1984):

Route licenses are not property. British Airways did not purchase its licenses Insofar as the state, through the licensing of air services, gives airlines an opportunity to operate profitably, these opportunities remain at the disposal of the state

On the other hand, when one scheduled airline acquires another as a going concern, it has usually acquired its traffic rights in addition to its tangible assets, existing staff and other contractual obligations and arrangements.

Any premium paid for the airline might be thought of as goodwill, but this would probably include the value of traffic rights. This was the case when British Airways acquired British Caledonian, and it was also the case more recently when British Airways acquired Dan Air. In both cases British Airways inherited a substantial number of scheduled routes out of Gatwick Airport, which were not returned to the state for re-allocation, although the competition authorities made various stipulations relating to market entry and slots being available to other airlines.

A stricter definition of goodwill would be the amount by which the value of a business as a whole exceeds the value of its individual assets less its liabilities. Assets, here, should include all intangible assets such as traffic rights, airport slots, concessions, patents or trademarks. But it is difficult in practice to separate the goodwill and intangible asset elements in any premium paid for an airline, since intangible assets are not valued and placed on the balance sheet.

In the USA, there was a considerable debate in 1982 when Braniff's Latin American routes were purchased by Eastern Airlines. But the Department of Transportation (DoT) finally approved the deal, with Judith Connor, then Assistant Secretary at DoT, proposing that *'this freedom to deal in what had once been valuable gifts from government should be made a permanent right'*.¹⁷

United Airlines acquired the Pacific Division of Pan American World Airways in 1985, including aircraft, route rights and valuable slots at Tokyo's Narita Airport. The transfer was opposed by the US Department of Justice, but was approved by the Transportation Secretary after an evidentiary hearing. Out of the total price of US\$750 million, it was estimated that only \$365.8 million was accounted for by aircraft and other tangible assets (Fisher, 1987).

In other parts of the world, there have been few scheduled airline complete take-overs, apart from the British Airways deals mentioned above and Air France's acquisition of UTA and Air Inter, both of which were within national boundaries.

In all these cases, the traffic rights have been transferred with the sale, although some routes have had to be handed back at a later stage following government (or European Commission) investigations of the anti-competitive implications of such deals. However, the practice of buying and selling route or traffic rights by themselves has so

¹⁷ Howard, B. (1982), The iron lady at DOT, Forbes, 7 June.

far only been observed in the US, although Air Canada did attempt (unsuccessfully) to buy all the international traffic rights held by Canadian Airlines International in 1993.

The value of traffic rights can only be realised once they are exercised by an airline. Some airlines can make more use of such rights than others, perhaps due to their greater marketing presence, or due to the fact that they complement their existing route structure and provide greater opportunities to feed traffic to other routes.

Thus the value of these rights can only be realised in conjunction with the production process, which is the carriage of passengers and cargo. In this respect they are similar to brands, which, although they can also be sold separately, only have value when applied to a particular product or service.¹⁸ The establishment of brand value involves considerable expenditure in improving product quality and consistency across the network, as well as communication to the marketplace. The successful brand should result in an airline achieving and sustaining both above average yields and load factors.

In accounting terms they would both be considered as intangible assets, since no physical equipment or facilities are involved. In the US, where airlines have acquired route rights they are generally included in their balance sheets and amortised over 40 years (IATA/KPMG, 1992). This latter figure is presumably based on their likely future useful or economic life. In other parts of the world, the premium arising on the take-over of another airline (including traffic rights) would either be written off against reserves, or amortised in a similar way.

4.2.2 Rights to airport slots

A growing number of capital city airports are suffering from runway congestion at peak periods. At such times, demand for take-off or landing times (slots) far exceeds the available supply. Examples of this are the slot controlled or 'high density' airports in the US (New York Kennedy and La Guardia, Washington National and Chicago O'Hare), London Heathrow and Frankfurt in Europe, and Tokyo Narita and Hong Kong Kai Tak in Asia. Some additional capacity can often be obtained by improved air traffic control techniques or technology, but badly needed extra runways are usually ruled out because of environmental restrictions or lack of green fields for expansion. New

¹⁸ Virgin Atlantic Airways franchised their brand to the Greek scheduled airline, SEEA, and the Irish carrier, Cityjet. These two independent airlines used the Virgin brand in conjunction with services they operated between London and Athens and Dublin respectively. In the first case, there was limited opportunity to feed traffic to Virgin Atlantic services, and, in the second case, none at all. SEEA services were taken over by Virgin upon the airline's demise, and the Cityjet arrangement has recently been terminated.

airports are sometimes possible (e.g. Hong Kong Chep Lap Kok or Munich), but these take considerable time and money to build.

Slots are allocated by a system of historical precedence or 'grandfather rights'. An airline that has used a slot in the previous season can use it again in the next corresponding season. Since airlines need both take-off slots at the origin airport and landing slots at the destination airport to be able to offer a viable service, this procedure needs to be co-ordinated internationally. This has historically been done through the airline trade association, IATA.

It is generally thought that it is the airports or government, rather than airlines that own slots. US legislation denies the existence of any right of ownership of slots, but the Federal Aviation Administration (FAA) does allow airlines to exchange, sell or lease the slots that it has allocated to them (Haanappel, 1994). In the US the sale or lease of slots to another airline needs to be accompanied by access to gates and passenger handling facilities that are usually owned or controlled by the vendor or lessor.

In Europe and other parts of the world, slots can be exchanged but not bought or sold. Unofficially, however, trading does take place, although not on a large scale. Legalised slot trading has recently been suggested by British Airways as a solution to the demands for increased access to Heathrow Airport by US carriers, in return for their approval of the proposed BA/American Airlines alliance.

4.2.3 Valuation methods

The value of an airline's intangible assets and goodwill could be inferred from a comparison of its total market capitalisation and the market value of its net tangible assets. The value of the traffic rights would then need to be separated from the other items of goodwill or intangible assets. For this method of valuation, the airline would also have to be quoted on a stock market, and a market price would have to be found for all tangible fixed assets. However, the market capitalisation of an airline that did not have a share price quotation could be estimated by applying the price-earnings ratio of a comparable airline that was quoted.

A discounted cash flow approach could also be used, given that the purchase of traffic rights could be seen as an investment that produced a stream of net benefits over its useful life (in the same way as for an aircraft). The present value of the net benefit stream, discounted at an appropriate rate, would then be the value of the traffic rights (Key, 1989). This approach is difficult to apply in practice, principally because:

- The useful life would be difficult to estimate, but judging by the accounting treatment of such rights would probably be over a long period
- Future revenues and costs would be impossible to forecast with any precision over a relatively long period principally due to uncertainties relating to the future economic regulation of the industry and the economic environment
- Re-investment requirements would need to be considered, and possibly the terminal value of the assets

A final method of valuing traffic rights is to analyse them as a function of one or more causal variables, and calibrating the resulting model against actual prices paid by airlines for route rights.

The valuation of slots has received recent attention as a result of proposals in Europe for the introduction of slot trading (see above). The implications of such a change for BA's balance sheet and return on capital were explored by equity research analysts using two methods of slot valuation.¹⁹ They suggested one approach based on previous slot trades by US carriers and the other on the treatment of landing and en route charges as operating leases, and calculating their discounted present value (over an unspecified number of future years at a 9% discount rate). Under the first method, they valued BA's Heathrow and Gatwick slots at around £1 billion, and under the second method at £710 million. The first method was based on an average price per slot of £4,200 (£5,000 at Heathrow and £2,500 at Gatwick), compared to their estimated slot prices of £10,200 and £17,200 paid by United and American respectively. The US airline prices probably included around 50% of the total of 11,000 annual slots in the peak period, but was also based on some fairly crude assumptions on the part of the total consideration paid that was attributable to the slots at the US end of the routes. No value appeared to have been assigned to the route authority as a separate asset from the slots.

For the purpose of attributing value to intangible capital which might be included in a productivity measure, it is not necessary to distinguish between route rights, goodwill etc. The approach also needs to be practical. This suggests the first approach described above, namely the market value of equity versus market value of financial and tangible assets.

Book value of equity = Book value of net assets (total assets less outside liabilities)

¹⁹ British Airways: selling slot(s), HSBC James Capel, November 1996, pp. 31-33.

Market value of equity = Market value of net assets (market value of total assets less outside liabilities)

In the second equation, book values would have to be used as approximations for ground properties, vehicles and equipment, current assets, current liabilities and non-quoted long-term debt. The market value of intangibles would then be:

Equity market value - market value of fixed assets - book value of net current assets
+ market/book value of long-term debt

This value would then approximate to all the different items of intangible capital discussed above. It is likely that it would fluctuate considerably over time. Announcements such as that of the breakdown of US-UK bilateral talks had a marked and immediate impact on the British Airways share price and thus market capitalisation. Given that the value of the other items in the above equation could not have changed by such a large amount, the intangible balancing item would reflect most of the change. In the particular case mentioned, the fall in market value of BA's equity and thus intangible capital value would have been a complex cocktail of:

- A fall in the value of the combined BA/AA brand, or a removal of the net present value of likely future alliance net revenues accruing to BA
- A re-inclusion of a number of BA Heathrow slot values into the equation

In evaluating capital inputs for use in productivity ratios, the question of time period would then arise. Assuming that productivity would be measured for a particular year, then intangible capital inputs would need to be estimated for the same period. Since equity market value changes on a daily basis, some average would have to be taken over the year, and this would have to be an average of the four end-of-quarter dates corresponding to the published balance sheet information.

In conclusion, the value and price of intangible assets present considerably greater complexity than for tangible assets. Their value can diminish unexpectedly through open skies agreements and the expansion of airport capacity. Unlike the ownership or even short-term rental of aircraft and other tangible assets, there are no defined contracts of this nature for intangibles. Few are placed on the balance sheet, and thus data which could be the basis for measures would be scarce. For these reasons, while it is recognised that they are a valid input to the production process, they will not be included in the analysis in later chapters of this thesis.

5 Measurement of airline capital inputs

5.1 Capital stock

It is important for the analysis of airline productivity to address the issue of measurement. This is because of the problems of definition discussed in Section 4, and also because it is not obvious what should be included under capital. Capital stock can be measured gross or net: the former involves recording the values of all assets used by an enterprise *before* an allowance for capital consumption or depreciation, and the latter after deducting such an allowance.

Gross assets are normally reported by airlines in their annual report and accounts, but these are the sum of various assets acquired in past years valued at their historical costs. This is useful for accounting purposes, but it is difficult to convert them to either constant prices (express them at price levels of a given year), or current prices (convert them to the prevailing prices in each year).

Net assets, after depreciation, are also shown in airline financial statements. These are based on financial depreciation policies that vary both between airlines and also over time for the same airline. This will be discussed in Section 5.2.1 below.

5.1.1 *Estimation of capital stock using PIM*

The Perpetual Inventory Method (PIM) is a common way of estimating gross capital stock in a form that can easily be converted to either current or constant prices. The alternative is to survey the firm being evaluated to obtain the acquisition date of each asset and its acquisition value at that date. This value would then need to be converted into current or constant prices using the appropriate price index, although this is also problematical as will be seen in Section 5.5 below.

There are two ways of applying PIM: one by estimating the gross capital stock directly, and the other via age-efficiency profiles. Both these are used by various countries in arriving at capital consumption for national accounts (OECD, 2001a), and they are equally applicable to economic analysis at the firm level.

The standard application of PIM starts with a baseline estimate of the capital stock and then adds capital investments in each subsequent year. Retirements are also subtracted from the total at the end of their service lives or through sale or damage. The baseline assets are at historical prices, rather than current or constant prices, but

the new investments can be adjusted to common price levels using the asset price indices. These are discussed more fully in Section 5.5. There is a problem with valuing stock formation through the acquisition of used aircraft, since they will not be valued at ‘new asset’ prices, which is a pre-requisite of the PIM method (since service lives will be applied as for new aircraft). In national accounts, this problem disappears, since one firm’s under-reporting is cancelled out by another’s over-reporting. In productivity studies, an adjustment would need to be made to bring the value up to a new *equivalent* asset, or a lower service life used which is commensurate with a used asset of this vintage.

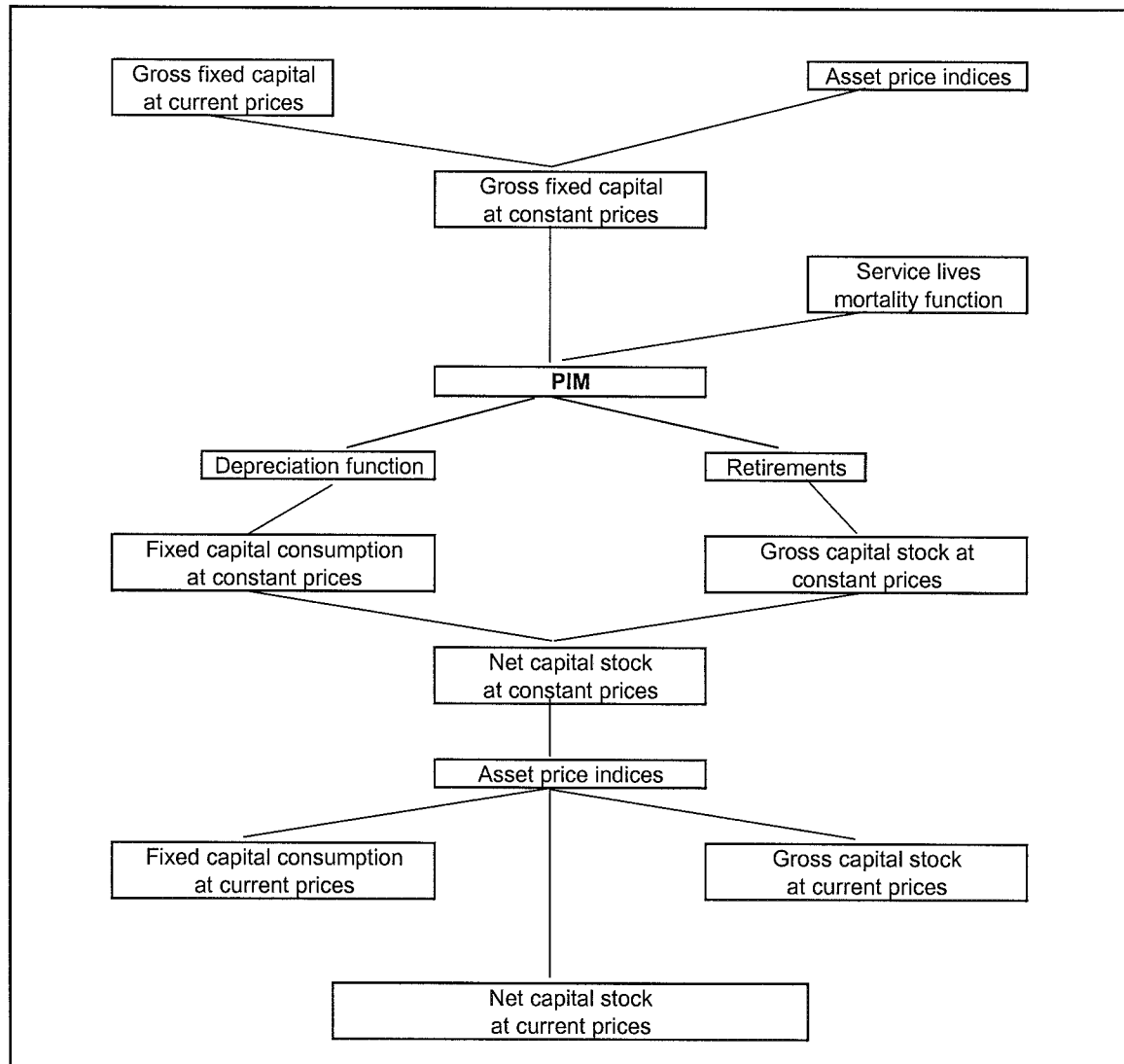
It is also necessary to estimate average service lives of assets, and the distribution of actual asset retirements around that average (mortality functions). This will be addressed in Section 5.3 below. The initial baseline assets will also have to be converted to ‘new’ prices. Balance sheet depreciated values can be adjusted to ‘new’ prices by examining differences between used aircraft and equivalent new aircraft prices. Any errors in this adjustment will disappear over time, as the baseline assets are retired.

This PIM estimation procedure is shown in the top half of Figure 5.1, which also shows how capital consumption is calculated.

The alternative to the PIM method to estimating capital stock uses ‘age-efficiency’ profiles for each asset and uses these to arrive at the age-price profile and thus the market value of the asset at constant prices.

The degree to which the efficiency of a hypothetical asset declines is shown in the second column of Table 5.1. After eight years, the asset will be less efficient in terms of the volume of services that it can deliver. The way this declines is shown in the table to be linear, but other types of decay are possible, such as geometric and hyperbolic. It is possible that no decline would be evident. The price is then the rental per unit of capital services in constant prices. The product of the two is then the rental that can be commanded by the asset in each year (age-efficiency profile).

Figure 5.1: Application of the PIM in Practice



Source: OECD (2001a), p.56

The asset value is then the discounted present value of this future stream of rentals, and this is shown in column five of Table 5.1, discounted at 5%.

Thus a new asset acquired at the beginning of year 1, and with a service life of 8 years, would have an asset present value of 43.7 monetary units, based on the constant price rental and the linear decline in its efficiency. Assets acquired in various years can then be converted to standard efficiency units by first multiplying their cost by their age-efficiency coefficient (column 4 in Table 5.1), and then by their age-price coefficient (or asset market price in the same year).

Table 5.1: Relationship between rentals and asset value

Year (t)	Capital		Rental (A*B)	Value of discounted rentals*							
	Service (A)	Price (B)		1	2	3	4	5	6	7	8
1	5.0	2.0	10.0	9.5							
2	4.5	2.0	9.0	8.2	8.6						
3	4.0	2.0	8.0	6.9	7.3	7.6					
4	3.5	2.0	7.0	5.9	6.0	6.3	6.7				
5	3.0	2.0	6.0	4.7	4.9	5.2	5.4	5.7			
6	2.5	2.0	5.0	3.7	3.9	4.1	4.3	4.5	4.8		
7	2.0	2.0	4.0	2.8	3.0	3.1	3.3	3.5	3.6	3.8	
8	1.5	2.0	3.0	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.9
Asset value PV				43.7	35.8	28.5	22.1	16.2	11.0	6.5	2.9

* at beginning of year (discounted at 5%)

Source: OECD (2001)

This method of estimation is recommended for productivity studies, since its approach is consistent with the consumption of fixed capital, using as it does efficiency units and a volume index of capital services (OECD, 2001, p.59).

The problem with applying this to aircraft is the difficulty in estimating their age-efficiency coefficient (decline in capital service). This would need to take into account the deterioration in the efficiency with which it uses inputs (especially fuel and maintenance labour) compared to a new model of the same type, as well as its overall reliability, and the number of times flights are cancelled or delayed (as a direct result of the aircraft ageing process). Price is also difficult to estimate for a given aircraft type, and both these problems will be discussed more fully in the remainder of this chapter.

5.1.2 Categories of stock of capital assets

Assets are usually split into three categories for accounting purposes: fleet related, buildings and structures (property), and equipment and vehicles. Fleet is divided into:

- Original aircraft (airframe and equipped engines)
- Spare engines
- Modifications to aircraft
- Rotable assets (parts normally maintained and re-used)
- Repairables (parts which can be repaired and re-used only a limited number of times)

Consumables, which are very short life items, are generally not considered as fixed assets, and thus included under 'current assets'. As mentioned earlier, these would be included with material (non-capital) inputs.

Buildings and structures include maintenance hangars, office buildings and furniture, fixtures and fittings for the administration, marketing and sales (including those needed abroad) and other departments. Equipment includes maintenance equipment, flight simulators, computer and communications hardware. Vehicles cover airside handling vehicles, as well as cargo trucks, buses and company cars.

Intangible assets were in the past written off by BA against reserves, so it was impossible to measure using balance sheet values. More recently BA purchased slots from other airlines, which from the 1998/99 accounts were put first under 'fixed assets – property' and from 2001/02 were moved to 'intangible assets', where they were combined with goodwill from the acquisition of other companies. BA amortise intangibles over periods of up to 20 years. US airlines, on the other hand, have always been allowed to account for intangibles as balance sheet assets, and write them off over periods of up to 40 years. This class of assets will not be included in the subsequent analyses, for the reasons given in the previous chapter.

5.2 Capital depreciation

Depreciation is the deterioration in value of a capital asset, as it is used or operated over its life. Two different concepts should be addressed here: accounting depreciation, which is required for bookkeeping and the preparation of financial statements (and the related tax depreciation, which may or may not be identical to accounting treatment), and economic depreciation, which is used in productivity studies. Both should be distinguished from asset deterioration or decay, since they are concerned with prices or values, and the decay is concerned with quantities (Hulten and Wykoff, 1996). It is however important to examine accounting depreciation first, since the data upon which it is based is often the starting point for measurement of economic depreciation.

5.2.1 Accounting depreciation

In accounting terms, it can be seen as the spreading of the historical cost of the asset over its useful life, often excluding a residual or scrap value that the asset would have at the end of this life. Thus the asset is used up over its life, but there is no notion of

replacement involved.²⁰ Current year's profits are reduced by the amount the assets have been 'used up' or 'depreciated', and the asset value on the balance sheet is reduced by the same amount.

An alternative way of looking at depreciation is the need to reduce the value of the asset on the balance sheet because of wear and tear and economic obsolescence. But there is normally no attempt to estimate its replacement or market value, although airlines sometimes provided for accelerated depreciation for some aircraft types (eg BA with their Lockheed Tristars), or to revalue certain aircraft based on market valuations. However, in Canada, Germany, Japan, Spain, Switzerland and the USA, revaluations were prohibited (Milne, 1994).

Airlines that depreciate their assets over an unrealistically short life are reducing near term profits and increasing profits in later years when the assets are fully depreciated.

Equal, declining or increasing absolute amounts of depreciation can be provided for in each year. Equalised or straight line is the most common method of depreciation. Alternatives are the progressive or regressive methods, and depreciation according to the number of hours or cycles (take-offs and landings) of aircraft usage. The regressive (or declining balance) approach is similar to that taken by some tax authorities in calculating capital allowances, whereby a given percentage is applied to the depreciated value (this was used by Japan Airlines, SAS and Air France). This would result in a net book value that corresponds more closely to actual aircraft values, particularly in the early years of its life. However, it produces higher charges, and lower profits, in the earlier years of aircraft operation, whereas management may prefer the reverse (Morrell, 2002, p.33). All Nippon Airways uses a method called 'sum of years' digits (Milne, 1994, p.55). This results in faster depreciation in earlier years than straight-line depreciation, but not as fast as with the declining balance method.

IATA accounting guidelines recommend straight-line depreciation '*in most circumstances*', but acknowledge that '*there is merit in the viewpoint that there is some correlation between the frequency of take-off and landing and the rate of depreciation.*' It thus also supports the use of a cycles method of depreciation (IATA/KPMG, 1996a).

²⁰ The interpretation of accounting depreciation as involving the replacement of assets or a sinking fund to replace assets at the end of their useful life is not strictly correct.

Fixed, tangible assets are normally depreciated, with the exception of land. Financial assets are usually stated at cost, with no provision for depreciation or loss of value, or market value.

In many countries, a separate set of accounts is prepared for tax purposes, using capital allowances that are required to be used for arriving at taxable profits. Depreciation allowances, on the other hand, are determined by the company's directors, taking into account any national accounting standards or guidelines.

The most recent International Accounting Standard relating to depreciation is IAS 16 and is reproduced as Appendix C. It refers to an asset's useful life and residual value, without specifying what they should be or how they should be determined. It also allows for frequent re-valuation to what would be a 'fair' value.

It should be noted that, for airlines in some countries such as Switzerland and Korea, extra or supplementary depreciation is charged in good years, but only normal depreciation in years when losses are reported. This is driven by tax considerations, and results in a distortion of profitability over time or comparisons with other airlines.

British Airways reported the following accounting policy on fleet depreciation in 2002 (British Airways, 2002):

Fleet assets owned, or held on finance leases or hire purchase arrangements, are depreciated at rates calculated to write down the cost or valuation to the estimated residual value at the end of their operational lives. Cabin interior modifications, including those required for brand changes and re-launches, are depreciated over the lower of 5 years and the remaining life of the aircraft. Residual values and operational lives are reviewed annually.

The cost on which BA's depreciation is based is the historical cost, net of manufacturers' credits, with the exception a small number of aircraft valued at 31 March 1988.

British Airways does not publish operational lives of their fleet, nor residual values, but it does show the effective annual depreciation rates in its annual report and accounts. This is the annual provision for depreciation expressed as a percentage of the aircraft's historical cost.

Table 5.2: BA Depreciation rate by aircraft type

	1995/96	2001/02
B747-200 and B747-400	4.2%	3.7%
B777	5.0%	3.7%
B767-300	5.0%	4.6%
A320, B737-400	5.5%	4.9%
Regional jets	5.5%	4.5%

Source: British Airways' Annual Reports

A depreciation rate of 4.2% would equate to an operational life of around 24 years and a zero residual value, or 20 years to 15%. The Boeing 747s rate for the latest financial year would equate to 25 years and a residual value of 7.5% of first cost. From the above table, it can be seen that the shorter the haul of aircraft, the shorter the life and/or lower the residual value. Such aircraft types are subject to more wear and tear, and might be expected to be depreciated quicker, although many aircraft parts or components that are affected in this way would be expected to be replaced at least once over the service life of the aircraft.

It is also clear from the above table that BA has reduced its depreciation rates over the five years to 2001/02, with operational lives increased, residual values increased, or a combination of the two.

Table 5.3 shows the rates of depreciation for various aircraft types in 1992 by region. In general, Asian airlines wrote all their aircraft down fastest, followed by the European and then North America with the longest lives and/or lowest residual values.

Table 5.3: Aircraft annual depreciation charge (% of cost per year)

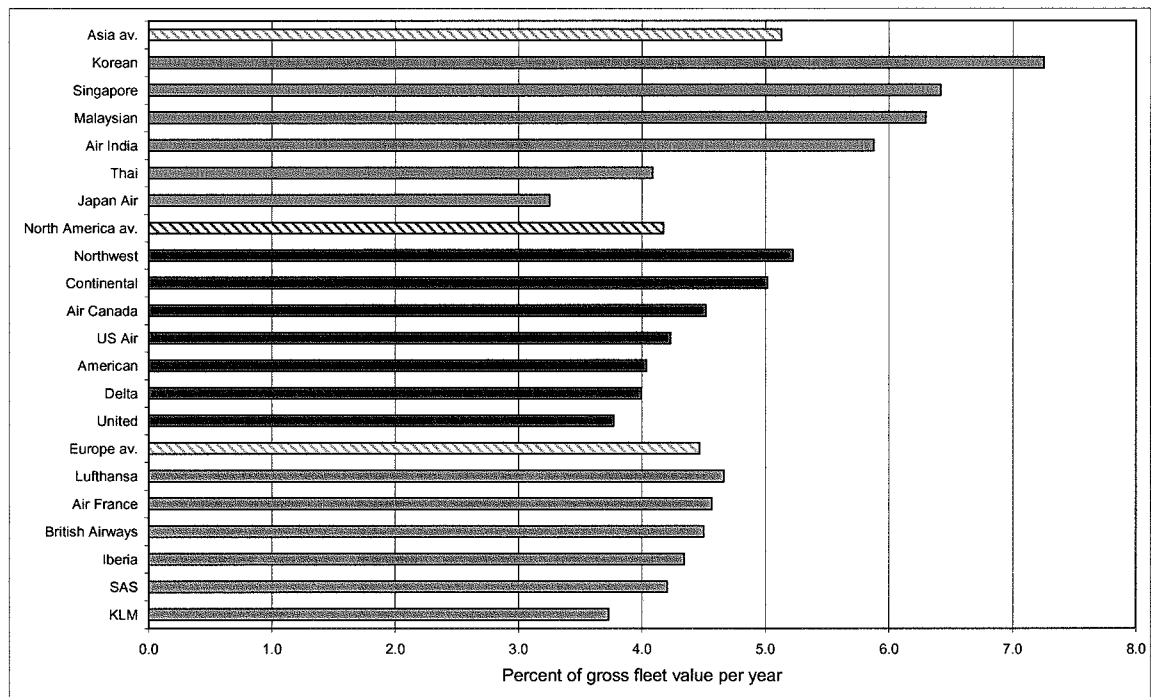
	B747	B767	B737	A300	A310/320
Highest airline	8.0%	6.0%	9.0%	5.9%	8.0%
Asia average	6.8%	n/a	8.2%	6.5%	7.0%
Europe average	5.1%	5.4%	5.6%	5.6%	6.3%
North America average	4.2%	4.5%	4.2%	4.8%	4.2%
Lowest airline	3.5%	3.5%	4.0%	4.8%	4.2%

Source: IATA/KPMG, 1992

A later IATA/KPMG survey found little change in rates of depreciation, with the range for the B747 remaining between 3% and 8% (IATA/KPMG, 1996a).

Most recent data shown in Figure 5.2 suggests that the European airlines may have lengthened fleet service lives, and are now closer to North American practice. Asian airlines still use faster rates of depreciation, but may have reduced their rates from the early 1990s.

Figure 5.2: Fleet depreciation rates: major airlines by region, 2000/01



Source: ICAO and Annual Report (Air France)

Three examples of major airlines reducing their depreciation rates were Lufthansa in 1992, Japan Airline in 1993 and Singapore Airlines in 2002. These major changes took place in a very poor year for profits, but all three airlines used atypically short lives prior to the change.

Lufthansa provide the first example of the effect on operating profit of a change in depreciation policy: in 1992 the airline changed its policy from depreciating its aircraft over 10 years to a residual value of 5%, to one of 12 years to 15%. This would have reduced the charge on a US\$140 million B747 from \$13.3 million to \$9.9 million. The overall effect of the change was to increase Lufthansa's 1992 group profits by DM 392 million (US\$250 million).²¹

²¹ Lufthansa Annual Report and Accounts, 1995.

Japan Airlines reduced their depreciation charge in April 1993 by Y17,842 million (approximately US\$160 million), thus reducing their operating loss for 1993/94 to Y29,627 million; this they did by increasing the useful lives of all aircraft except B747-400s from 10 years to 15 years (international) and 13 years (domestic).²²

Most recently, Singapore Airlines changed its depreciation rate for passenger aircraft in August 2001 from 10 years to 20% residual value to 15 years to 10% residual value. This brings it closer to industry practice, the rate of depreciation falling from 8% to 6%, although it is still higher than most European and North American airlines. The change improved the profit of the airline by S\$265 million, in a year when they were scarcely above break-even.²³

5.2.2 Economic depreciation

Economic depreciation measures the difference between gross capital stock of assets and the net capital stock, both the latter and the former being the valued at market prices. This difference is the ‘consumption’ of capital that has taken place since the asset was acquired, or the economic depreciation. The market price is then the replacement cost of an identical asset, which takes into account efficiency deterioration, obsolescence and the other factors referred to in Section 5.3. The price or value at any point in time should amount to the present value of the future profits, net revenues or rentals that the aircraft or other assets can earn over the remainder of its service life. Thus older assets will have a shorter life over which to earn such returns, regardless of whether its technical condition has deteriorated and reduced its ability to earn net revenues.

Economic depreciation differs from accounting depreciation in using objective market criteria on such variables as obsolescence and useful life, rather than subjective policies of directors or accounting guidelines. Applications of this are described in Section 5.2.1. The practical problems of applying these criteria are discussed in the following sections.

5.3 Aircraft useful life

A key problem concerns the length of useful or economic life of the capital equipment. Useful life is often defined as the period over which the asset is expected

²² Japan Airlines Annual Report, 1995-1996.

²³ Singapore Airlines Annual Report, 2001/02.

to be operated by an airline, and the economic life is the total service life of the asset. The latter is often defined in physical terms, for example number of flying hours or number of take-offs and landings (flight cycles). This could then be approximated to numbers of years, given typical usage. However, the appropriate life here is the economic life, which will also depend on such factors such as:

- The availability of more competitive aircraft of the same characteristics
- Labour costs and new aircraft prices
- Mandatory modifications
- Maintenance costs
- Fuel prices

It is impossible to predict how these factors will influence future aircraft economic lives. Hulten and Wykoff (1981) found no evidence of the early scrapping of industrial equipment as a result of higher energy prices, but airlines react to this by utilising fuel-inefficient aircraft less. The timing of economic cycles will also be important, a major downturn leading to a sharply reduced demand for aircraft. In this situation, airlines either retire old aircraft early, or defer the introduction of, or ground, newer types. The starting point to arrive at aircraft lives is to examine past behaviour.

Aircraft remain by far the largest group of investments for airlines and it is thus relevant to examine their useful or economic life. Other assets will be addressed later.

Aircraft investments generally comprise the airframe, engines and other installed equipment, as well as associated spare parts. The latter can be further subdivided into spares and rotables. The useful life of these assets is clearly an average of a broad range of lives of individual parts. At one extreme is the airframe or structure. This is critical, but experience has shown that it can be extended considerably, although sometimes only with expensive modifications.

British Airways' first B747, the B747-136 model, was retired after 102,570 flight hours and 22,161 landings. This was acquired in May 1970, and left the fleet in 1998, after 28 years. Thus, this aircraft was well beyond its expected service life, and even its fatigue test life, according to the Boeing estimates in Table 5.4, but it probably averaged considerably fewer cycles per year than the 2,000 used by Boeing for long-haul types. BA recorded an average of only 374 cycles per B747-200 aircraft (a type used on similar sectors to the B747-100) in 2001 (CAA, 2002). Applying this figure to the Boeing flight cycle service life cycles would result in a service life of over 50 years!

Table 5.4: Aircraft life estimates

Aircraft	Service Life (flight cycles)	Equivalent years*	Fatigue Test (flight cycles)	Equivalent years*
B707	20,000	10.0	50,000	25.0
B727	60,000	15.0	170,000	42.5
B737	75,000	18.8	150,000	37.5
B747	20,000	10.0	40,000	20.0
B757	50,000	12.5	100,000	25.0
B767	50,000	16.7	100,000	33.0
B777	44,000	22.0	60,000	30.0

* assuming 2,000 cycles per year for a long-haul type and 4,000 cycles for a short/medium-haul type

Source: Boeing Airliner April-June 1996

Boeing has also increased the structural life of two fuselage sections of the derivative B747-400 to 40,000 cycles (see Table 5.4) and 60,000 cycles respectively. This follows fatigue tests on those parts of the airframe, which had been considerably improved in design from the original B747-100. Boeing are confident that current production aircraft *'have significantly improved structural performance. They are more durable, damage tolerant, and corrosion resistant than the previous-generation airplanes'*.²⁴

Lives can be extended by re-engining, possibly to meet new noise regulations, and investments will in any case be required over the life of the aircraft in mandatory modifications or optional retrofits. The life of the BA B747-100 might also have been extended by conversion to freighter use, although such a conversion would not have been economic with that particular type, which was too noisy for night movements at many airports.

Both Airbus and Boeing make assumptions on aircraft service life and retirement for their annual global aircraft forecasts. Boeing's most recent published assumptions stated that they used information from airlines, and, where this information was not available:

Airplanes designed before 1980:	single-aisle	25 years
	Twin-aisle	28 years
Airplanes designed after 1980:	single-aisle	28 years
	Twin-aisle	31 years

²⁴ Boeing Airliner, April-June 1996.

They assumed a service life of 35 years or more for freighter aircraft.²⁵ The basis for assuming longer lives for widebodied jets is their longer haul operation and less stress and wear and tear because of a lower number of landings.

Airbus use various default ages for aircraft replacement from passenger service, depending on world region. Their world average was 24 years, with North America being 25 years, Western Europe 22 years and Asia/Pacific 20 years.²⁶

The UK Inland Revenue looked at all jet aircraft that were built between 1970 and 1972 and still in service after 25 years.²⁷ They found that, of those built in 1970, 70% were still in service 25 years later, and that for all B737s the percentage was 75% versus 72% for the B747. For the 1971 builds, the total percentage was the same, with B737s at 76% and B747s at 73%. For 1972 models, the total still in service had risen to 74%, the B737s had climbed to 91% and the B747s to 78%. These findings suggest that first the Boeing assumptions may be too low, and second there may not be empirical evidence for expecting a longer life for the widebodies. Unsuccessful aircraft programmes such as the HS Trident or the Mercure are exceptions to this, with the Inland Revenue finding no Tridents in service beyond 15-16 years.

The Intergovernmental Panel on Climate Change (IPCC) report on aviation suggested a typical time-history for a medium range commercial aircraft from technology development and testing through to final retirement. This gave a range of 25 to 35 years for the aircraft in-service lifetime.²⁸

Somewhat more conservative assumptions were used for a joint European Commission and European Civil Aviation Conference (ECAC) working group on global aircraft emissions: older Chapter 2 aircraft were retired after 15-25 years and newer Chapter 3 types between 20 and 30 years.²⁹

Asset service lives are needed for estimates of capital assets and consumption in national statistics. The Perpetual Inventory Method is based on the removal of assets

²⁵ Boeing, Current Market Outlook, 1998.

²⁶ Airbus Industrie, Global Market Forecast, 1998-2017.

²⁷ The author is grateful to Keith Wright of the Inland Revenue for providing this data, which was undertaken following the introduction of legislation in the UK in November 1996 that gave capital allowances of only 6% for assets with lives of over 25 years, as opposed to the 25% allowed for shorter life assets.

²⁸ Aviation and the Global Atmosphere, IPCC, Cambridge University Press, 1999, p.224.

²⁹ ANCAT/EC2, Global Aircraft Emissions Inventories for 1991/92 and 2015. ECAC/ANCAT and EC Working Group, 1998.

from gross asset stocks at the end of their lives, and much work has been done in certain countries on the lives of various types of asset. The following table summarises the estimates for aircraft that have been produced for these statistics (OECD, 2001a):

Table 5.5: Aircraft service lives estimated for National Statistics

	Life in years
Netherlands	25
USA Post 1960	20
USA Pre-1960	16
Singapore	15
Czech Republic	13

Source: OECD, 200, p.47

In addition the German Statistisches Bundesamt reported that the German Ministry of Finance was in regular contact with firms concerning changes in asset lives, and this source noted that a number of changes had been made, and '*with the exception of commercial aircraft, all are reductions*' (OECD, 2001a, p.46).

Table 5.6: Estimated useful lives for aircraft depreciation

	Life in years
B747	10 to 25
B767	15 to 22
B757	10 to 20
B737	5 to 20
A300	10 to 22
A310/320	10 to 22
MD 80/81	12 to 20

Source: IATA/KPMG, 1992

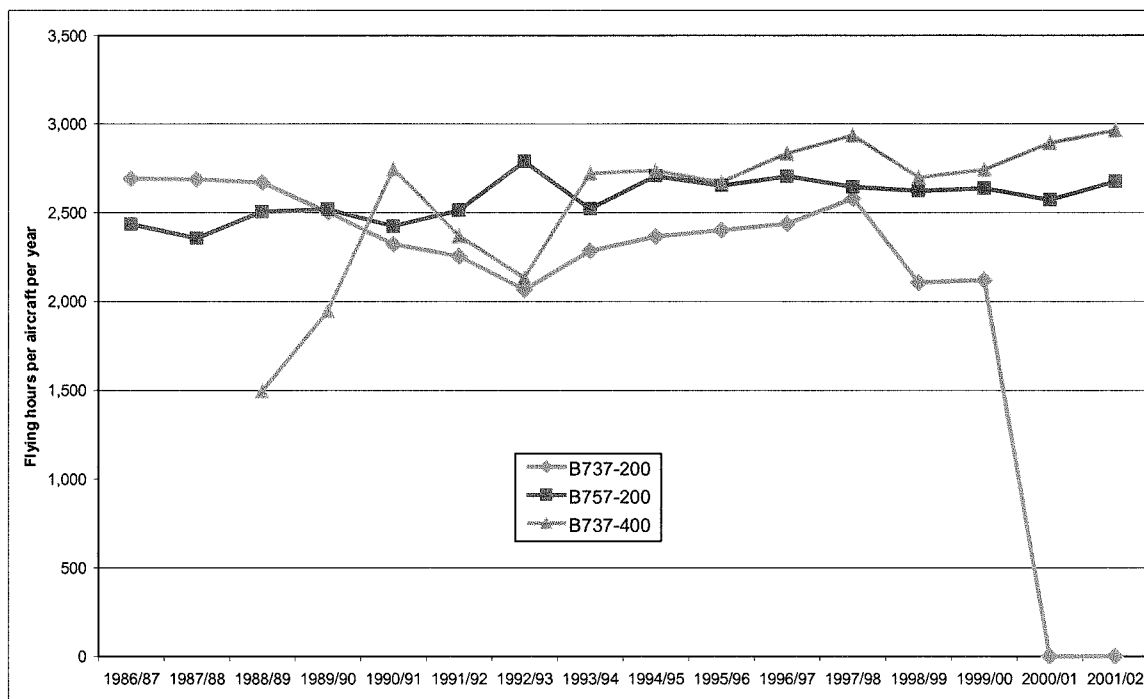
A survey of Chief Financial Officers from 25 major international airlines revealed a wide range of aircraft useful lives summarised for selected aircraft types in Table 5.6 (IATA/KPMG, 1992).

Those adopting shorter lives sometimes depreciated aircraft to quite high residual values (up to 40% of the original cost for many of the types shown in Table 5.6).

5.4 Aircraft age-efficiency profile

Once the aircraft's useful life has been established it is necessary to see how its usefulness declines from new to retirement. This could be because of a decline in output efficiency (output-decay), or a decline in input efficiency (input-decay). Both these are likely to take place in the latter part of the aircraft's life, but teething problems (involving mostly output-decay) may also be evident for new aircraft, experienced especially by lead operators of a new type.

Figure 5.3: Aircraft utilisation: BA's B737-200 and B757-200 aircraft



Source: BA Annual Reports

Figure 5.3 shows the number of flying hour BA generated from its B737-200, B737-400 and B757-200 fleets over their time in BA service. This utilisation will depend on the type of network the aircraft is operated on, since longer sectors tend to generate higher daily and annual utilisation. BA's B737-200s did suffer a decline in utilisation in the early 1990s both as a result of the post-Gulf War decline in traffic, and the addition of larger B737-400s for longer sectors, and retirement of the shorter-range BAC 1-11s. But their utilisation did not show any overall fall over the whole period to retirement, at which point the oldest models were just over 20 years old.

The Boeing 757s consistently achieved above 2,500 hours a year, despite the oldest in their fleet being almost 20 years old in 2002. Boeing referred to two stages of an aircraft's useful life: the first stage is 'lower utilisation in response to increasing maintenance downtime or increasing operating costs. The second stage is often the sale of an airplane to another operator who has different utilisation requirements' (Boeing, 2002, p.17).

BA are perhaps just approaching this first stage with their A320s, although this stage may now be deferred beyond 20 years with improved maintenance diagnostic techniques. Their B757s jumped to Boeing's second stage, with their sale to an integrated carrier (parcels operator, UPS), who need to operate the aircraft intensively overnight, but can ground them for much of the daytime, and thus do not need to operate them at such high utilisation.

Efficiency has been defined here as the ability of the aircraft to provide the services as scheduled, and the measure was annual flying hours or capacity offered. What this measure does not show is the possible decline in punctuality, as delays become more prevalent for technical reasons. This might lead to a decline in traffic, as passengers switch to competing services. The condition of the aircraft in terms of interior attractiveness might also do this, although the aircraft would have one or more interior re-fits over its service life. It would be difficult to argue that a 15-20 year old B737-200 would not produce the same loads and reliability as a new B737-500, which is of identical size and cabin volume. The reason for its consistent performance over time is the very high level of maintenance applied, as well as the initial engineering specification.

A new aircraft might technically be able to take-off with a higher payload than an old aircraft, but this is not taken into account in the government safety oversight and airworthiness programmes, which determine take-off weights and safety margins.

Input decay would certainly take place in the later part of an aircraft's life, and many of the reasons for this were discussed in Section 5.3 above. Maintenance costs would increase, principally from unscheduled component removals and repairs, and interiors would need refurbishment. Fuel consumption would also increase, but this could be partly corrected (at least for engine efficiency, but not for increased drag from the ageing airframe) at major overhaul intervals. However, neither form of input-decay is particularly conducive to measurement, although Boeing (1992, p.2.45) suggested that fuel burn would be up to 6% higher for older aircraft, while airframe maintenance costs would deteriorate by 1% for every 1,000 flight hours.

5.5 Aircraft price and market value

5.5.1 Aircraft price

New aircraft prices are quoted according to their list price, which may or may not be increased in line with inflation from year to year, with discounts on the list price for offers to particular customers. New aircraft prices will be discussed first, before moving to used aircraft values in the following section.

Aircraft are manufactured and marketed as basic models, with a number of variants offered where necessary. The most common of these is engine choice (accounting for 20-25% of the total aircraft cost), especially on the larger long-haul aircraft. Examples of this for the main aircraft that British Airways has purchased are shown in Table 5.7.

Table 5.7: British Airways' jet fleet and engine choice

Airframe	Engine choice*
B747-200B	Rolls-Royce RB211-524D Pratt & Whitney JT9D7Q/70A General Electric CF6-50E
B747-400	Rolls-Royce RB211-524H/G/HT General Electric CF6-80C Pratt & Whitney PW4056
B777-200ER	Rolls-Royce Trent 884/892/895 General Electric GE90 Pratt & Whitney PW4084
B767-300	Rolls-Royce RB211-524H/H3 General Electric CF6-80A2 Pratt & Whitney PW4060
B757-200	Rolls-Royce RB211-535C and -535E4 Pratt & Whitney PW2037
B737-400	CFMI CFM56-3C1
B737-200A	Pratt & Whitney JT8D-15A

* British Airways selections in bold

Most of the aircraft types in Table 5.7 have been ordered with each engine type by a number of different airlines, such that the second-hand market is reasonable good for

all of them.³⁰ Boeing have sold a total of 258 of the above B777-200ER with the following engine variants:

53 aircraft with P&W 4084 engines

21 with GE90-85Bs

69 with GE90-90Bs

7 with GE90-94Bs

17 with RR Trent 884s

81 with RR Trent 892s

10 with RR Trent 895s

If all B777 models are included (B777-200ER and the less popular B777-200A and B777-300), then 14 different airframe/engine combinations have been sold. A small number of aircraft have also opted for a large aft cargo door, and an overhead crew rest area is also under consideration. Two further airframe models are expected soon: the B777-300ER at the end of 2002, and the B777-200LR in 2004. *This alone would present significant problems for selection of the most appropriate market value or lease cost from published data, leaving aside the age of the aircraft.*

However, some engines have had limited market penetration on certain airframes. A notable example was the DC-10, which was sold to all airline customers except one with General Electric engines (DC10-30). The exception was Japan Airlines, which ordered the DC10 with Pratt & Whitney engines (DC10-40), which resulted in aircraft that had considerably less value in the used aircraft market.

A key driver of used market value is thus the number of other airlines that already operate the specific airframe/engine combination.

The basic aircraft of standard specification, equipped with certain items listed in the Master Minimum Equipment List (MMEL), will need to obtain a certificate of airworthiness. The airline can opt for some items to be installed by the manufacturer, which are not standard, and these are part of Seller Furnished Equipment (SFE), which will be incorporated into the purchase agreement (Clark, 2001). These could be expensive, and, in addition to engines (discussed above), include:

- Air conditioning units
- Autoflight systems

³⁰ The exception is the Rolls-Royce powered B767-300, which has only been sold in significant numbers to BA.

- Fuel systems
- Electrical systems
- Hydraulic systems
- Auxiliary Power Units (APUs)
- Brakes

Installed avionics will typically account for 3.5% of the total aircraft cost (Charles and Ghobrial, 1995, p.605). Other equipment may be purchased by the airline, and installed by the manufacturer (Buyer Furnished Equipment or BFE). This will include galleys, communications and navigation equipment, seats and in-flight entertainment systems.

Aircraft operating lessors such as GE Capital Aviation Services (Gecas) and ILFC will try to specify both SFE and BFE items that are likely to be attractive to most of their potential airline customers. However, some airlines might still require different items to be installed although this is likely to be costly, and only justified for longer lease periods. Gecas generally offers only GE engines, since it is a wholly owned subsidiary of GE, but ILFC offers all the engine types available on all its fleet except B747s, where it does not use Pratt & Whitney engines.

The prices of new aircraft are generally linked in some way to a 'list price'. Discounts are applied according to the status of the potential buyer, and these depend principally on:

- The size of the order
- The degree of competition for the order
- The wish to secure a new customer, which has potential for a considerable number of future orders, or is considered strategic
- The wish to launch a new aircraft programme
- The need for orders to keep production lines open

Discounts can range from 20-45%,³¹ depending on the size of order and other factors listed above. United Airlines paid US\$89 million for an initial batch of B777-200 aircraft introduced in 1995, compared to the list price at the time, which ranged from \$122-138 million, depending on specifications. Taking the mid-point of this range would give a discount of 32%, both because of order size and the fact that United was one of the launch customers.

³¹ Jim Poore, AirFinance Journal, January 1996, p.22.

Competition is fierce between Airbus and Boeing for some orders, where their respective aircraft specifications are quite close. This has occurred in the past with the B767 versus A310, and more recently with the B777 and A330.

For example, in early 2002 when the industry was weakened by 11 September and there was considerable excess supply of aircraft and capacity, Boeing were offering substantial discounts of up to 35% on the list price of their B747-400 (US\$195.0 million). This would also be due to the expected future competition from the Airbus A380. Customers placing large orders would get higher discounts, and new customers to a particular manufacturer or type of aircraft might also get special inducements. An example of the latter was Pakistan International's discount of 38% on eight new B777s.³²

Air NZ almost certainly got a large discount on an order for 35 A320s from Airbus, both because of a new customer for the manufacturer and competition with Boeing, who complained that they were unable to drop their price any further.³³

Boeing publishes their list prices on their web site, and the trend over the past five years for BA's main types is shown in Table 5.8.

Table 5.8: Boeing list price trends for selected BA aircraft

	B737-400/800*	B757-200	B777-300	B747-400
1997	45.0	64.5	160.0	165.0
1998	45.0	65.5	162.3	167.5
1999	47.8	69.3	172.5	177.3
2000	56.5	73.5	180.0	184.5
2001	60.8	76.5	190.3	197.0
2002	61.0	77.0	191.0	198.0

* B737-800 from 2000; Source: Boeing Commercial Airplane web site

The differential between list prices and negotiated prices is thought to have increased significantly over the past 10 years, with the list price now increased according to the escalation formula that accounts for labour and material cost rises.³⁴ However, this may not be strictly true if the above recent list price increases are compared with the formula, which is described below.

³² Commercial Aviation Value Report, September 2002, p.8.

³³ Orient Aviation, September 2002, p.29.

³⁴ Aircraft Value News, 12 April 1999.

The US Department of Labor's Bureau of Labor Statistics reports monthly changes in prices of aircraft and aero-engines. Its methodology is described in the BLS Handbook of Methods, where it describes the general basis for the price indices of industrial products, which include aircraft and engines.

The aircraft price index is computed from information voluntarily reported by US manufacturers. It tries to take into account discounts, and any other rebates or sales techniques that *'affect the net proceeds ultimately realized by the producer'*. Aircraft model changes are addressed by comparing overlapping series, and it also tries to take into account changes in the capability of similar products. For example, in Table 5.10 above, the improved capability of the B737-800 over the aircraft it replaced (B737-400) should be taken into account by obtaining price estimates for the changed aircraft features. How far this last point is actually incorporated in the index is debatable.

Avitas reported that BLS has made numerous attempts to account for quality changes and government-mandated safety equipment installation. They added that *'people still doubt the ability of BLS to accurately incorporate quality adjustments, especially in "high-tech" industries'*.³⁵

One study did address aircraft quality changes by examining revenue generating capabilities of aircraft. This was based on data for 1970-80, and the aircraft price index adjusted for quality changes was on average 91% of the official BLS price index for identical models. The study did not, however, take into account mandatory safety features (Gordon, 1990).

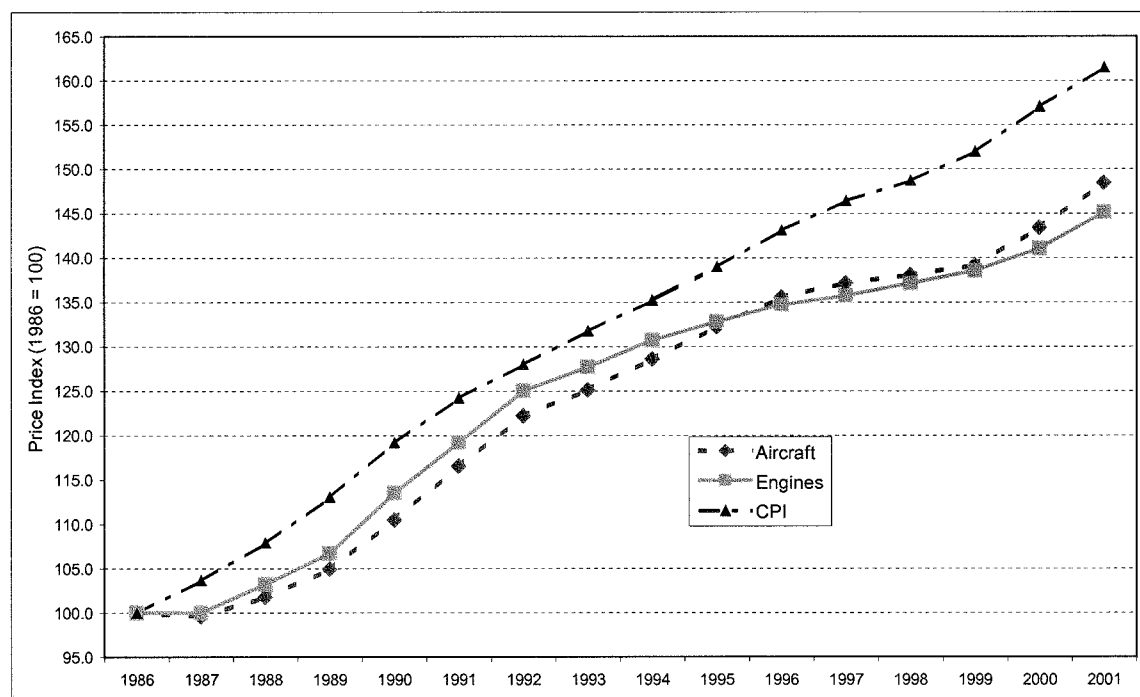
Figure 5.4 shows the two BLS price indices of relevance to this thesis, namely that for US built aircraft, and that for aero-engines, both compared to the US Consumer Price Index (CPI). As mentioned above, the flattening out in the first half of the 1990s was due mainly to a slowing down in materials and labour inflation. However, in the second half of the 1990s, Boeing were also replacing earlier B737 'classics' with improved B737-600/700/800s and the increases in prices in this period may have also reflect some aircraft quality improvements not adjusted for by BLS.

It can be seen in Figure 5.4 that the prices of both aircraft and their engines declined in real terms over the period, especially in the period 1995 to 1999.

³⁵ Avitas: 1998 global outlook for air transportation

During this period, Boeing introduced various ‘lean manufacturing’ initiatives, which also resulted in the speeding up of their production lines. This would enable them to reduce costs, and thus prices, due to the fact that less capital would be tied up over the production cycle. At the same time, competition with Airbus also intensified, against a background of some over-capacity in the marketplace. The steeper rise since 1999 reflects the disappearance of any excess supply, with the 2001 downturn in demand not yet reflected in aircraft availability.

Figure 5.4: BLS Price Indices of US built aircraft and engines



Source: US Department of Labor, Bureau of Labor Statistics web site

Price data for Airbus aircraft data was not available, but it is likely that they matched or even undercut Boeing on most deals. In fact, Boeing’s exclusive supplier deals with Delta and American Airlines created a pricing floor below which Boeing could not go. If Airbus could obtain this information (which they probably could), they could then easily undercut Boeing where they were particularly keen to penetrate markets, giving them a distinct advantage.

Avitas looked at US inflation and aircraft prices between 1987 and 1997, and concluded that aircraft prices were more volatile, but that over the whole period they

moved broadly in line. They go on to suggest that in the future aircraft prices should increase more slowly than the CPI, mainly because of more intense competition between Airbus and Boeing.³⁶ This is confirmed over the period examined in Figure 5.4 above. CPI is thus not a good proxy for the prices of US commercial jet aircraft.

While actual and list prices have diverged over the years, it is still interesting to see how list price increases have slowed to less than 1% in 2002, following the slump in traffic and excess supply of aircraft. Table 5.9 also compares list price changes with both the BLS aircraft index (see above), and a composite index used for price escalation clauses in contracts between aircraft manufacturers and airlines.

Table 5.9: Boeing list price trends: % changes vs price indices

	B737-400 /800*	B757-200	B777-300	B747-400	BLS Aircraft ¹	Composite ²
1998	0.0	1.6	1.4	1.5	0.6	-0.4
1999	6.1	5.7	6.3	5.8	0.8	2.6
2000	18.3	6.1	4.3	4.1	3.0	6.2
2001	7.6	4.1	5.7	6.8	3.5	2.5
2002	0.3	0.7	0.4	0.5	n/a	n/a

1. US Dept. of Labor aircraft price index; 2. US index of labour and materials prices
Source: Boeing; * B737-800 from 2000

The price adjustment is usually applied separately for airframe and engines. The airframe formula for the revised base price of Boeing aircraft at delivery is based on US indices:

$$P_a = (P_b + F) * (AA + BB) - P_b \dots\dots\dots (5.1)$$

Where:

P_b = the base price of the aircraft less engines

$F = (0.005 * N * P_b)$

N = The calendar year of aircraft delivery minus the base year in which the contract defines aircraft delivery conditions

$AA = 0.65$ (AHE or ECI index vs base period)

$BB = 0.35$ (ICI index vs base period)

³⁶ Avitas, 1998, p.72

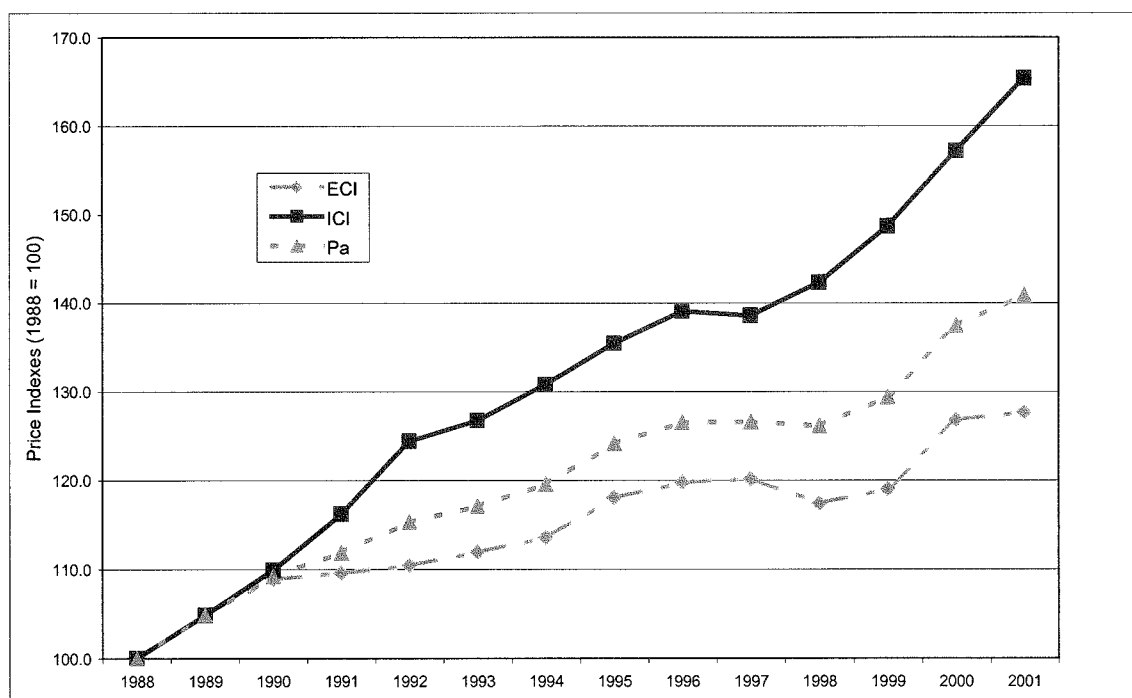
AA is the three month arithmetical mean of the US Department of Labor index of average gross hourly earnings for production workers in aircraft manufacturing companies (or Employment Cost Index).

BB is the three month arithmetical mean of the US Department of Labor Industrial Commodities index

Both AA and BB are usually specified with reference to the delivery month of the aircraft, and, for example for a March 2003 delivery would be for the three months August, September and October in 2002. The base period is the month in which the base aircraft price is agreed and the contract signed (see example in Appendix D).

The coefficients applied to the two indices reflect the approximate weight of labour and materials in the total cost of the aircraft. Aero-engines purchased new from engine manufacturers would have a somewhat different formula, with 60% of costs accounted for by labour and the same index as above, and 40% accounted for by two different metal/metal products indices.

Figure 5.5: Price adjustment indices of US aircraft applied to base price

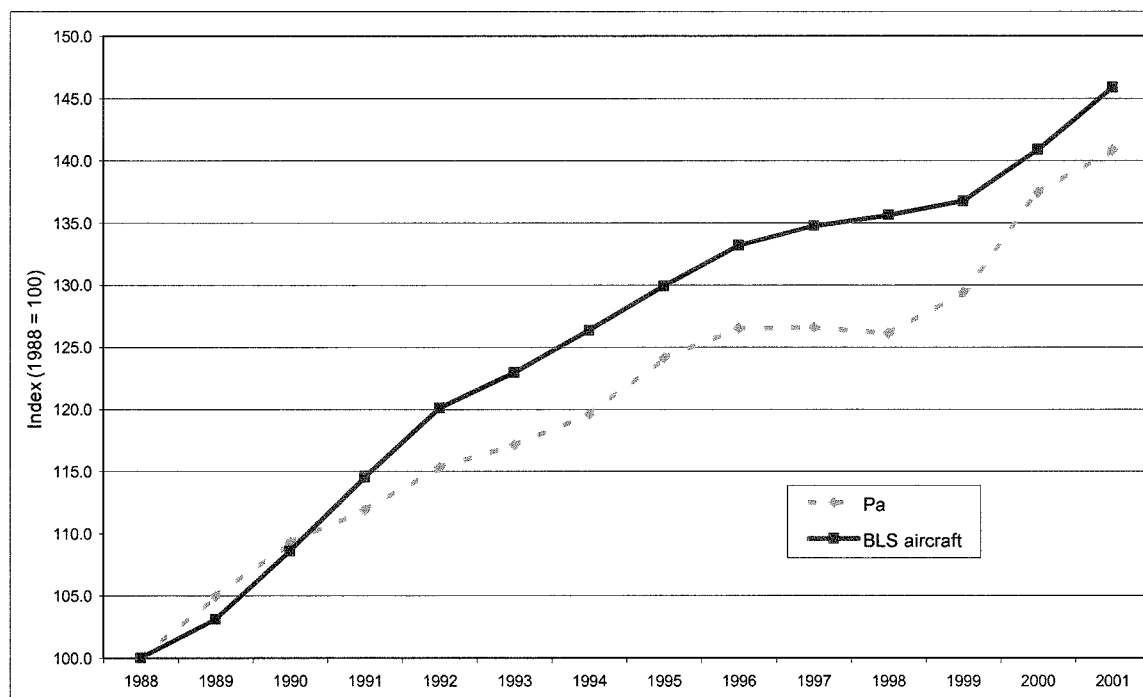


Source: US Department of Labor and author's calculations

The Airbus formula is similar to the above, the only difference being the higher weight of the hourly earnings index (0.75), and the lower weight of the materials price index (0.25). This would imply that the Airbus manufacturing process is characterised either by higher wages (very likely) or lower productivity (less likely), or a combination of both. It is also surprising that Airbus use the US indices, although this would be consistent with their quoting the base price in US dollars. However, this would assume that exchange rates always adjusted European manufacturing price inflation to US trends, or reflected relative purchasing power changes over time. Over shorter periods, this may not hold true, but Airbus probably would wish to avoid the complexity of two different indices in three principal manufacturing countries.

Figure 5.5 shows that the Industrial Commodities index has increased at a faster rate than the employment cost index over the period 1990 to 2001. Employment costs take into account labour productivity improvements, and so the dip in 1998 may have been due to Boeing's programmes, as well as the savings following Boeing's take-over of McDonnell Douglas.

Figure 5.6: US aircraft price adjustment index vs BLS index



Source: US Department of Labor and author's calculations

Figure 5.6 shows that the price adjustment formula, based on the prices of the constituent inputs to the manufacturing process, moved up more slowly than the prices that were reported by US aircraft manufacturers to BLS over the period 1988 to 2001.

In particular, the BLS aircraft price index did not reflect the decline in input costs recorded between 1996 and 1999. Demand for aircraft was strong at that time, and manufacturers were able to recoup some of the margin that they had lost at the time of the post-Gulf War downturn.

5.5.2 Aircraft market value

Aircraft market values are published by a number of journals and consultancies, and are used by financial institutions to estimate their risks and exposure on aircraft financing transactions. These could be used to arrive at age-price profiles for the aircraft types that make up an airline's fleet.

The International Society of Transport Aircraft Trading (ISTAT) distinguish between two types of value for valuations of used aircraft (see Appendix E for an example of a recent valuation):

Base Value (BV): the appraiser's opinion of the underlying economic value of an aircraft in an open, unrestricted, market with a reasonable balance of supply and demand.

Fair Market Value (FMV) or Current Market Value: The appraiser's opinion of the most likely trading price that may be generated for an aircraft under the market circumstances that are perceived to exist at the time in question.

In addition to these two, a third type is recognised for special situations:

Distress Value: This is the price that an aircraft might be sold for under circumstances of an exceptional weak market for the particular type of aircraft, combined with the need for a quick sale by the buyer.

Gecas related the three above prices to the list price of new identical models,³⁷ discussed above, illustrated in Table 5.10 for typical 1996 jet aircraft.

³⁷ Future jet aircraft requirements and related considerations, Wolfgang Issel, Gecas. Presentation to ECATA Follow-up Seminar, Hamburg, 9-11 October 1996.

Table 5.10: Discounts on manufacturers' list price

	US\$/seat	% vs list
List price	275,000	
Av. appraised values:		
Base	225,500	-18%
Current	214,500	-22%
Distress	176,000	-36%

Source: Gecas

Gecas estimated the 2002 market value to be around 5% below the base value, which was the discount used more recently by Morten Beyer & Agnew for new A320-200s, as seen in Table 5.11.

Table 5.11: Base versus current market values (US\$ million)**A320-200 (CFM56-5A)**

Year of build	Base value	2002 market	Market as % base
1988	20.5	16.4	80.0
1989	21.7	17.6	81.1
1990	22.9	18.8	82.2
1991	24.2	20.1	83.2
1992	25.5	21.5	84.3
1993	26.9	23.0	85.4
1994	28.4	24.6	86.4
1995	30.0	26.3	87.5
1996	31.7	28.1	88.6
1997	33.5	30.0	89.6
1998	35.4	32.1	90.7
1999	37.4	34.3	91.8
2000	39.5	36.6	92.9
2001	41.7	39.1	93.9
2002	44.0	41.8	95.0

Source: Morten Beyer & Agnew in ISTAT Jetrader, Aug/Sep 2002

The usual way of expressing the value of second hand aircraft (residual values) is as a percentage of their original value, updated to current prices. This has been calculated for three short/medium haul aircraft in 2002 in Table 5.12.

The Morten Beyer & Agnew data referred to above for the higher gross weight version of the A320 shows a faster decline in value to only 39.2% of new value in 2002 for 14 year old aircraft (and to 58.8% for an eight year old aircraft). It should be stressed that these values are not based on frequent deals between buyers and sellers of

standardised products, such as shares dealings on a stock exchange. Valuers often have no deals of similar aircraft upon which to base their valuations. One article stated that ‘although appraisers may have good industry contacts, they can rarely give specific detailed examples to support their valuations’.³⁸

Table 5.12: Aircraft market values for short/medium haul types

	A320 LGW		B737-300 LGW		B757-200 RB211	
Age in years:	US\$ m	Index	US\$ m	Index	US\$ m	Index
New	39.5	100.0	20.7	100.0	47.1	100.0
2	36.2	91.6	19.1	92.3	43.6	92.6
4	32.9	83.3	17.5	84.5	40.0	84.9
6	29.6	74.9	15.9	76.8	36.5	77.5
8	26.3	66.6	14.3	69.1	33.0	70.1
10	23.0	58.2	12.7	61.4	29.4	62.4
12	19.7	49.9	11.1	53.6	25.9	55.0
14	16.3	41.3	9.5	45.9	22.4	47.6
16					18.8	39.9
18					15.3	32.5
20					11.8	25.1

Source: *Aircraft Value News*, 29 July 2002

Furthermore, airlines in the US did not have to report aircraft transaction data after 1992, whereas before that year there was a compulsory reporting requirement to the Department of Transportation.

The speed at which aircraft values decline over time is dependent on many factors, which can be summarised as:

Economic factors:

- Economic growth and exchange rates
- Inflation rates
- Passenger and cargo demand and supply
- Real interest rates
- Aircraft fuel prices

Aircraft specific factors

- The condition of the aircraft
- Whether the aircraft is still in production
- Location of other aircraft of same model

³⁸ Aviation Strategy, The value of values, Issue No.11, September 1998

- Government regulations (eg noise and engine emissions)

Both existing and expected future trends in the above will be important.

Economic factors:

Economic growth rates are important through their impact on demand, and hence the supply/demand balance, and also through fuel prices. It is possible to argue that the supply/demand balance has a greater influence on short/medium haul aircraft prices, since frequencies can be adjusted more easily and aircraft grounded than long-haul aircraft. However, the markets for long-haul types are much smaller than for shorter haul aircraft, and the sale of a few aircraft at times of economic recession can lead to plunging values.

Real interest rates affect investment by firms in general, and also the decision by an airline to invest in new rather than used aircraft (via the discount rate). Aircraft fuel prices move according to supply and demand for crude oil products in general, but are also an important input into comparisons of different aircraft types.

Exchange rates are important in investment decisions, since aircraft are usually priced in US dollars and airline revenues are generated in a variety of currencies. Exchange rates also affect trade flows and thus both cargo and passenger demand.

Aircraft specific factors:

The maintenance and incident records of an aircraft will show the condition of the aircraft and the number of flights or cycles remaining before the next check or overhaul. They will also show which airworthiness directives have been complied with, and the type of operations that the aircraft has performed over its life to date. Valuations usually specify half-life conditions, and so estimates for maintenance checks and other work need to be added to, or subtracted from this value to arrive at the particular aircraft's current value.

An example of this adjustment can be seen from valuations of US Airways' fleet, following the airline's entering Chapter 11 administration in 2002 (see also Table 5.16). The value of its B737-400 fleet was given as between US\$9.5 and \$11 million. These values were reduced to between \$8-9.5 million, after deduction of various costs in order to ensure that the aircraft were in half-time condition for airframe, engines

and components.³⁹ They would thus be equivalent to aircraft fresh from a C-check or equivalent, which met all current Airworthiness Directives. The difference of \$1.5 million reflected the degree to which they did not at that time meet those criteria. No costs were deducted for carrying capital costs, storage and remarketing costs that would be incurred by the financial institutions re-possessing the aircraft.

The age of the aircraft and its components will play a key role in value. Aircraft will pick up weight over its life and suffer from increased drag due to repairs and dirt, which will further worsen its performance. Deterioration in engine fuel consumption will take place from new up to the first major overhaul (after between 10,000 and 15,000 flying hours). The overhaul will then return the engine 'close to its fuel consumption performance when new'.⁴⁰ This deterioration is likely to amount to between 3-5%.

If the aircraft is still in production, it is thought that used aircraft should have generally higher values, since it probably means that no very near alternative is available. However, it might also mean that there is, or will be, an excess of supply of a particular type.

A broader distribution of the model around the world should have a positive effect on residual value, since it should thus suffer less in the future from a sudden downturn in demand or collapse of one operator. This, in turn, would have less of an impact on the present value of its future cash flows, and thus value.

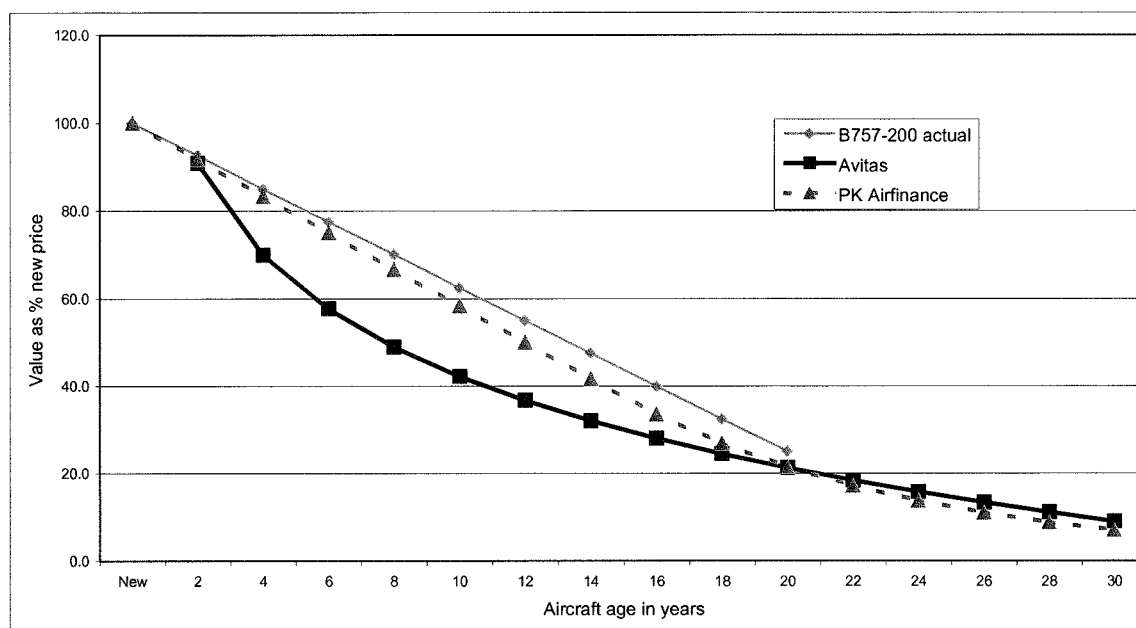
Finally, existing and likely future environmental regulations will affect values. Some types can only meet regulations in some parts of the world (for example domestic operations in some countries). In other parts of the world, perhaps hush-kits are available but these might make the aircraft uneconomic at present or likely future fuel prices. Future regulations like the new 'Chapter 4' noise rules might also curtail an aircraft's useful life.

Because of the importance to institutions of accurate predictions of aircraft residual value, a considerable amount of effort has been invested in producing models of aircraft value (or value relative to new) against time. Risk analysis is then performed on these estimates, as well as the likely impact of economic cycles.

³⁹ Seabury Advisors LLC, in Commercial Aviation Value Report, No.80, September 2002.

⁴⁰ David Pickett of Pratt & Whitney, in The Aircraft Engine Selection Process, Handbook of Airline Economics, 2nd edition, 2002, p.321.

Figure 5.7: Aircraft value as % new price: actual vs modelled



Source: PK Airfinance, Avitas and Avmark

The market values shown in Table 5.12 have been expressed as a percentage of new prices, and are all in 2002 prices (see Figure 5.7). These trends only go as far as 20 years, and often bankers are often more interested in the period between 20-30 years. Most analysts predict from models of past values and transactions the straight-line decay of value up to 20 years (B757-200). On the other hand, Avitas have used a simple log-linear regression model:

$$y = -0.3019 \cdot \ln(x) + 1.1174 \quad \dots\dots\dots (5.2)$$

where: y = jet value as a percentage of new value

x = jet age in years

This gives the curved relationship, which is plotted in Figure 5.7 alongside the B757-200 values. The Avitas model does not perform well at the two ends of the spectrum, especially in the early years, where it can be seen not to go through the 100% point. PK Airfinance used a different model, which they think fits better with the 'ski-jump' type of deterioration in value that they see from actual transactions:

$$RV_t = RV_0 \left(1 - \frac{t}{t_b}\right) \dots\dots\dots (5.3)$$

for $t < t_p$

where: RV_t = Residual value at time t

RV_0 = Price of new aircraft

b = Aircraft base life

p = Aircraft prime life

Base aircraft life (b) is defined as the point at which its economic value would be zero, say at between 22 and 26 years. Prime life (p) is defined as the point beyond which the aircraft value starts to decline, as a result of its reduced ability to generate cash flows, exponentially to zero. Up to p , which is between 15 and 18 years, value declines on a straight-line basis. The formula for the period after 'p' is:

$$RV_t = RV_0 \left(1 - \frac{t_p}{t_b}\right) * e^{\frac{t_p}{t_b - t_b}} * e^{\frac{-t}{t_b - t_b}} \dots\dots\dots (5.4)$$

for $t > t_p$

The PK Airfinance line is very close to the Avitas projection for aircraft ages beyond 20 years. However, their straight-line decay up to 20 years is much closer to actual B757 values than Avitas.

A more complex regression model was used to predict the ratio of aircraft value (transaction price) to new price using a number of independent variables (Goury, 1999):

- Age of aircraft (A)
- Position in the cycle (P) determined by the difference in traffic and capacity growth rates; a P value of 5% means traffic is growing 5% faster than capacity, and the transaction took place in the upturn part of the cycle
- Number of seats installed in the aircraft (N)
- Stage 3 compliance ($S3$ - dummy variable, 1 = yes)
- Lease attached (L - dummy variable, 1 = yes)

Based on the PK Airfinance used aircraft transactions (numbering 3,455), the following equation was fitted by means of the ordinary least squares regression technique:

$$\text{Price as \% new price} = 90.5 - 0.82 (A) + 0.97 (P) - 0.03 (N) + 6.07 (S3) + 1.02 (L)$$

The equation explained 71% of the variations in the dependant variable, suggesting that there was a reasonably large unexplained element that could not be quantified.

Assuming that the position in the cycle is neutral ($P = 0$), then the equation gives a faster depreciation compared to the PK Airfinance line in Figure 5.7 in the earlier years, and a slower one in the later years. However, it shows negative values for an aircraft of 30 years and above.

The cyclical swings in the difference between traffic and capacity growth oscillate between around +7% and -7%, according to PK Airfinance, after adjusting for the longer term upward trend. According to the above model, this would increase used aircraft *relative to new prices* by 7% at the top of the upswing, and prices would decline by 7% at the bottom of the downswing. These fluctuations would be greater were it not for the fact that new prices are also reduced during downturns, but by less than used prices. Manufacturers do not drop prices as far as owners of used aircraft, and may park them pending an upturn in the market. On the upside, manufacturers are able to increase prices, but again not as fast as sellers of used aircraft, who have capacity immediately available, which the manufacturers often do not.

5.6 Capital flows: aircraft

It can be concluded from the preceding sections that there are numerous problems both with the prices of new aircraft and with used aircraft values. Thus the estimates for capital stock at either replacement values or adjusted to constant prices can never be very precise.

The earlier chapters proposed that the flow of capital consumed in each year, rather than the stock of capital, would be the best indicator of what was available to provide airline and related services in that year. However, where the flow is based on a wide range of value estimates, the same, if not more severe, problems will be evident. The question is whether 'so called' market operating lease rates might be a more direct and better way of estimating capital flows, at least for aircraft.

Some previous studies have used published operating lease costs as an economic cost of capital. For example, Oum and Yu (1998, p.46) stated that aircraft are purchased

on world markets and the cost is approximately the same for all airlines. This is not true, and their approach would lead to distortions in both capital prices and weights. This has been used both as a weight to form an index of capital quantity input, and as a price deflator. The use in the production of an index only works with aircraft, and not with ground equipment, since the latter are too heterogeneous to be treated in this way. Indeed, the basis for combining numbers of aircraft into an index using cost weights is justified by the assumption that their quantitative and qualitative contribution to output is proportional to their lease cost. This assumption requires closer scrutiny, first by examining the published lease costs or prices.

The only consistent series of lease costs by aircraft type is published by Avmark.⁴¹ These prices are for five year operating leases, and give a range from the oldest good-condition, half-life aircraft to newer versions in a similar condition. They add in a footnote that actual (lease) rates are variable, depending on lessee's credit, duration of lease, tax considerations and residual value assumptions. They might also have added demand for the particular aircraft type or the market situation (Barrington, 1998, p.59), since there is a tendency for lessors to keep their aircraft flying and generating some cash during recessionary periods. The best way of doing that is to offer at least their better customers offers that they cannot refuse in terms of very low lease rates. These will probably be adjustable upwards in the not too distant future when market rates have picked up again.

Table 5.13: Fair market operating lease rates, March 1998 (\$/month)

	High/Newer	Low/Older
Babcock & Brown		
B737-500	\$250,000	\$220,000
Avmark		
B737-500	\$275,000	\$170,000
Babcock & Brown		
A300B4-200	\$145,000	\$95,000
Avmark		
A300B4-200	\$180,000	\$55,000

Source: Avmark Aviation Economist, Feb/Mar 1998 and Barrington, 1998, p.66

Table 5.13 shows first the very wide range of values, and thus the need to know the vintage of aircraft to be priced, and second the difference between the two published figures (one source valuing the A300 at almost twice the other source). Part of this

⁴¹ These have been published in the Avmark Aviation Economist since 1990.

difference is presumably explained by the age and condition of aircraft considered, but it is also likely to be because of the limited number of actual deals upon which to base the price. The figures in the table above all refer to 'good' quality lessees, so this factor should not have played a part in the variations.

IBA have developed guidelines for what they call Typical Current Rental Rates (TCRR). This is to try to ensure that lease rates are quoted on a like for like basis. In addition to the five-year lease term mentioned above, they include:

- Lessee is considered to be medium risk paying cash or cash equivalent deposits in the amount of three months' rental with no history of early returns or defaults
- Lessee pays full maintenance reserves for all aspects of the aircraft
- All lease rentals are paid monthly in advance in cash
- The aircraft has been purchased from the manufacturer new, and owned or held by the lessor since new

Monthly rental rates are generally considered to lie in the range between 0.85% and 1.5% of the aircraft's market value, with modern jet aircraft within a closer band of 0.9% to 1.1% (Barrington, 1998, p.59). Avmark data suggest an even wider band for older aircraft, at least at the top end. This was based on a number of actual deals for B737-200s (see Table 5.14). Avmark reported that they 'continuously track the market, especially for aircraft values'. They also track the market for actual lease rates, which they say 'tend to be less volatile than market values'.⁴² This may be because the shorter one and two year leases re-negotiated in downturns are not reflected in their standard 5-year lease rate data.

Table 5.14: B737-200 lease transactions (>3 years)

Year of build	Lessee	Lease rate US\$/month	Aircraft value \$m	Lease Factor
1968	Braniff	78,000	5.25	1.49
1968	Icelandair	135,000	6.25	2.16
1973	Braathens	162,610	7.90	2.06
1975	Braathens	185,150	8.70	2.13
1977	Aloha	142,800	9.70	1.47

Source: Avmark, November 1989

Operating lease rates are typically based on a period of around five years and the six month US dollar LIBOR interest rate. The monthly lease rate may be adjusted

⁴² E-mail from Tom Burke of Avmark, 26 January 2003.

upwards or downwards every six months, depending on which way and by how much LIBOR has changed. Thus, the lessee may have a higher or lower rental to pay, which for a B737-300 may be plus or minus US\$ 20,000 for every 0.5% movement in interest rates.

Because of the range of values described above, an alternative approach was considered for the estimation of capital flows for given stocks of capital. This was done by taking the average gross (or market) value of the fleet in each year (ie before depreciation) and calculating the lease equivalent using the following standard lease formula:

$$\text{Periodic Rental Payment} = PV \div a$$

where: PV = the present value, or equipment cost
a = the rental factor, which is:

$$a = \frac{1-(1+i)^{-(n-x)}}{i} + x \dots\dots\dots (5.5)$$

where: x = number of rentals payable in advance
n = number of payments in lease term
i = interest rate per period

The above formula is a simplified form of the value of an asset being the present value of the rental streams that it generates over its service life:

$$PV_t = \sum_{n=1}^n \frac{f_{t+n-1}}{(1+i)^n} \dots\dots\dots (5.6)$$

where: PV is the value of the asset at the beginning of year t
f is the real rental payment in each period
n is the service life of the asset

The factor x has been introduced in the first equation to allow for any advance payments of rentals.⁴³

⁴³ ie when the period specified is monthly. x = 0 means that the first payment is made at the end of the first month, and x = 1 means it is due at the beginning of the first month and so on.

The above formula can be applied to both new aircraft where 'n' is the full life of the aircraft, or to used aircraft, where 'n' is its remaining life. It was applied to the lease terms and lease rates in Table 5.15, and the aircraft values (and thus residuals) required to replicate the actual lease rates offered were calculated. The value of the six month US dollar LIBOR for mid-1989 was used, with a 2% premium for all the airlines.

Table 5.15: Used B737-200 lease transactions

Year of build	Lessee	Lease rate US\$/month	Aircraft value (\$m)	Aircraft age (yrs)	Lease term (yrs)	Implicit value (\$m)	Implicit residual value (\$m)
1968	Braniff	78,000	5.25	21	4.0	3.00	2.25
1968	Icelandair	135,000	6.25	21	5.0	6.23	0.02
1973	Braathens	162,610	7.90	16	3.0	4.97	2.93
1975	Braathens	185,150	8.70	14	4.0	7.18	1.52
1977	Aloha	142,800	9.70	12	5.0	6.58	3.12

Source: Avmark, November 1989, and author's calculations

The implicit present values shown in Table 5.15 suggest a wide range of residual values used to calculate the lease rate offered. For older aircraft of over 20 years, the residual value might have been expected to be very low, as was the case with the lease to Icelandair. However, for the Braniff lease, the aircraft would be 25 years old when it came off lease, and it would have at best another few years in which to generate \$2.25 million less its scrap value. It should be emphasised that the lease rates shown in the table are from actual contracts in the market, while the valuations are presumably not. The margin of error for estimating values of 15-20 year old aircraft is high, and thus the residual value margin of error is also very high.

Thus the Icelandair aircraft valuation may have been on the low side and the Braniff aircraft too high. This would lead to higher and lower residual values respectively, and bring the lease factors more in line with expectations in Table 5.14.

Table 5.16 applies the lease formula to estimated values and lease rates for aircraft in the US Airways fleet in 2002. This gives the number of years or term over which the aircraft would have to be leased at the indicated rates to result in a zero residual value at the end of the term. This results in economic lives with a large range from 16 to 24 years.

Table 5.16: US Airways fleet values (2002)

		Years	Value \$000	Term (yrs)	Lease \$000	Life (yrs)
B737-300	oldest	17	7,500	9.0	90.0	26.0
	newest	13	8,500	8.6	105.0	21.6
	mid	15	8,000	9.1	97.5	24.1
B737-400	oldest	14	9,500	9.4	110.0	23.4
	newest	11	11,000	10.2	120.0	21.2
	mid	13	10,250	9.8	115.0	22.3
B757-200	oldest	20	17,000	11.1	175.0	31.1
	newest	7	19,000	9.4	220.0	16.4
	mid	14	18,000	10.1	197.5	23.6
B767-200	oldest	15	18,500	9.4	215.0	24.5
	newest	9	19,500	9.2	230.0	18.2
	mid	12	19,000	9.3	222.5	21.3

Source: *Commercial Aviation Value Report, September 2002, JP Fleets, and author's calculations*

The final part of the comparison of operating lease rates with aircraft values looks at ratios and differences over time for a large long-haul aircraft (B747-400), a large medium-haul aircraft (B757) and a smaller short-haul aircraft (B737-400). The three were also the mainstay of the BA fleet over the period analysed in Chapter 8. Three years are examined: 1993, indicative of the low point in the economic cycle in terms of aircraft values; 1996, mid-way into the upturn; and 1999, which was close to the end of the upswing. Avmark lease rates and aircraft values are shown for these three years in Appendix F. The aircraft values have been converted into lease rates using the formula 5.5 above. The term has been taken as the remaining number of years before retirement after 25 years (variable depending on the aircraft's age), and the interest rate has been taken to be 0.5% over the average market US\$ six month LIBOR rate. This might be the sort of rate that a large operating lessor such as Gecas or ILFC would pay.

The analysis shows that calculating lease rates from the formula gave lower rentals compared to the market ones in 1999: 80% of market rates for the B747-400, 85% for the B757-200 and 64% (increasing to 75% if its life was shortened to 20 years) for the B737-400. In 1996, the B757/B737 percentages were still well below 100%, but the B747-400 was 93%. This indicated that lease rates had been reduced for this widebody to clear the market. The 1993 percentages were 64% for the B747, and around 70% for the others. What was surprising was that the 1993 lease rate for the B747-400 was so high, but this probably means that the B747-400 market rates are

based on very few deals. However, the B737-400 lease rates also looked quite high, at a time when the number of parked aircraft peaked.⁴⁴

A commonly used rule of thumb to capitalise annual operating lease rentals is to multiply them by seven. This would be equivalent to the monthly rental being 1.19% of market value before discounting the rentals to present value. The rental of 1.19% would need to be discounted over 10 years at 5% to arrive at the 100% of market value. Appendix F shows that the rule works quite well for the B737-400, but less well as aircraft size increases. BA (see Section 7.1) and SAS (see Section 7.3) use this rule, and most of both these airlines' operating leases are short-medium haul aircraft, which suggests that the rule probably works quite well for them. For the larger medium and long-haul aircraft, however, the value estimate would be out by a large margin. This is because lease rates on these aircraft tend to be lower in relation to their value so as to make them attractive enough to lessees, and they may also expect the rental stream to continue over a much longer period (beyond 25 years).

It has to be concluded that 'market' lease rates need to be treated with some caution, and that their use for productivity studies, especially for widebodied aircraft, could lead to considerable bias. Similarly, the 7x rule to go from annual lease rates to capital values appears to work reasonably well for narrow-bodied short-haul aircraft, but not for larger aircraft. The operating lease market is much more highly developed for the former aircraft types and thus lease rates probably more reliable.

5.7 Capital flows: non-aircraft tangible assets

Non-aircraft assets would include land, buildings, hangars, equipment and vehicles. Land is often excluded from capital inputs, since it is not used up in any real sense (unless it is contaminated, as in a nuclear plant, or depleted in the case of a mine). It is important to stress that spare parts, simulators and some related equipment may be combined with aircraft assets, and given identical service lives as the aircraft to which they relate.

The only data published on the values of these assets is found in the company's financial statements, where they are usually stated gross at historical cost, and net of depreciation. BA group these assets into 'property', which covers hangars, structures and buildings, and 'equipment' which covers all remaining fixed tangible assets which are not related to the fleet or property.

⁴⁴ See Boeing 1996 Current Market Outlook, p.4.

Ideally, these assets would need to be valued at replacement cost at the start of the period of analysis, and identified vintage and remaining by economic life. However, even with the benefit of surveys it would be a very costly task to identify individual items and then generate the necessary data.

A more practical approach, using published data, converts balance sheet amounts at historic prices to market values and applies the PIM method described above. As with aircraft, a major problem arises with additions, which may be new or used, and thus have very different remaining lives. A way round this will be proposed in the next section.

5.8 Proposed method of estimating capital flows

5.8.1 Aircraft

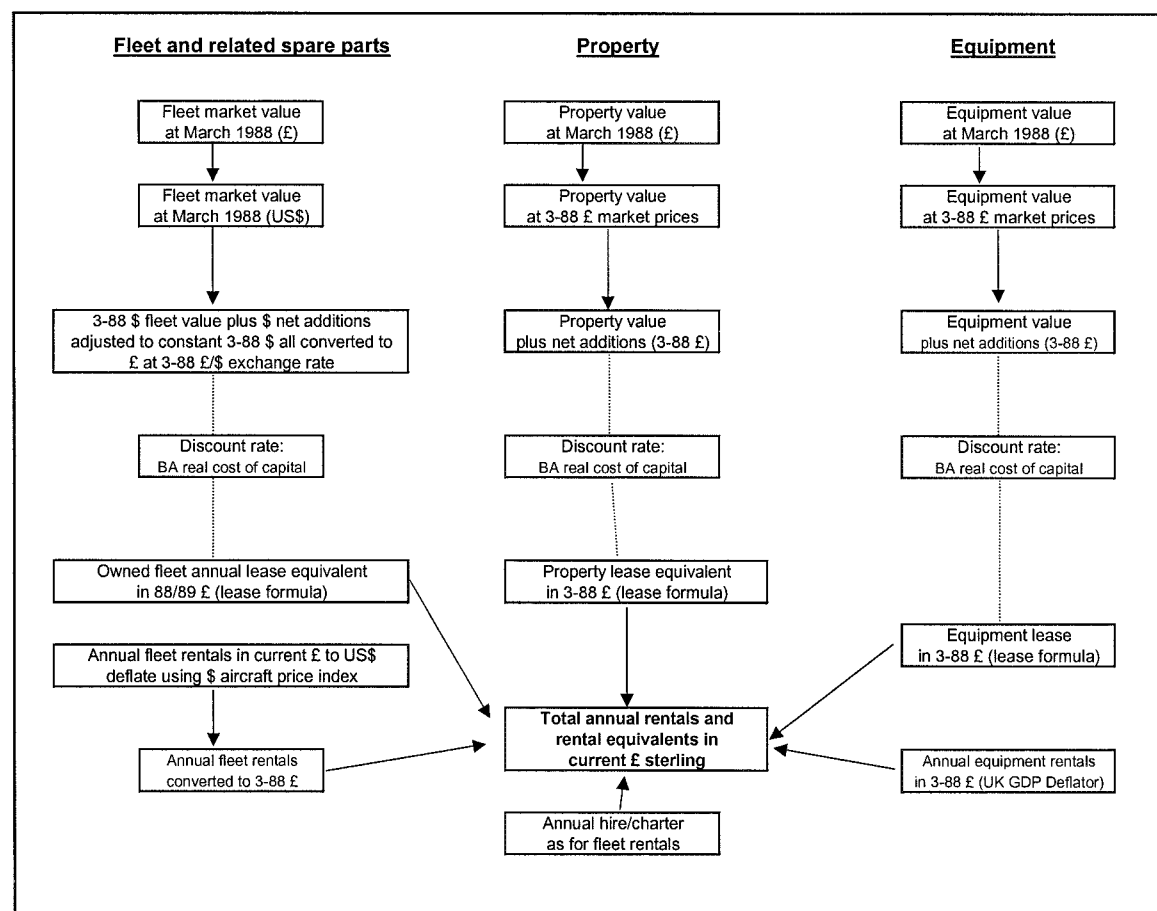
In this chapter, the measurements of both capital stock and flow have been considered. It was determined that the aircraft service life was at least 25 years, and that this life did not seem to vary significantly between narrow-bodied and widebodied or short-haul and long-haul aircraft. The technical efficiency of aircraft does not suffer much over its life in terms of output-decay, but it does from input-decay. Thus, as it ages, it requires more labour and materials to maintain its performance. Its output is also maintained through one or more major modifications and refurbishments over its life. For aircraft, it is difficult or impossible to estimate their age-efficiency profile, and so this has to be arrived at via their age-price profile. This was shown to combine straight-line and geometric characteristics.

It can also be concluded from the discussion in this chapter that published aircraft values and lease rates need to be treated with care in any analysis of capital inputs or weights. Airline fleets often include aircraft of widely differing age and characteristics, even for one specific type such as the B737-200. Without examining detailed operating data and maintenance records it would be difficult to apply published values, or ranges of values, to arrive at estimates of fleet value in current terms. In any case, such published values are often not based on market transactions, but rather valuations, and these might differ significantly between valuers.

An alternative approach is proposed first relating to aircraft, and then to other tangible assets in the next section. This is shown in Figure 5.8. This will be applied to a time series analysis of BA in Section 8.4.

The first step is to convert the baseline gross historical cost fleet assets from the balance sheet (ie owned) into replacement or market values. Applying published aircraft values to the various aircraft types in the fleet could do this. This estimate would then need to be converted into US dollars (published aircraft prices would normally already be in dollars), if it were expressed in local currency. The reason for this is the choice of deflator to be used: the composite aircraft manufacturing price index used in contracts, which is based on US dollar prices. This index seems most appropriate to deflate new fleet additions back to baseline prices, since it excludes any quality changes that are hard to remove from other price indices.

Figure 5.8: Proposed approach for estimating capital services



Source: Author

Aircraft added to the fleet, net of aircraft retired, would be valued at baseline constant US dollars, and added to previous capital amounts. This would give a constant price

fleet capital stock in each year, which would reflect aircraft of different type and age. The average age of this fleet should be known, and this would indicate the average remaining economic life over which this capital stock would generate returns. Those aircraft in the fleet that are relatively new would be valued at new prices, albeit adjusted to baseline manufacturing costs. Older aircraft would be valued at replacement rather than new cost, again adjusted for inflation.

The next stage is to determine the flow of lease rentals that this stock of aircraft could earn over the remainder of their lives. The application of the equation described Section 5.6 in does this, using an appropriate discount rate. This should be in real terms, and could be either in US dollars or local currency terms. Conversion back to local currencies (either before or after the lease calculation) should be at the baseline US dollar exchange rate.

In addition to owned aircraft on the balance sheet, most airlines have a number of aircraft on operating lease, and possibly some on very short term charters or wet lease. The annual cost of these can be added to the flow of capital services from owned aircraft, but suitably deflated to baseline price levels. Lease rates are normally quoted in US dollars, so it would be preferably to switch the expenditure to US dollars, use the same deflator as for owned aircraft, and convert them back to local currency using baseline exchange rates. An alternative approach would be to capitalise annual rentals paid for operating leased aircraft: this could be done by discounting future rentals to the present, using the airline's cost of capital, or using a rule of thumb such as seven times annual rental payments (see Section 7.1).

A similar procedure would be needed for chartered aircraft, after removing any non-capital costs (eg crew, maintenance and insurance). This could be estimated from data of aircraft operating costs.

5.8.2 Non-aircraft tangible assets

The cost of non-aircraft assets are probably mostly incurred in local currency, and can be treated in the same way as aircraft, but keeping them in local currency and using a home country price deflator.

Baseline property and equipment gross values need to be converted, if possible, to market prices, and any net additions added to these after applying a suitable deflator. This crucial step is often impossible, since the age profile of the assets is not known. Some airlines revalue property from time to time and equipment lives are generally

relatively short. A price index for commercial property would be appropriate for property assets, and one for machinery and equipment for other assets. The major problem is to obtain gross asset values either in current market prices or in constant prices. These are not often available, but if they have been re-valued in any past two years, the intervening years could be estimated by interpolation.

6 Measurement of airline non-capital inputs

It is necessary to include non-capital inputs in any detailed analysis of capital investment and productivity. This is because investment in new technology generally has a significant impact on the efficiency with which many key inputs are used. Investment in new aircraft and new engines leads to reductions in fuel efficiency, and will also incorporate improved maintenance systems and possibly increase the time between overhauls. New aircraft will also be labour saving, whether in the cockpit (two versus three crew) or on the ground through ease of handling (containerised baggage transfer). Other investments such as self-service check-in are also labour saving.

This chapter will discuss some of the problems with definitions of these other inputs, starting with labour, which accounts for the largest non-capital input.

6.1 Labour

Labour covers those employees who are contracted directly by the airline, whether under a short or long-term arrangement. The simplest measure of labour is average annual employee numbers. This should be adjusted for part-time staff if possible, in terms of manpower equivalent (MPE). Actual man-hours per annum worked would be a better measure, to take into account differences in holiday entitlement, sickness and absenteeism, but this number is not usually available. The number of hours worked per annum has generally declined in most advanced countries,⁴⁵ such that productivity trends over time using annual staff numbers would tend increasingly to understate labour productivity. Similarly, the number of hours worked per annum varies by country, even within the EU, resulting in similar distortions for cross-sectional comparisons.

The major problem in using equivalent annual employee numbers on the payroll is in its relationship to output. Employees may work on contracts for other airlines, and this will not appear in physical measures of output, although it will appear in total revenues under third party work. Conversely, part of output may be produced by employees of other firms, to whom part of the production is outsourced. This would

⁴⁵ For example, annual hours worked per employee has declined between 1975 and 1994 by just under 3% in the US, by 9.5% in the UK and just over 12% in France and Germany (Source: The Economist, 25 November 1995).

show up in the cost of services provided by other firms. Both these could be converted into equivalent staff numbers.

A number of papers avoided this problem by including incidental revenues in outputs (third party work for other airlines), and material and other services bought in as inputs (Oum and Yu, 1995). The same paper measured labour input by taking a weighted index of various categories of staff, the weights reflecting the cost share of each category. This should thus incorporate quality changes.

The alternative approach to determining labour (quantity) input is to take the annual employee cost and deflate this by an appropriate price index. Quality changes could also be included here, depending on the price deflator chosen.

A second problem relating to labour is the quality of staff, which is not reflected in any physical measures. This quality will be higher where specialist training is required, or where experience can be built up and used to advantage in performing the job better or more quickly.

One example of this is in building or loading containers: experience would lead to less time required to pack air cargo shipments or passenger baggage into a container. Experienced check-in staff can deal with difficult requests from passengers more quickly, while more experienced maintenance engineers can solve technical problems more rapidly.

Some airlines might contract out all lower paid, less specialist, jobs to outside firms, so that their labour input measured in staff numbers under-estimates the amount of labour that is used. This addressed in some studies by producing an index of employee numbers, weighted by the share of staff costs contributed by each staff category. This means that pilots and senior management would have a higher weight in the input index.

6.2 Fuel

Fuel is consumed principally by the engines of an airline's fleet of aircraft, as well as ground vehicles, heaters and air conditioners. The engines of both turbo-prop and jet aircraft both use a similar grade of aviation jet kerosene. This is supplied by one of the large oil companies. Larger airlines will have contracts with a number of these companies covering uplift at the majority of the airports they serve on a regular basis.

There are four major spot markets for aviation kerosene around the world: Rotterdam, Singapore, New York and the US Gulf. Contracts can be linked to the market prices reported from trading in these markets, or linked to the price of crude oil. In the past, jet kerosene prices have not always moved in line with crude prices.

The average price an airline pays for fuel will depend on prices at their main operating bases (which in turn depend on transport costs), their scale of operations, the nature of their operations and the scope for tankering from low cost airports. Some airports impose their own charges on access to fuel supplies. Average contract prices in May 1997 in Western Europe varied from 77 US cents per US gallon at Vienna to 61 cents at London Heathrow, with Budapest in Eastern Europe as high as 82 cents (Doganis et al, 1998, p.23). This casts doubts on the assertion that 'variations in fuel prices among the airlines are not significant' (Oum and Yu, 1998).

In order to protect themselves against sudden upward movements in prices, many airlines purchase forward contracts or futures for some of their future requirements. These are financial transactions in commodities whose price movements are closely correlated with kerosene prices, since the aviation fuel market is not large enough to justify its own futures or forward contracts. Thus airlines aim to offset higher aviation prices with profits from hedging contracts, rather than contract for forward delivery of fuel (see Serafimides, 2001). Variations in the degree of hedging across airlines introduce an additional source of difference in the average net price paid.

The physical quantities of fuel used by airlines are expressed in US gallons or litres, but this is not often published. One approach to estimating fuel consumption was to use a regression equation of consumption against ATKs, aircraft kilometres, load factor, and other explanatory variables for the airlines that did report gallons consumed (Windle, 1991, p.33, and Oum and Yu, 1995, p.185). A recent study relied on Oum and Yu (1995) to estimate fuel consumption by Ansett Airlines, by comparing it with that used by other airlines operating over a similar average sector length (Forsythe, 2001, p.204). The same study obtained a fuel price series from the Australian BTCE. Another recent study combined energy prices with airport fees as a multilateral index, without specifying the sources of each of them (Ng and Seabright, 2001).

Another approach took the average prices of fuel in 12 world regions published by ICAO⁴⁶ and weighted these by the traffic levels for each carrier in those regions (Good, Röller and Sickles, 1995, p.511).

However, annual data is available on the fuel actually consumed by various aircraft types operated over a network of given average stage distance.

Table 6.1: Fuel consumption by aircraft type in 2001

	US Airways		Northwest	
	A321	B757-200	B747-400	B747-200
Gallons/hour	927	1,092	3,387	3,536
Sector kms	2,262	1,786	7,218	5,448
Av. seats/aircraft	169	182	405	357
Gallons/seat hour	5.49	6.00	8.36	9.90
Percent difference	-8.6		-15.6	

Source: US DOT, Form 41 in *The Airline Monitor*, August 2002

Table 6.1 shows the fuel consumption for two short/medium haul aircraft and two long-haul ones. BA's current strategy is based on the gradual replacement of B757s by smaller A321s, and the table shows that the smaller aircraft is just under 9% more fuel-efficient than the larger, but operated over slightly longer sectors. This would give it a small advantage, but nevertheless it shows the advances in fuel burn for newer technology aircraft. Similarly, the larger and newer technology B747-400 has a significant fuel advantage over the older B747-200.

BA replaced B747-100s and -200s by B747-400s, and more recently by B777s. The latter type consumed 2,134 gallons per hour for all US operators in 2001, or 8.02 gallons per seat hour. This was 19% more fuel-efficient than the B747-200 and 4% more than the B747-400, operated over sectors of only 5,700 km. This gives an indication of the fuel savings that BA's new strategy will eventually introduce.

6.3 Airport and ATC Services

Almost no airline owns an airport, although some have invested in their own passenger and cargo terminals, which is common in North America. They are thus required to pay aeronautical charges to the airport operator for the provision of runways, taxiways and aprons, and, outside North America, terminal buildings (and

⁴⁶ ICAO no longer publishes these.

their access networks). Fees are also paid for office space, check-in desks, baggage handling facilities and passenger lounges.

Physical measures of airport inputs are thus impossible to construct: the amount of airport resources used by each passenger will depend on both the type of passenger (eg scheduled or charter, terminating or transfer, international or domestic), and the requirements of the airline (aircraft type, remote or contact stand etc).

Volume measures can also be obtained by adjusting time-series of total airport costs by a suitable price deflator. An index might also be based on the relative cost of turning round a typical mix of aircraft.

Airports are very capital intensive, and cannot easily add or subtract facilities according to demand. Once new capacity is added, marginal costs of attracting additional flights are very low, and airports tend to offer low aeronautical charges to attract new airlines and routes. This brings passengers, and customers to their shopping and other commercial outlets.

Providers of Air Traffic Control services also levy fees, covering both the airport approach and en route phases of flights. These are usually based on a formula that includes aircraft maximum take-off weight, and (for en route charges) distance flown.

6.4 Distribution

Distribution normally includes sales, booking, ticketing and promotion. A large part of this has in the past been the commissions paid by airlines to travel agents. Airlines also have to pay booking fees to Global Distribution System (GDS) companies, and commissions to credit card companies. In 1996, ticketing was estimated to account for 2-3% of US airline total costs, commissions 10%, GDS fees 2% and credit card fees 2-3%.⁴⁷

Recently, the cost of each booking and ticketing transaction has declined considerably, using ticketless or e-ticket booking via the internet. High GDS fees have also encouraged airlines to re-establish similar facilities (eg Orbitz and Opodo). Prior to the development of e-tickets, airlines spent considerable time developing an Automated Ticket and Boarding Pass (ATB2), which became the industry standard.

⁴⁷ The 1996 Airline Almanac, Merrill Lynch, 7 June 1996, p.9.

However, the low cost airlines have demonstrated that distribution can be very successfully managed through ticketless internet booking, which saves both travel agent commissions and airline ticketing expenses.⁴⁸

The cost of distribution thus combines a number of different physical processes, both internally and externally. Each booking can involve an agent's time (airline reservation and/or travel agent staff), and communications with a GDS or the airlines' own reservations system. Prior to that, air fares are made available through GDSs, ATPCo (an electronic publisher of global air fares) and direct to agents. A physical ticket may need to be produced and delivered to the customer, although this requirement is declining fast. The ticket or e-ticket will need to be verified at check-in, and a boarding pass issued (manually or by machine). Promotion and advertising will also require inputs of specialist time and the use of IT/communications equipment and various media.

These physical processes all have a price element, whether it is the price that GDSs charge for each booking (increasing over the past few years), or the price the travel agent gets for each revenue dollar generated (decreasing over the past 5-10 years). Credit card companies charge a commission per transaction, and advertising agencies also price their services. Internally, an airline allocates the cost of distribution staff time on the basis of wage and salary costs.

Overall, the cost of distribution has been falling recently, both because of much greater automation as a result of past capital investments, and also from a decline in prices charged. The latter has been forced on travel agents, who realise that their monopoly position has been weakened by the greater ease of direct booking and less need for providing paper tickets.

6.5 Other inputs

The remaining inputs amounted to about 30% of total costs for BA in 2001/02. The major item was outsourced catering and ground handling costs, which accounted for about half of these remaining costs. Engineering, insurance and administration accounted for the rest.

⁴⁸ Low cost airlines do not need any interline capability and thus can go ticketless rather than need to develop e-tickets which can be used for interline bookings.

Apart from the head office administration, these inputs have been subject to a substantial degree of outsourcing over the past decade, not just by BA but other airlines. Competitive market prices will be paid for the provision of such services as in-flight meals, passenger and aircraft handling, engine overhauls, IT support, cleaning and vehicle maintenance. These are all areas where there are a number of competing high quality suppliers, often operating globally. This last characteristic is well suited to an airline with international operations.

However, because of commercial confidentiality, it is impossible to obtain data for many of these price trends. Volume measures are also not reported, and impossible to estimate. Thus, previous productivity studies have applied readily available GDP deflators or consumer price indices to deflate expenditure for all remaining airline inputs under the heading 'materials'. For example, Oum and Yu (1998, p.52) construct a 'materials' input price index using the GDP PPP exchange rate and the US GDP deflator. Materials cost is defined as all costs not attributable to labour, fuel or capital, which accounts for '35-50 percent of airlines' total costs'.

As demonstrated above for landing fees, this could give a very false impression of productivity trends, especially over the past decade when prices for these inputs have often been falling as a result of increased competition and investment in new technology. Splitting other inputs into materials and services and using more appropriate price deflators goes some way to meeting this criticism (Pitt and Norsworthy, 1999, p.123). Materials were defined as maintenance materials and passenger food, with the related price indices being those reported by the US Bureau of Labor Statistics for aircraft parts and processed foods. These are not ideal, and the first may not be a good reflection of component overhauls, and the second may not take into account moves towards greater outsourcing. Furthermore, these price indices are not reported in many other countries.

7 Economic capital consumption measures used in previous work

Before the empirical analysis of capital productivity, it is necessary to provide a comprehensive survey of capital consumption measures used in previous work. This will first look at such measures used by airlines, and then in previous academic studies. The survey will be confined to economic measures, since accounting measures have already been discussed in Section 5.2.1.

Those measures presented for BA, Lufthansa and SAS have been developed in conjunction with investment banks, as a means of demonstrating the creation (or destruction) of value to the investing community. They have also been considered for setting internal targets to replace ones based purely on accounting ratios. The measures used in academic studies are generally developed for use in productivity studies, but the airline measures are no less relevant for this research.

Their relevance here is the substitution of economic for accounting measures of capital. While not strictly productivity measures they applies economic theory in the same way, and also takes as a starting point an airline's financial statements: this is the approach taken for the analyses in the next two chapters.

Only those airlines with active stock market trading in their shares would be interested in these measures, and there are no others that appear to have shown an interest in them. In North America, no such reporting is evident, although there are a number of analysts that convert reported accounting data to economic values.

The next section in this chapter examines another ratio (Tobin's q) which is also based on market based measures of value, and is thus also of relevance here. The chapter concludes with a critical examination of measures used in previous academic studies.

7.1 British Airways example

Around five years ago, British Airways have developed Cash Value Added (CVA), which is designed to measure the shareholder value that the airline is adding, after providing for an economic return to long-term capital investors. CVA requires an economic measure of capital consumption to be determined. It is similar to Economic Value Added (EVA), originally developed by the US firm Stern Stewart and Co, and is increasingly being used by firms, and more recently airlines such as BA and

Lufthansa. CVA differs from EVA in the reduced number of adjustments that are made to the accounting measures, such that it is easier to communicate to stakeholders.

The starting point for CVA is cash flow, or EBITDAR, earnings before interest, tax, depreciation, amortisation and rentals. This is essentially operating revenues less cash expenses, plus income from associates, dividends and interest received. However, the BA example below does not add in interest received. EVA takes as a starting point Net Operating Profit after Tax (NOPAT), which is similar to EBITDAR but after deducting tax.

From EBITDAR, tax is deducted, and an asset replacement charge designed to reflect the economic cost of replacing assets. For BA's 1999/00 financial year, this resulted in a sustainable cash profit, before the capital charge deduction, of £466 million (see Table 7.1).

The asset replacement charge is where CVA departs from many of the ratios used in the past. This is an economic depreciation charge for assets that are owned, or on finance or operating leases. Its starting point is total depreciating assets: gross fixed assets from the balance sheet are adjusted for inflation and combined with the present value of leased assets. This is similar to replacement cost. For property and aircraft under operating leases, the annual rentals are multiplied by seven to give a broad estimate of present capital value.

The difficult part is inflating the historic costs of aircraft to current replacement values on a like-for-like basis. It appears that BA is currently taking equivalent new aircraft, since they are then depreciating the values over an average asset life of 22.2 years. This would imply, for example, that the historic balance sheet gross value of a B737-200 would be replaced by the *new cost* of a B737-200. Since these are no longer in production, in this case they would presumably take a B737-500, which is similar in most respects, but presumably has lower fuel costs. They did not apparently take the replacement cost of a B737-200, of *similar vintage and operating characteristics*. This latter approach would give roughly the right fuel and maintenance costs (which have already been assumed under cash operating costs), but the economic life would need to be 22.2 less the aircraft's vintage.

The annual asset replacement charge (£379 million in 1999/00) is calculated by finding the annual amount, which, if discounted over the asset's economic life using the weighted average cost of capital (WACC, which for BA was 7% in real terms) as

the discount rate, would equal the total of depreciating assets. This is identical to the lease equivalent approach suggested above in Equations 5.5 and 5.6 in Section 5.6. The crucial difference, however, is that BA replace the assets with new, on a like-for-like basis and take the full useful or economic life of the asset from new. The approach to be adopted for the BA and international airline analyses here is to adjust the gross assets to market values and take the remainder of the used assets' lives.

BA's approximation to the asset life is arrived at by dividing gross fixed assets by the annual depreciation charge for 1999/2000. Gross assets are as at the end of the year, rather than more correctly averaged over the year, and the resulting average asset life is 22.2 years.⁴⁹ This is a weighted average of the long-haul fleet, which are depreciated over 25 years, and the shorter lives of the short-medium haul fleet.

The economic depreciation rate that BA applied to total depreciating assets of £18.9 billion in 1999/2000 was calculated by combining a compound interest rate (WACC) and the economic life of 22.2 years. The weights assumed for the debt and equity cost in the WACC calculation were 50:50, based on a target net debt to equity ratio of this ratio. They were applied to the nominal cost of debt, after tax, which was taken to be 5.3% for their base case, and 4.8% for two alternative scenarios.⁵⁰ The cost of equity followed the Capital Asset Pricing Model (CAPM) procedure (see Pike and Neale, 1999), with a risk-free rate of 5.3% (coincidentally the same as the after-tax debt cost, but without the tax allowance), a beta of 1.25 and an equity risk premium of 6.6%.⁵¹ This gave a nominal cost of equity of 13.6% and thus a nominal WACC of 9.5%. The real WACC then assumed a rate of inflation of 2.5%, resulting in the 7.0% referred to above.

BA took two alternative scenarios for the WACC calculation: betas of 1.35 and 1.50, and equity risk premiums of 2.5% and 4.0%. The difficulty of finding the correct beta is discussed in Turner and Morrell (2002, p.17), and the Economist drew attention to the range of views on equity risk premiums.⁵²

From the BA figures published, it is difficult to determine the basis for the tax charge, but this appears to have been the full UK rate of tax (30% in 1999/00) applied to the cash profit.

⁴⁹ CVA in British Airways. Internal presentation by Tim Howie and Robert French, 11 December 2000, slide 20.

⁵⁰ Ibid, slide 24.

⁵¹ Ibid, slide 25.

⁵² Great expectations, The Economist, February 2, 2002, p.81.

The figure in Table 7.1 for gross assets at current cost is the total of depreciating assets plus debtors and stocks less provisions and non-interest bearing liabilities. This is equivalent to shareholders' funds and external liabilities, and this total (£17.241 billion in 1999/00) was multiplied by WACC to arrive at the capital charge.

Table 7.1: Cash Value Added calculation for BA

£million	1999/00
Operating revenues	8,940
Operating costs (less lease rentals and depreciation)	(7,890)
Other income	5
Asset replacement charge	(379)
Tax on the above	(210)
Sustainable cash profit	466
Gross assets at current cost	17,241
Capital charge	(1,207)
CVA	(741)

Source: British Airways Factbook, 2001

The total of the asset replacement charge and the capital charge amounted to £1.586 billion according to BA's figures. This compares with the conventional accounts figures for 1999/00 of depreciation (£648m), interest paid (£357m), and rentals (£318m), or a total of £1.323 million.

A negative CVA (as BA have experienced over the past few years) implies that they are not generating sufficient cash returns to cover their economic cost of capital. New capital should thus be diverted to investment opportunities where a positive return can be earned.

7.2 Lufthansa example

Lufthansa's annual report and accounts for 2001 provides the basis for the calculation of its cost of capital (WACC), and its broad approach to the calculation of its CVA. CVA for FY2001 is reported to have been €0.9 billion before tax, and €0.6 billion after tax. The starting point for their CVA was Earnings before Interest and Tax, to which depreciation and amortisation was added to get EBITDA, and then a further adjustment was made with the addition of changes in retirement benefit obligations. This amount was then multiplied by WACC, and this capital charge is then subtracted from EBITDA (plus retirement obligations) to get CVA. This appears very similar to

the approach taken by BA, without the crucial adjustment of gross assets to current prices, or replacement cost. Lufthansa argued that depreciable assets had to earn their historical cost over their life, and not replacement cost or market value. This was what investors tracked and compared to returns on assets of similar risk.⁵³ This view has some validity, since airlines that purchase large orders (or are launch customers) for aircraft and obtain large discounts are attractive to equity investors for that reason, and their expected return is on this value of the assets, not one based on opportunity cost or market value.

Table 7.2: Lufthansa's basis for calculating the cost of capital, 2001

	2001
Risk-free interest rate	5.1%
Market risk premium	5.7%
Beta factor	1.05
= cost of equity after taxes	11.1%
Equity share	
(market value, target capital structure)	55%
After-tax cost of debt	6.3%
Debt share	
(target capital structure)	45%
= WACC after taxes	8.9%

Source: Lufthansa, Annual Report, 2001

Lufthansa's WACC is lower than BA's nominal 9.5%, with an assumption of 55% equity compared to BA's 50% for the target capital structure. Lufthansa's risk-free rate is also roughly the same as BA's, but they take a lower beta (1.05 vs 1.25) and a lower equity risk premium (5.7% vs 6.6% for BA). An earlier Lufthansa estimate of 12.1% for the cost of capital was based on a beta of 1.1 and a 6% risk premium, which combined with net debt of 5.9% gave a WACC of 9.6%.⁵⁴

7.3 SAS example

SAS has for a number of years been publishing for its investors and the capital markets value-based and market adjusted rate of return metrics. These have centred on two ratios: Cash flow return on investment (CFROI), and the traditional Return on Capital Employed (ROCE). The former is one of the most important ratios used by

⁵³ Personal communication (e-mail) from Ulrich Heising, Corporate Controlling and Cost Management, Lufthansa, 27 September 2002.

⁵⁴ Value-based management. Lufthansa internal presentation, FRA CC, 15.11.2001.

investment analysts for assessing the value created by an airline. The latter is a traditional accounting ratio, and will thus not be discussed further here.

CFROI relates cash flow (before depreciation, amortisation and rentals, also called EBITDAR) to the adjusted capital concept. It avoids accounting measures of depreciation, and takes into account the market values of its fleet and other assets, as well as the present value of the cost of operating leases. Their adjusted capital, or asset value (AV) is defined as:

*The book value of total assets, plus the surplus value in the aircraft fleet, plus seven times the annual cost of operating leases for aircraft, minus the share of equity in affiliated companies, minus non interest-bearing liabilities and interest bearing assets.*⁵⁵

An alternative formulation arrives at the same number using shareholders' equity and interest-bearing debt. It should be noted that only owned aircraft are re-valued, and not other fixed assets, and also that current and future lease rentals are not discounted to their present values, but the rule of thumb is used instead (x 7). This was because the original approach of discounted present values (PV) did not fully reflect the capital tied up in these operating leases, especially where many of the leases only had two or three years to run, and SAS had the option to extend them for a further term at expiry.

Table 7.3: Present values of SAS contracted operating lease rentals

US\$ million	2000	2001	2002	2003	2004	2005	2006
Boeing 737	21	21	21	21	20	19	17
Boeing 767	63	33	11	0	0	0	0
Douglas DC-9	19	11	3	0	0	0	0
Douglas MD-80/90	45	37	26	19	5	0	0
Fokker 50/Saab 2000	18	2	2	0	0	0	0
Total	166	104	63	40	25	19	17
PV @ 5.5% in US\$ m	381						
PV @ 5.5% in SEK m	3,245						
Rentals for 1999 SEK m	1,291						
Total rentals PV SEK m	4,536						

Source: SAS Annual Report, 1999, p.18

Table 7.3 illustrates this point, since the discounted PVs of the contracted operating leased aircraft amounted to SEK3,245 million, to which should be added the 1999 rentals of SEK1,291 million (not discounted), making a total of SEK4,536 million,

⁵⁵ SAS Annual Report, 2001, p.116.

considerably less than seven times the current year's rentals of SEK9,037 million. This was why SAS abandoned the PV approach in favour of the seven times rule of thumb, from the 2001 Annual Report onwards. In this report they comment that the 7x rule gave SEK15,023 million, while the average PV of the lease rentals only amounted to SEK5,115 million.

The discount rate used in Table 7.3 was 5.5%, which was its after-tax cost of debt (and not WACC). WACC was calculated to be 10% before tax, based on a 50:50 debt:equity ratio. The beta and equity premium values were not given.⁵⁶ It should be noted that the WACC did not need to be used for the new method of capitalising operating leases, but it was presumably still used internally for investment appraisal.

The CFROI calculation for the financial year 2001 was as follows:

EBITDAR	SEK3,168m
Adjusted average capital employed*:	
+ shareholders' equity	SEK16,887m
+ minority interests	SEK218m
+ surplus value aircraft	SEK4,666m
+ capitalised lease costs	SEK15,023m
- equity in affiliates	- SEK1,087m
+ net debt	SEK3,629m
=	SEK39,336

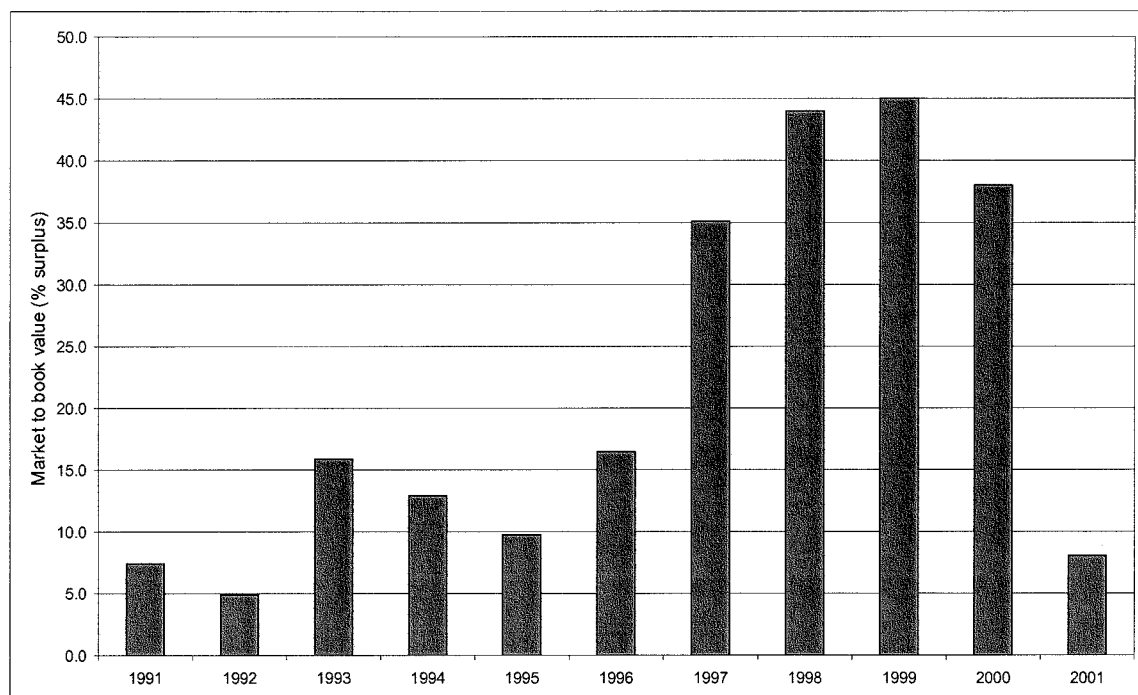
$$\text{CFROI} = \frac{\text{EBITDAR}}{\text{Capital}^*} = 8.1\%$$

SAS's goal is to achieve a minimum CFROI of 17% over any business cycle. The group as a whole, but not the airline, achieved the target in 2000, and in the years 1994-98 inclusive.

Figure 7.1 shows how SAS's fleet market values has compared to net book values over the past 11 years. It can be seen that this difference turned up after the business cycle upturn (but with some time lag), and turned down somewhat before the latest economic and traffic downturn.

⁵⁶ SAS Annual Report, 1998, pp.8-9.

Figure 7.1: SAS fleet market values compared to book values



Source: SAS Annual Reports and investor briefings

7.4 Tobin's q

The use of economic depreciation is also required for the ratio of a firm's market value to its replacement cost of its capital assets. The latter overcomes many of the problems associated with accounting measures of firm profitability, and is often referred to as 'Tobin's q'.

Tobin's q is defined as:

$$q = \frac{M}{T + I} \dots\dots\dots (7.1)$$

where: M is the market value of a firm's debt and equity
T is the replacement cost of its tangible assets
I is the replacement cost of its intangible assets

Market values are forward looking, and can be seen as being the discounted present value of future or expected profits. Replacement costs of assets give a true idea of the

assets in place, which enable these future profits to be generated. Accounting ratios, on the other hand, are backward looking at past profits and assets valued at their original cost (McFarland, 1988).

The application of Tobin's q presents some problems:

- The firm may have no stock market quotation for any of its ordinary shares
- The firm may have no stock market quotation for its debt securities
- The quoted price of the firm's securities may not be a good estimator of value
- It may be impossible to estimate replacement costs of assets on a like for like basis

It is obviously impossible to calculate ' q ' if there is no stock market quotation for its equity. This is still the case with many international airlines. If there is no market quote for debt securities, studies often use the book value of debt.(eg Li, Oum and Zhang, 2002). Debt maturities are often over 10 years ahead, and interest rates can change very significantly in this period. Thus, high interest debt issued in the late 1980s would have increased in value since then such that its yield is in line with much lower yields today. Alternatively, the market value of the debt should reflect the discounted present value of its future income stream, which for higher yielding securities would be larger. Using the book value of such debt would seriously underestimate capital employed, and distort the relationship between this and the replacement or market value of assets. However, some studies also take the book value of assets, which gives greater consistency between numerator and denominator of ' q ', but corrects fewer of the disadvantages of using conventional accounting or balance sheet measures.

There is also the question of equity prices being a good indicator of firm value, in the sense of reflecting the discounted present value of future earnings. Liquidity is required in terms of a reasonable number of trades. Many international airlines have a stock market quotation but, because of blocks of shares being tightly held, do not experience much trading (Turner and Morrell, 2002, p.13).

Even for airline equities with a high turnover of shares (eg British Airways), there is the problem of trading on the basis of little or inadequate information. This can also be described as 'noise', and the assertion that much trading activity is based on 'noise' rather than rational expectations of future company earnings (Black, 1986). Noise trading leads to more trading by those with information (or those that believe they have information), which increases the liquidity of the markets, but makes prices less

efficient. ‘*What’s needed for a liquid market causes prices to be less efficient*’. (Black, 1986, p.532).

7.5 Economic capital consumption in previous academic studies

A comprehensive list of academic studies that have used capital input measures or capital consumption is given in Appendix B. Many of these have already been referred to in earlier chapters of this thesis. This section will discuss those studies that have used economic measures, highlighting their pros and cons.

The earliest study mentioned (Morrell and Taneja, 1979) converted the amount of capital consumed in each year by the equivalent number of man-years of labour. Capital consumption was defined as depreciation, interest and rentals from the airline’s accounts, and this was divided by the average wage in US aircraft manufacturing industries in the same year. The main disadvantage of this measure was its inclusion of the accounting bias that arises from different depreciation policies. Furthermore, the growing market share of Airbus aircraft would now require European manufacturing wages to be included. The measure also suffers from not allowing for the various ages of aircraft, and thus differing amount of labour embodied in each type.

Caves and others (1981) split each airline’s fleet into eight categories and applied annual lease costs divided by an aircraft price index to arrive at the real consumption of capital in each year. The aircraft price index used was the Avmark series of lease rates. The multilateral index procedure was used to combine the aircraft categories into an overall capital consumption index. This measure had the advantage of producing a good index, but interpretation was more difficult than for measures involving units. It used eight aircraft categories, rather than calculated the lease cost and price for each type, an approximation that may not have mattered too much, but the lease rates did not necessarily apply to the vintage of aircraft under consideration, and they may not have reflected ‘market’ conditions.

Swierenga and Crandall (1982) used a different approach, taking the accounting cost of aircraft and facilities depreciation, interest and leases, and deflated the change between 1972 and 1979 by a cost index. The cost index was calculated as an index of the average book interest rate. This is not strictly an economic measure, but rather a constant price accounting amount. Good and others (1995) combined the number of aircraft with a price index that also used interest rates, this one based on government

and corporate long-term bonds. Forsythe and others (1986) used a similar approach, but combined capital with other inputs using a Törnqvist multilateral index. Brunning (1991) used the same accounting costs, as well as insurance, maintenance and tax in an econometric modelling approach. Jha and Sahni (1992) used data on airline capital expenditure deflated by a Canadian aircraft and spare parts price index.

Caves and others' (1981) approach was adopted by many other studies in the 1990s: Windle (1991) and Windle and Dresner (1992) used nine aircraft categories, but the same lease price and multilateral index procedures, with international airlines included in the analysis. They used the Perpetual Inventory Method (PIM) for ground property and equipment (GPE) combined with a price index (GDP deflator). Ehrich and others (1994) used an identical approach, also with nine aircraft categories and 23 international airlines. Oum and Yu (1995) also used the same method for both aircraft and GPE, as they did in their subsequent study (1998), and this was also the way that Forsythe (2001) measured capital for his study of Australian domestic airlines. Another recent study by Ng and Seabright (2001) used aircraft numbers and aircraft operating lease rates (published by Avmark from 1987 on, but 1-1.5% of jet values prior to 1987), combined with PPP index deflated materials inputs using the translog procedure.

Good and Rhodes (1991) and Sickles and others (2002) used the average number of aircraft in each airline's fleet multiplied by the average seat capacity to obtain capital inputs in their Data Envelope Analysis (DEA) work. This was an unorthodox approach, which failed to take account of the growing volume of cargo space available in widebody jets. It also did not account for the level of technology associated with aircraft (and thus seats) of various ages.

Baily and Zitzewitz (2001) used a very different approach for their analysis of 24 international airlines: the current values of physical capital stock were depreciated over their remaining useful life to obtain the capital consumption in each year. This had the advantage of taking into account asset vintages, and also the economic lives of existing aircraft. They did not include GPE or IT equipment.

To summarise the above studies, the pioneering Caves and others work in 1981 led to a large number of studies that largely copied this approach. In particular, capital inputs were calculated from aircraft numbers in the fleet by type, the operating lease rates (which were taken to be a proxy for the market price that each type could command), and a procedure that produced an index of capital inputs using the

multilateral translog procedure. The main problem with these approaches was the applicability of aircraft lease rates (these problems were discussed in Section 5.5).

The other approach was based on accounting costs of the various capital inputs, deflated to constant prices, as an approximation to 'volumes', using various aircraft and GPE price indices. Indices used were based on interest rates, aircraft prices and GDP deflators. These methods suffered from the major problems inherent in comparing accounting items, as well as the difficulty in finding an appropriate price index.

7.6 Conclusions

Economic capital consumption measures used both by airlines in devising more appropriate value metrics and academics for productivity studies have been evaluated in the previous sections.

Common problems with the previous measures used by academics were:

- The difficulty in finding an aircraft price deflator that takes into account aircraft age (and also one for other assets)
- The disregard of asset vintages, lives and thus remaining earning capability
- The use of aircraft operating lease rates as a proxy for the market price of a particular asset or aircraft type, regardless of an aircraft's age and airline credit rating

On the other hand, the airline analyses avoid some of the above pitfalls, and, for example, attempt to take into account the future earning capability of their asset stocks, measured in economic terms. They also value stocks in terms of replacement costs or prices.

The approach proposed in Chapter 5 goes a long way towards overcoming the problems encountered in the previous academic studies, while using some of the features of the airline approaches (especially that of British Airways). This approach will be applied both to time-series and cross-sectional airline data in the following two chapters.

8 Productivity and performance: British Airways

This chapter looks at capital investment and productivity over time for one airline, namely British Airways (BA). The next chapter will then compare BA with other major world airlines. All input and output data for BA in this chapter will include its mainline airline operations together with all consolidated subsidiary airlines (eg go, Citiflyer Express and Brymon, once they were majority owned). Most supporting data will also be presented on this basis where possible. For most of the period there was not a large difference between mainline and total group (consolidated) operations.⁵⁷

The selection and measurement of output and input variables is based largely on the discussion and conclusions to Chapters 3 and 5. Before productivity measures are proposed, the development of BA's fleet and other investments will be examined.

The period chosen for the preliminary analysis is 1984/85 to 2001/02. At the start of this period, BA was established as a public limited corporation and had completed the phase-out of its Trident fleet and was strengthening the balance sheet prior to privatisation in February 1987 (see Appendix G for the major events for BA since then). Lord King had taken over as Chairman in 1981 and Colin Marshall had been appointed as Managing Director.

BA faced increasing competition on European routes during the second half of the 1980s, culminating in complete liberalisation of intra-EU routes in 1993. Transatlantic routes were already fairly competitive in the early 1980s, but there was less competition on other long-haul routes. These latter routes often allowed only one UK designated carrier, and in these cases BA was the choice in some geographical regions (eg Asia) and the second UK airline, British Caledonian in others (eg South America). However, in July 1987 BA announced the take-over of British Caledonian, with the two companies merging in April 1988. It from this date that the productivity measures will be developed and analysed later in this chapter.

8.1 BA output definition and trends

Before looking at output measures in more detail, it is helpful to obtain an overview of BA's operations over the period. BA's airline output consisted almost entirely of scheduled services over the whole period (Table 8.1). Passenger traffic dominated the

⁵⁷ Mainline scheduled services accounted for 94% of group operations in terms of ATKs in 1999/2000; The difference was due to the operations of Deutsche BA, Air Libert , CityFlyer Express and go.

total, with freight a by-product to the operation of passenger services. Other services were provided where BA has excess resources and the expertise needed to undertake airline related work for the group (eg handling, catering and maintenance). This section will examine trends in output, first looking at physical measures and then revenue based measures.

Table 8.1: BA Operating statistics, 1984/85 to 2001/02

	Average stage kms	Scheduled route kms (000)	Percent ATKs on scheduled services
1984/85	n/a	521	92.8
1985/86	n/a	555	92.5
1986/87	1,300	555	93.0
1987/88	1,333	692	93.5
1988/89	1,353	677	96.1
1989/90	1,369	685	96.7
1990/91	1,435	665	96.8
1991/92	1,494	584	96.8
1992/93	1,608	599	95.3
1993/94	1,458	643	94.2
1994/95	1,459	743	93.9
1995/96	1,488	767	97.5
1996/97	1,451	759	96.9
1997/98	1,524	769	95.6
1998/99	1,524	686	95.5
1999/00	1,379	678	94.4
2000/01	1,477	739	93.8
2001/02	1,392	n/a	n/a

Source: BA Annual Reports and Factbooks

8.1.1 Physical output measures

Physical output measures use traffic or capacity data, which for many airlines account for a large percentage of total output. Incidental and other group services are not directly measurable in this form and need to be combined with other outputs.⁵⁸

⁵⁸ Physical measures could be developed for numbers of meals sold to third parties or components overhauled, but data would be hard to collect, even with full access to internal airline records; the problem would remain of combining such volume indices with the other elements of output.

Physical units most often used in aggregate measures are available tonne-kms (ATKs) or revenue tonne-kms (RTKs). The first describes production or capacity, and is relevant to those inputs such as flight operations whose effort is related to this, while the second is a measure of traffic, of greater relevance to sales and handling personnel.

Overall, the second is to be preferred over the first, since it is the ability of the airline to convert inputs into sold capacity that is of interest. Those ATKs not sold cannot be stored for later sale, as in the case of manufacturing industries.

RTKs are tonne-kms of traffic (passengers, freight, or mail) that generate revenue. Up to and including 2000, the International Civil Aviation Organisation (ICAO) definition followed by many airlines defined traffic as paying 25% or more of the normal applicable fare for the journey (or rate for the trip). From 2001 on, however, the definition was changed to include passengers travelling:

- Under publicly available promotional offers (eg two-for-one)
- Through the redemption of frequent flyer points
- As compensation for denied boarding

These passengers would previously been excluded if they were on free tickets (or were paying less than 25% of the full fare). Only one year of the period examined is affected. The Association of European Airlines (AEA) is following ICAO in revising its definition from 2001 onwards.⁵⁹

In order to sum passenger and cargo traffic, airlines convert passenger-km traffic to passenger tonne-kms. Standard weights are used internally by each airline. If no such standard exists, the ICAO recommends that 90 kg per passenger is used, to include the weight of the passenger and free and excess baggage (checked and carry-on). This was originally based on an average passenger weight of 70 kg plus 20 kg of baggage.

BA used 90 kg per passenger internally up to and including 1981/82, and in reporting to the AEA, but varying weights for their own reporting from 1982/83 onwards. Thus BA's statistics used for this analysis incorporate an average of just below 92 kg to just above 93 kg from 1984/85 to 1988/89, around 95 kg up to 1994/95, and around 100 kg per passenger since then. This means that, for example, 5% of the increase in

⁵⁹ The new definitions also make it clearer which carrier should report traffic carried under block space agreements: previously this was the airline taking the risk for the sale of the capacity. The new definition requires the operating airline (the one whose flight number is used for ATC purposes) to report all traffic carried on its flight.

passenger tonne-kms over the previous year for 1995/96 of 16% came from the rise in average passenger weight from 95 kg to 100 kg. Given that passengers have a 75% share of total RTKs, 4% of the total RTK increase of 12% in that year came from the revised definition of passenger weight.

Three measures of physical output were developed for BA for the period 1984/85 to 2001/02. These are presented in index form in Table 8.2.

Translog Index: This used the multilateral translog approach developed by Caves et al, (1982) and described in Equation 2.10 in Section 2.2.1. The index combines BA's passenger tonne-kms (scheduled and charter together), revenue cargo tonne-kms and incidental services into one index using revenue share weights. Incidental service revenues were indexed and deflated using the UK RPI.

Equivalent RTK Index: This approach summed RTKs by traffic type (scheduled passenger tonne-kms, charters tonne-kms, cargo tonne-kms), together with equivalent RTKs for incidental services calculated by dividing each year's revenues by BA's total revenue from traffic (RTKs) by RTKs performed (yield).

Equivalent RTK Index weighted by revenue shares: This approach combined passenger tonne-kms, cargo tonne-kms and equivalent RTKs for incidental services (calculated in the same way as the equivalent RTK index above) using revenue share weights.

Table 8.2 shows that BA's output has increased by something approaching three times over the 17 year period using the two indices based on converting incidental revenues into equivalent RTKs. The more complex translog multilateral index grows only slightly slower than the others over the whole period, and this is because of the lower weight that it ascribes to the faster growing freight traffic. Thus for time-series analysis (at least for airlines with a large passenger share), it does not have the distinct advantage over the other forms of index that it has for cross-section and panel data, where chaining is not possible. The table also shows that BA's output growth slowed considerable after the Gulf War, but did not decline. However, following 9/11 and the economic downturn, BA's output fell by around 10%: this was due to their change in strategic direction (no longer targeting very low yield market segments), as well as the more drastic impact of 9/11 compared with the Gulf War on the North Atlantic (which by March 2001 accounted for 47% of BA's total passenger-kms compared to 35% in 1989).

Table 8.2: BA physical output indices

	Translog Index	Equivalent RTK Index	Equivalent RTK (revenue weighted)
1984/85	100	100	100
1985/86	108	108	107
1986/87	114	115	106
1987/88	132	136	128
1988/89	150	157	156
1989/90	163	170	170
1990/91	169	177	179
1991/92	171	180	181
1992/93	191	201	204
1993/94	213	223	225
1994/95	228	242	240
1995/96	258	269	277
1996/97	276	289	295
1997/98	287	306	308
1998/99	314	333	341
1999/00	314	339	339
2000/01	313	340	339
2001/02	277	298	301

Source: BA Annual Reports and author's calculations (see Appendix H).

In addition to passenger weights, there are also the problems of standard of service and traffic mix, which were discussed in Section 3.2. First, one passenger-km recorded by an airline focusing on business traffic, say, Austrian Airlines, would be expected to be of better quality or standard of service than a leisure or low cost carrier. Furthermore, BA's 1980s first class passenger-km would be of lower quality than the flat bed product offered from 1995 onwards. Second, the passenger-km total hides a variety of traffic mixes, for example between premium and economy travellers. This mix would be different across airlines, and for one airline over time, and passenger-kms do not capture such differences.

Passenger-kms or RTKs could be adjusted for quality and product mix by comparing actual seats offered in each aircraft type against a high density standard maximum based on cabin volume and safety requirements. For example, BA operates their A320s with 149 seats compared with the maximum all-economy configuration of 180 seats. The percentage difference (21% in the A320 case) between the airline configuration and the maximum provides a measure of relative comfort, which takes into account both seat pitch and the distribution of seats by class or cabin.

This measure was developed for the whole of BA's fleet in 1995: the number of seats for each of the aircraft in the fleet in actual and maximum all-economy configuration were weighted by annual block hours flown, and the maximum exceeded the actual by an average of 40.8%.⁶⁰

In other words, the weighted average number of seats could have been increased by 40.8% by reducing the seat pitch to a high density, all-economy configuration (29-30 inch seat pitch throughout each aircraft). For the mainline fleet, the difference was 41.7%, while for the TAT and Deutsche BA fleet it was only 14.4%, since the latter's aircraft were already in quite high density configuration.

The use of aircraft hours for the weights was dictated by data availability; however, this data reflected the split between long- and short/medium-haul revenues very closely for BA in 2001/02 (62.5% seat-hours on long-haul services compared to 61.5% of revenues earned from long-haul destinations).

The same measure was calculated for the BA fleet in 2001/02, when the fleet mix, mix of seats by cabin and seat pitch had largely been changed to conform to the new strategy. In that year the seat comfort factor had increased to 65.3%. The increase from 42% in 1995/96 to 65% in 2001/02, or 16%, was due to:

- An increase in the share of total block hours accounted for by the B747-400 and B777 aircraft from 17% to 39%
- A significant reduction in seat density for both these aircraft types (from an increase in seat pitch and a greater proportion of premium seats)

BA's change of strategy has led to a change in long-haul aircraft mix from 14 B767-300s, 31 B747-100/200s and 32 B747-400s to 6 B767-300s, 43 B777-200s and 56 B747-400s. This would be likely to lead to higher frequencies, and thus a higher quality of service, but does not indicate seat comfort. This is shown in Table 8.3 for the B747-400, where it can be seen that the mix of seats has changed significantly towards business and economy plus, which was combined with extra legroom in the premium cabins. The average seat pitch (weighted by numbers of seats) for the B747-400 was 34.6 inches in 1995, and this increased to 38.2 inches in 2001/02 (assuming the first class bed offered about 80" pitch).

⁶⁰ Data on block hours by aircraft was obtained from British Airways' annual report from 1995/96; data on seat configuration for each aircraft type was taken from BA's 1995 Factbook, cross-checked against JP Fleets for 1994/95 (data from ICAO Digest of Statistics: Fleet-Personnel was considered too unreliable).

Seat comfort is the major element of quality for long-haul passengers. A business traveller survey revealed that 66% of respondents rated seat width, pitch and comfort as the highest priority, with airport lounges only mentioned by 21%, ticket flexibility 18%, speed on the ground 18% and in-flight catering 15% (IATA, 1996). Extra comfort and legroom was ranked fourth in another survey of all passengers on both long-haul and short-haul flights, after schedule convenience, reputation for safety and punctuality (OAG, 1998).

Table 8.3: BA's configuration for the B747-400 fleet

1995/96			
<i>Seats:</i>	<i>Standard</i>	<i>Lite</i>	<i>Pitch (")</i>
First	18	18	62
Business	64	68	40/50
Economy plus			
Economy	318	340	31
Total	400	426	
No. of aircraft	28	4	
2001/02			
<i>Seats:</i>	<i>Standard</i>	<i>Hi</i>	<i>Pitch (")</i>
First	14	14	bed
Business	38	70	73
Economy plus	36	30	38
Economy	263	177	31
Total	351	291	
No. of aircraft	52	4	

Source: BA annual reports, Factbooks and JP Fleets

It should be noted that not quite all B747-400 aircraft were equipped with the new configuration by the end of the 2001/02 financial year. A major product change such as this can only be completed over a number of years: new aircraft will have the new configuration, but existing aircraft have to wait for major maintenance checks to be performed. The re-structuring of the short/medium haul fleet was started more recently and will not be complete for a year or so.

The decline in physical output of 12% between 1999/2000 and 2001/02 should be viewed against an increase in the 'quality' index based on seat pitch of 16%, albeit over the slightly longer period needed to convert all the aircraft to the new configuration.

Other components of the quality index were also considered, such as reliability and punctuality. These did not change significantly over the period, and were thus excluded (see Section 3.2).

8.1.2 Revenue based output measures

With revenue based output measures, it may appear relatively simple to combine the outputs of differing units into one total. However, it is often difficult to find the right price deflator to remove any price effects, a necessary step for productivity estimation. Furthermore, BA earn around 60% of its revenue output in foreign currencies, and thus market exchange rates (which are a form of relative price adjustment) will have been used before gross output totals can be calculated.

Gross revenues are recorded in local currencies for accounting purposes at the market exchange rate prevailing at the time of sale. International accounting standards (IAS 18) state that 'revenue from service transactions should be recognised when there is no significant uncertainty regarding the consideration or the associated costs from rendering the service to which it relates'.⁶¹ For most airlines, this is when the transportation takes place. Revenues reported in local currency will thus reflect the use of exchange rates applied to sales in many different currencies (over 100 in the case of BA) at various times over the year.

BA report the average rates of exchange used in calculated revenues in local currencies, as well as end year rates for balance sheet conversion. These are between the pound sterling and its major trading currencies (the US dollar, Euro, Japanese Yen and Australian dollar). For international reporting (for example for the ICAO Digest of Statistics, Financial Series), BA and other airlines will convert their local currency amounts to US dollars, and show the average rate used.

A second series of problems related to revenue figures concern what is included. When the ticket is sold through a travel agent, the airline records it as gross revenue and includes a commission to the agent under operating costs. However, increasingly, airlines such as BA are offering some agents a net or discounted fare, which the agent then marks up to its corporate or retail customer (in order to earn a profit).

⁶¹ IATA/KPMG (1996b), p.4.

The net fare is used by the airline for revenue accounting, with no commission reported under costs. A greater use of net fares (and direct internet sales by-passing agents) will lead to lower output and lower costs (commissions) than would be the case under the traditional business model. This could distort partial productivity ratios, and possibly lead to some distortions when airlines incorrectly net commissions against revenues. It also points to a preference for traffic based output measures.

There may also be some confusion as to where to report in-flight sales or excess baggage. These should normally be reported under passenger revenues, but may be included in other revenue or cargo revenue (excess baggage charges). These problems (discussed in Section 3.4) could affect partial ratios and in any case the choice of deflator to use.

Table 8.4: BA revenue based output indices

	Gross Revenue Index (1)	Gross Revenue Index (2)	Value Added Index(3)
1984/85	100	100	100
1985/86	108	107	106
1986/87	111	111	98
1987/88	135	130	147
1988/89	146	146	161
1989/90	164	155	232
1990/91	160	160	274
1991/92	183	164	311
1992/93	184	183	298
1993/94	213	210	323
1994/95	245	227	413
1995/96	265	244	460
1996/97	288	260	527
1997/98	308	274	556
1998/99	327	303	589
1999/00	314	306	625
2000/01	302	298	630
2001/02	275	257	577

(1) Gross revenue in sterling deflated by overall yield per RTK (index)

(2) Passenger revenue deflated by passenger yield, cargo by cargo yield indices, and incidental revenues by UK RPI; composite index weighted by revenue shares

(3) Gross revenues deflated by yield per RTK less third party input costs deflated by UK RPI

Source: BA Annual Reports and author's calculations (Appendix H).

In order to convert revenue output to volumes or quantities, a suitable price deflator needs to be applied. This should track changes in the average prices of the outputs under consideration. For airlines, the average yield per RTK in local currency could

be used, or the yields for passengers and cargo separately.⁶² The former was applied to total revenues for the gross revenue index in the second column of Table 8.4.

Value added is defined as gross revenue less input costs paid to third parties. This is a potentially more useful measure than revenues, but ignores the price and productivity changes that take place for such inputs as fuel and airport charges. Deflating these values is more complex, since gross revenues should be deflated and also the inputs that are deducted from them (see OECD, 2001b, p.33 on double deflation). This procedure is followed for the index shown in column four of Table 8.4.

The reason that the value added index increases faster than any other is because output prices have showed little increase over the whole period, whereas the input price deflator used here has increased. Thus gross output has not been reduced much by inflated prices, while significantly deflated inputs have been deducted from them. This reduces the usefulness of value added output measures, at least without obtaining better data on input price changes.

The deflator used for gross revenues is BA's yield index. This is supposed to represent movements in price from year to year for the same product. It would 'remove' price change elements from output to give 'volumes'. The problem with yield is that, in addition to reflecting the price change for a seat of given quality on a sector of fixed length, it also takes into account:

- Changes in the mix of sector lengths operated and sold
- Changes in mix of passengers across a range of seat quality
- Changes in output mix between passengers and cargo

BA's average sector length operated has not changed significantly over the period studied (Table 8.1). The average passenger trip length was 2,406 km in 1984/85, and 2,656 km in 2001/02. This indicates the incidence of multi-sector flights, but does not capture the effect of passengers buying a ticket which involves a transfer at the hub airport. This involves two coupons, and the passengers are counted separately on the two sectors. Yield, however, is reduced since the first sector is often offered at very low price. This type of traffic increased rapidly for BA in the second half of the 1990s, but has recently been cut back.

⁶² Some distortions would still remain if the exchange rates used to switch foreign sales to local currencies were significantly out of line with its PPP equivalent, as is the case currently with South African and Australian sales.

Yield could also be depressed by a shift of traffic from higher to lower quality seats. This would reduce the deflationary impact on output, but the higher output would be of lower average 'quality' than previously (and vice versa). Yield could also be depressed by the faster growth of air cargo, which tends to be much lower rated than the passenger output. This would also raise output volumes and reduce the resources required to service the output.

Monetary indices only have an advantage over traffic based ones if they are able to reflect output quality changes. BA's output quality has undoubtedly increased since 1998, both because of changes in traffic mix and also in increased product quality. The financial year 2001/02 is distorted by the 9/11 impacts, but the change between 1998/99 and 2000/01 should reflect both unchanged levels of traffic (passengers down slightly and cargo up) and an increase in quality. The monetary indices developed in this section fell by between 2% and 8% (leaving aside the value added index). This was because the price index used (yield) was not quality adjusted, and rose with increased quality of product (the premium that passengers paid) and a change in mix to higher yield traffic (Forsythe, 2001, also faced this problem).

A better way of constructing a price deflator for application to revenue outputs would be to develop a price index for each type of product (first, business, full economy, economy) and adjust it for quality changes. Thus if first class fares paid rose when flat beds were introduced, this increase would be removed from the price index (see Gordon, 1990). The true 'price' index could then be constructed by weighting each product by traffic share. Such an index would be extremely difficult to develop, since data on actual fares paid after discounts by product type can only be obtained by surveys of passengers (and may still be problematical).

Similar comments apply to cross-section analysis, with an added dimension of the need to convert monetary values in different currencies to a common yardstick. PPP exchange rates would do this, but they would need to be based on air fares, and not the goods and services included in the published series.

8.1.3 Preferred output index

From Table 8.2 and Table 8.4 it can be seen that (leaving aside the distorted value added index) both 'volume' output indices based on gross revenues increased somewhat slower than those based on physical output or RTK equivalents (although not the multilateral translog index), over the period as a whole. They are closer up to

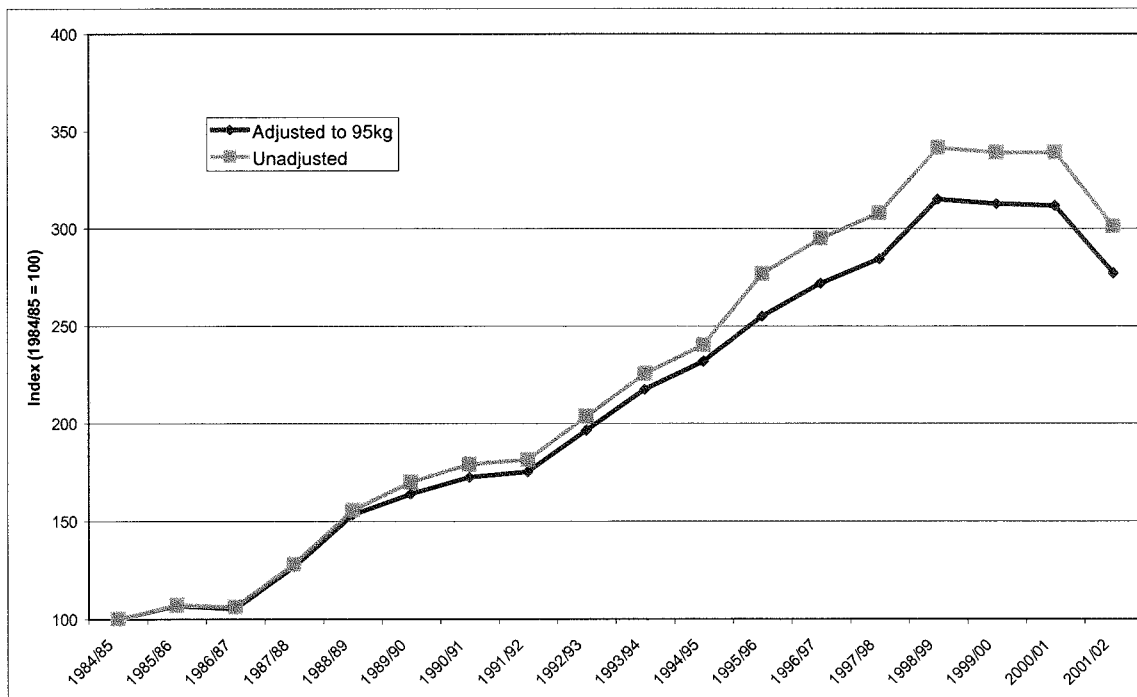
1998/99, when BA's new strategy focusing on higher yield passengers started to take effect, after which the monetary measures lose ground.

Physical measures are generally preferred over monetary ones because:

- Revenues are an aggregate of many foreign currencies converted to the local reporting currency at market rates of exchange that may not reflect relative purchasing power parities (leading to possible distortions when deflated)
- Physical measures can to some extent be adjusted for output quality, whereas econometric techniques need to be applied to revenue based ones
- Data is not available to construct a 'correct' revenue deflators which properly compares identical output in each period

Incidental revenues need to be converted to physical 'equivalents' using average airline yields, at least for airline related services. Other incidentals could be deflated by producer price indices and combined with traffic indices using revenue weights (although this split of incidentals is not often reported).

Figure 8.1: BA RTKs with/without standardisation of passenger weight



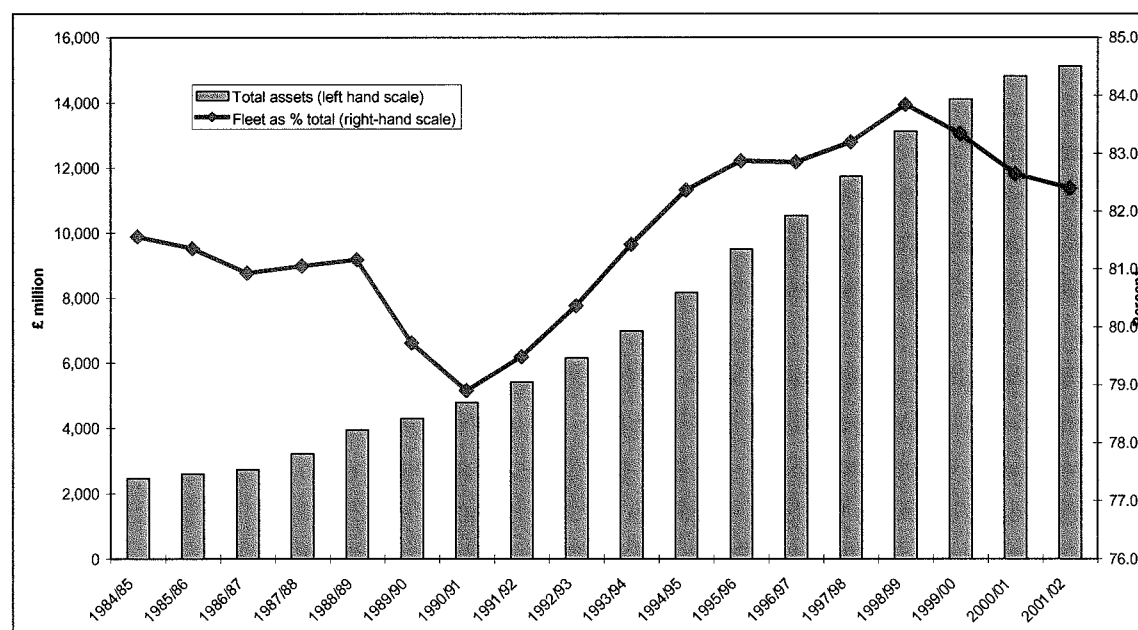
Source: Revenue weighted equivalent RTK index in Table 8.2, and the same index adjusted for standard 95 kg passenger weights (Appendix I).

Care should be taken to adjust for changes in average passenger weights, where such changes are merely changes in reporting (see Figure 8.1), otherwise passenger kms could be used in index form. Quality is difficult to address over time, but cross-sectional adjustments might be made to reflect output mix and standard of service. Thus, passenger-kms or passenger RTKs could be adjusted for quality and product mix by comparing actual seats offered in each aircraft type against a high density standard (maximum based on cabin volume and safety requirements. This could be done for one or two years (for a cross-section of airlines), but it is doubtful whether data is available for a longer time series analysis.

8.2 BA asset accumulation and investments

This section examines BA's gross assets, in particular for their fleet, and related investments over the period, before addressing measures of capital input. Immediately prior to privatisation, no major changes occurred in BA's fleet, with no net increase in aircraft in 1985/86 and an increase in fleet size of only six aircraft in 1986/87.

Figure 8.2: BA Gross asset accumulation, 1984/85 to 2001/02 (£ million)



Note: Annual data is an average of beginning and end year positions; Source: BA Annual Reports

Figure 8.2 shows that the value of BA's gross assets increased at 11.3% a year between 1984/85 and 2001/02, with a slightly higher growth rate recorded during the economic upswing following the Gulf War. The right hand scale gives the share of

fleet assets in the total. This figure has not changed very much over the period, with a decline to just below 80% following the acquisition by BA of the second, much smaller, UK airline British Caledonian. The latter's gross fleet assets were only 61.2% of total assets,⁶³ such that combining the two airlines resulted in a drop in the fleet share. The relatively low fleet share for British Caledonian was due to the substantial investments in non-airline subsidiaries such as training, hotels and tour operations. Most of these were subsequently sold.

Gross fleet assets are normally valued in the balance sheet at historical cost, with the original cost of old aircraft deducted upon their retirement, and the new aircraft added at cost. Thus, when aircraft are retired, there will be a reduction in gross assets, albeit at the prices applicable at the time of original purchase, probably 20 years or more previously.

However, BA re-valued most of its fleet when it acquired British Caledonian, and the new values were put in the balance sheet at the end of 1987/88. Market values for the combined fleet were estimated by Avmark International for each aircraft type. Newer B747-200s and B757s were valued on the balance sheet at close to their market values, and were thus left unchanged. Most of the B747s, all B737s, Tristars and BAC 1-11s were together increased by £277 million in the books.

BA's gross assets increased somewhat faster in US dollars in the earlier part of the period up to 1990/91, as the pound strengthened against the dollar. In the past few years this trend has reversed, such that the dollar indices of gross assets in 2001/02 were broadly the same as in 1998/99. BA have a good balance of US dollar revenues and expenditures (including aircraft debt servicing and interest payments), such that most of the £/US\$ exchange rate risk is hedged naturally.

Other tangible assets are split between 'property' and 'equipment'. Property comprises offices, buildings and hangars. Prior to April 1995, the majority of these were short leasehold (57% of the net book amount), with a further 26% being freehold. However, BAA granted BA 150 year leases on 224 acres at and adjacent to their Heathrow maintenance base. Thus BA revised their valuation of these properties at 31 March 1995 to an open market basis, with an additional £136 million added to gross assets.⁶⁴ As at 31 March 2002, the net book amount of properties comprised short leasehold (44%), long leasehold (32%) and freehold (24%).

⁶³ British Caledonian Group, Report and Accounts, 1986, p.38.

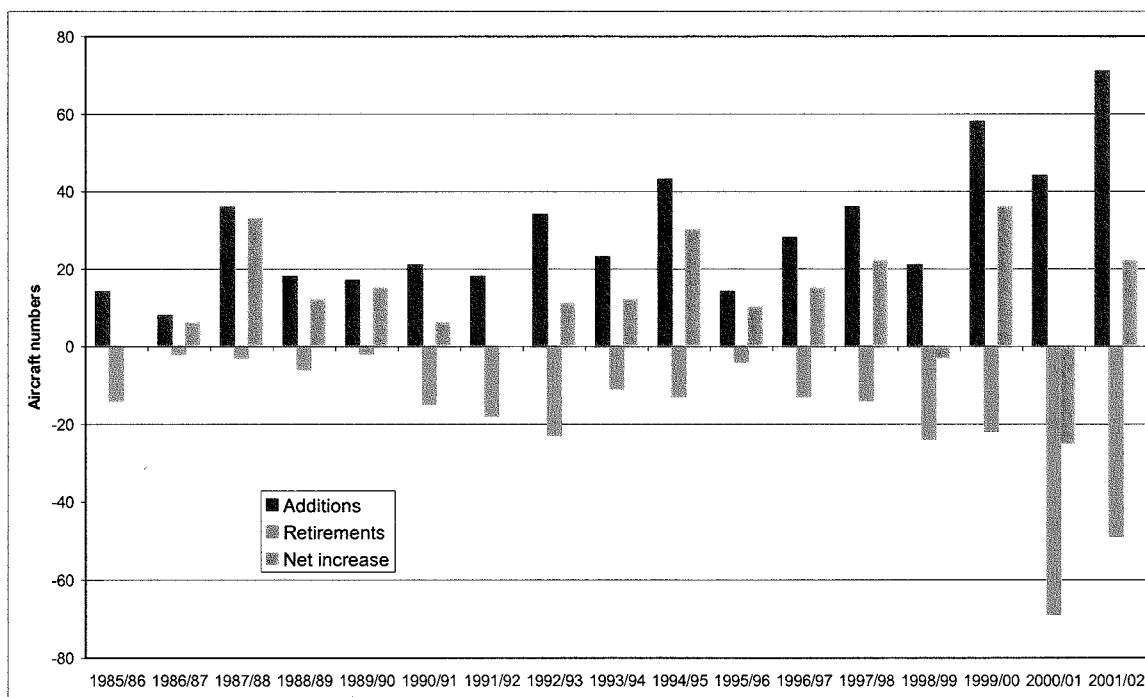
⁶⁴ British Airways Factbook 1996, and Annual Report 1994/95

The application of accounting standard FRS5 in 1995 led to BA bringing 24 aircraft onto the balance sheet from extendible operating leases. These were 13 B747-400s, seven B767-300s and four B737-400s. This meant that balance sheet gross tangible fixed assets increased by £870 million at 31 March 1995. These ‘new’ assets were treated in the same way as finance leases (depreciation and interest), and operating lease rentals declined as a result.

Financial investments are also valued for balance sheet purposes, but have been excluded here, since they are claims on the assets of other associated corporations. These associate companies are excluded both in terms of capital inputs and airline or other service outputs.

As explained in Chapter 5, BA’s intangible assets were only valued for balance sheet purposes from 1998 onwards. Before then, intangible assets were written off against reserves. For example, when BA acquired British Caledonian they paid £353 million more than the value of its net assets, after allowing for related investments and adjustments. This goodwill amount was written off against BA’s reserves in 1987/88, rather than being amortised over subsequent years (as would have been the case in the USA). It has, however, been excluded from this analysis (see Section 4.2).

Figure 8.3: BA fleet additions and retirements, 1985/86 to 2001/02

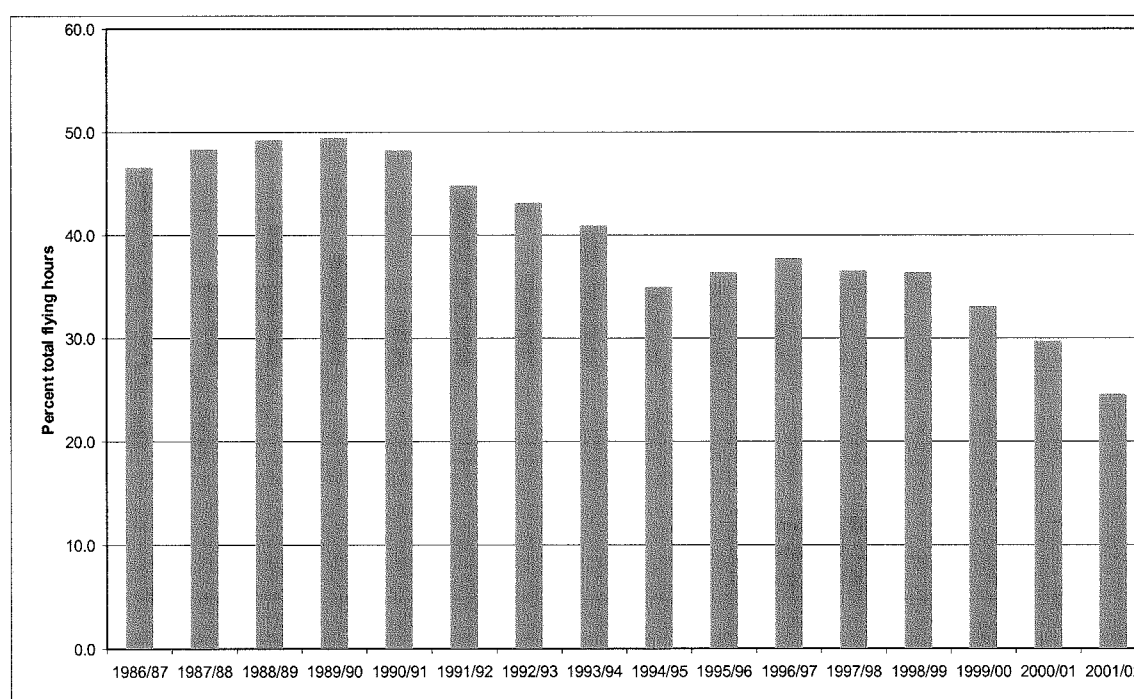


Source: BA Annual Reports

Figure 8.3 shows the net new investment in fleet assets for BA in each year since 1984/85, and also the fleet additions and retirements over the period. It should be noted that over half of the increase in 1987/88 was due to the fleet revaluation. Gross fixed assets did not show much evidence of a cyclical downturn in the early 1990s, partly because of the time lag from orders to deliveries, but more importantly because of the weakening of the £ sterling. This inflated balance sheet values, at a time when BA was cutting back on any new investment. BA had already started reducing capital expenditure prior to 11 September in US\$, but again, with a weak £, this was not that obvious from the balance sheet. It was also not reflected in aircraft deliveries (see Figure 8.3), which continued to rise because of the time lag and greater emphasis on smaller, less costly, aircraft.

Years of large numbers of additions to the fleet were 1987/88, when the BAC1-11 and B747-200 fleets were expanded, 1992/93 with the arrival of B757s, B767s and B737-400s, 1994/95 adding extra turbo-props, and the last few years with B777s, A319s and regional jets. The largest retirements years were 1985/86 (Tridents), 1992/93 (BAC 1-11s), 1998/99 and 1999/200 (both B747-100s and B737-200s) and the past two years (B747-200s and B757-200s).

Figure 8.4: BA percent total flying hours operated by 3/4 engaged aircraft



Source: BA Annual Reports (and Appendix K)

Figure 8.4 shows the decline in number of 3 or 4 engined aircraft operating BA's services. This declined from 47% in 1986/87, with the Tristars still in service, to only 25% in 2001/02, with only B747s in this category. The percentage temporarily increased over the two years 1995/96 and 1996/97 with the acquisition of two additional B747-400s and three DC10-30s, but the latter were soon to be completely retired from service. The twins that replaced them (B767 and B777) could operate long-haul services and provide savings in labour, fuel and other inputs.

8.3 BA use of operating leased aircraft

Prior to privatisation in 1987, the UK government imposed capital spending limits on the airline of £250 million a year. Thus, leasing was at that time the only option for acquiring additional aircraft to replace the old and inefficient Trident fleet, as well as replacing Tristars by more efficient B747s.

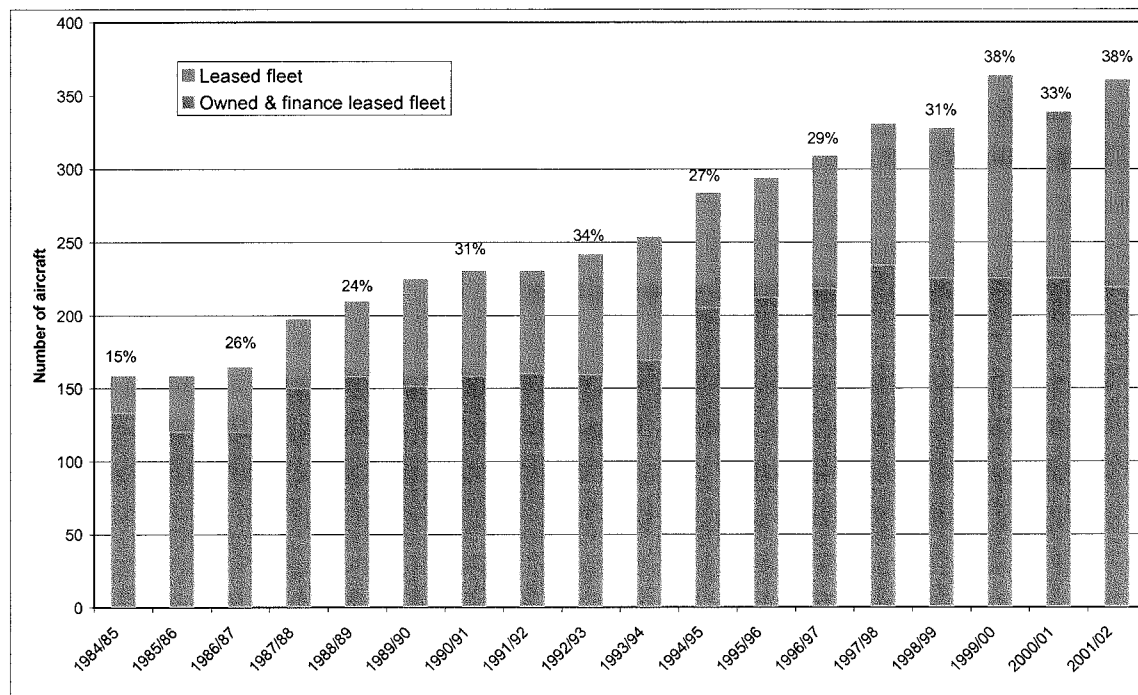
Short-term operating leases tend to be expensive, and so BA arranged to take mainly new B747s and B757s on extendible operating leases. The first ones covered B747-200s and ran for a term of 23 years, with break points at five-year intervals when the aircraft could be returned or the lease rates renewed. The five-year breaks meant that the leases could at least initially be treated as short-term leases and be kept off the balance sheet.⁶⁵ A total of 66 aircraft were acquired on this basis by the peak year of 1991/92.

Some existing aircraft were also sold and leased back short-term (20 B737-200s in the early 1990s), and were thus taken off the balance sheet. Other aircraft such as the B737-300s were acquired on normal 5 year operating leases. The total fleet, and the share of aircraft acquired under extendible (those still allowed to be off balance sheet) and normal operating leases are shown in Figure 8.5. It can be seen that the percentage of leased aircraft has steadily increased to reach almost 40% in 2001/02.

Excluding the extendible operating leases which are still permitted to be placed off balance sheet, operating leased aircraft for BA currently account for just under 30% of the total fleet numbers. Rental expenditure for these aircraft gives a good estimate of capital consumption in any year. For owned aircraft, the equivalent lease amount needed to be determined so that total capital input from these aircraft could be estimated (this will be done in Section 8.4.5).

⁶⁵ A change in UK reporting requirements led to their being placed on the balance sheet in 1995

Figure 8.5: BA leased and owned aircraft, 1984/85 to 2001/02



Source: BA Annual Reports

Table 8.5: BA leased aircraft and average monthly rental

	Av.monthly rental (£000)	Number of leased aircraft
1984/85	41,667	24
1985/86	137,387	37
1986/87	166,667	43
1987/88	204,710	46
1988/89	206,667	50
1989/90	207,176	72
1990/91	333,333	71
1991/92	285,024	69
1992/93	230,453	81
1993/94	194,779	83
1994/95	142,857	77
1995/96	117,708	80
1996/97	111,423	89
1997/98	111,404	95
1998/99	123,762	101
1999/00	115,572	137
2000/01	164,435	112
2001/02	118,452	140

Source: BA Annual Reports

The average monthly rental payment shown in Table 8.5 reflects both the market lease rates, and the share of larger, long-haul aircraft in the total. The sharp drop in 2000/01 leased aircraft was partly due to the end of 13 B737-200 leases, which pushed the average rental higher. The decline in average rental rates in the first part of the 1990s was due to a softening of rates and the termination of some more expensive B747-400 extendible operating leases.

As already mentioned, in 1994/95, 24 aircraft on extendible operating lease were put on the balance sheet and this explained the drop both in numbers of aircraft on lease in that year and the average (20 of the 24 were long-haul aircraft with relatively high lease rates).

8.4 BA capital inputs

8.4.1 Fleet: capital stock

BA's fleet has been acquired by three different methods over the past 20-30 years: ownership, financed by cash or finance leasing, operating leases and hire or charter. The first currently accounts for over 80% of the total value, and is financed by a mixture of long-term finance (leveraged) leases (79%), and various bank loans in a number of different currencies (21%). It also includes hire purchase finance or Japanese Leveraged Leases (JLLs) that were popular in the early 1990s. The second, operating leases from companies such as ILFC and Gecas, was more important in the earlier part period. The third consists of very short-term charters or wet leased aircraft from third party suppliers, or from other airlines.⁶⁶

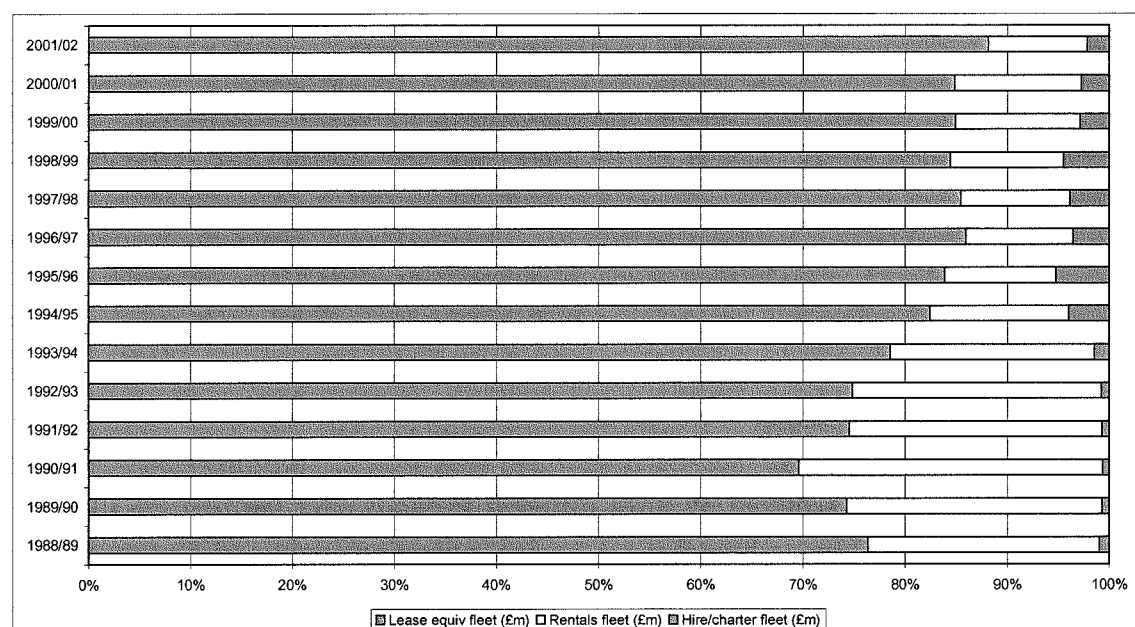
Aircraft on hire or charter include some labour, maintenance and insurance elements, since the contract would include cockpit crew and possibly cabin crew. It is difficult to remove these costs, without knowing the specifics of each contract. The cost of these aircraft has been taken from the operating accounts for each year, in current pounds sterling, and an estimated 30% has been taken of these costs to account for capital, and a further 30% for labour.⁶⁷

⁶⁶ An example of this was the charter by BA from US Airways of a B767 for Gatwick/Pittsburgh services; the aircraft was in BA livery, staffed by US Airways cabin attendants in BA uniforms.

⁶⁷ This was arrived at after looking at the US Form 41 aircraft operating costs for both 1996 and 2001. The percentage of capital in total aircraft operating costs for the B737-300 (the type of aircraft BA might have chartered) declined over that period from 35% to 30%, and the lower estimate was taken to account for older aircraft and any costs that had been missed.

The cost of aircraft on operating lease is also shown in the notes to the accounts under 'aircraft operating lease costs', and this has been taken to be the current cost of such aircraft.

Figure 8.6: BA fleet value by method of acquisition



Source: BA annual reports (Appendix J)

The remainder of the fleet are placed on the balance sheet, and the current 'consumption' of these assets shown as depreciation and interest in the profit and loss statement (interest is also implicit in both leased and charter costs). The way the annual capital cost is split between these three forms of acquisition is shown in Figure 8.6, with the marked reduction in operating lease rentals evident (although somewhat artificial due to the reclassification of extendible leases).

Depreciation and interest costs indicate the accounting consumption or cost of assets, but not the economic cost, since this would need to be based on the opportunity, rather than historic costs of the assets. There is also the problem of what level of interest costs to include, since not all borrowing is directly attributable to fleet financing.

The approach taken here is to estimate the value of fleet assets in baseline (1988/89) prices, and to determine the amount that these assets could command by way of a capital lease over their remaining life (see Section 5.8.1). This has been done using

the total fleet assets and average age of the fleet, rather than looking at each aircraft in the fleet, its current cost and age. The latter approach would be very time consuming to undertake for each year, and published values for aircraft (especially long-haul types) are not altogether reliable (see Section 5.5.2).

The task of valuing the total BA fleet was made somewhat easier by the fact that the whole fleet was re-valued in April 1988, and thus placed on the balance sheet in *current market*, rather than *historic* prices at that date. This provided the starting point, and each year's net additions to fleet assets were added to this figure after being converted in each year to baseline prices by means of an aircraft price index. This approach avoided using either the values of aircraft published by appraisers, or 'so-called' market lease rates, which had been used in a number of other airline productivity studies, and did not reflect the present value of the future net revenue streams that the aircraft could command.

The major problem is thus the choice of price index, which can be used either to get back to baseline prices, or to project forward to current prices. The relevant price here is the cost of obtaining an aircraft of similar characteristics to the ones in the BA fleet at replacement or current market prices. There are a number of candidates (discussed in Section 5.5):

- The US BLS index of aircraft prices (US dollars)
- The cocktail of indices used by both Boeing and Airbus (P_a in US\$)
- An index of appraisers' values for a representative aircraft, or weighted average of a number of types

The first index (BLS) is supposed to track changes to the selling prices of new aircraft, adjusting where possible for quality changes. This is based on the net proceeds ultimately realised by the manufacturer, and thus should include discounts. It therefore should take into account the supply/demand balance (cycles) as well as technical obsolescence of some of the manufacturers' product lines. The US department of labour reported that the use of list prices by respondents originally covered only 20% of such indices, but this share is now much reduced under their new reporting system.⁶⁸ It is, however, an average of all aircraft types and equipment forming part of those aircraft, weighted by values of shipments of each of the constituent products. It is only available for Boeing aircraft, although this would cover the majority of BA's fleet over the period examined.

⁶⁸ Bureau of Labor Statistics website ../#description of survey, September 2002

The second index (P_a) tracks changes to the costs of manufacturing aircraft. Again, this index is based on US conditions, and perhaps not appropriate to Airbus products. The index is obviously cost based, but as such does bring the historical costs of aircraft to current prices. Taking a B737-200 as an example, it would allow a fair price to be calculated for the old technology aircraft in current prices, even though production of this type has long been discontinued.

The third possible index would be one derived from appraisers' valuations of one or more aircraft over time. The problems with using these values were discussed in Section 5.5, and it would be difficult to use these for long periods where one type was not operated continuously. Widebodied and narrowbodied aircraft prices tend to react differently to a change in the demand/supply relationship, and so any index would need to incorporate both series.

The most plausible index to be used for inflating the historical costs of aircraft to current prices is the one used by aircraft manufacturers to increase their prices between contract signature and delivery. This was discussed in Section 5.5.1 and is calculated in Table 8.6 (P_a), where it is compared with the BLS and two sterling price indices. There is surprisingly little difference between the two aircraft indices, and even the UK GDP deflator. But the BLS moves ahead rather too strongly in the early 1990s at a time when higher discounts were offered to airlines. It is questionable whether these were incorporated into the index.

Table 8.6: Alternative price indices

	P_a	BLS aircraft	UK CPI	UK GDP deflator
1988/89	100	100	100	100
1989/90	105	103	108	107
1990/91	109	109	118	115
1991/92	112	115	125	122
1992/93	115	120	130	126
1993/94	117	123	132	129
1994/95	120	126	135	130
1995/96	124	130	140	133
1996/97	127	133	143	136
1997/98	127	135	147	139
1998/99	126	136	152	142
1999/00	129	137	156	144
2000/01	137	141	159	146
2001/02	141	146	163	148

P_a is a weighted index of US labour and materials prices

BLS aircraft is an index of new aircraft and related equipment published by the US Bureau of Labor Statistics

Source: OECD Economic Outlook, UK National Statistics and BLS

Pa was applied to the US dollar value of BA's gross fleet assets at market prices, and subsequent net additions, to obtain the fleet value in current US dollars. This is then switched to UK pounds by applying BA's annual average US\$/£ exchange rate in the base year (1988/89).

Table 8.7 compares the gross value of BA's fleet using historical book prices and current prices, using the PIM method described above (which assumed that retirements were subject to 'sudden death'). The two values are close together in 1988/89, one year after the fleet had been re-valued at market prices. Inflation and few additions to the fleet increased the difference in the early 1990s, after which it narrowed first as a result of large additions to the fleet and more recently as inflation slowed significantly. BA's strategy director gave an estimate of their fleet value at current prices of £17.6 billion at a presentation to investors in March 2001. This provides a useful cross-check with the above figures.

Table 8.7: Gross value of BA fleet: current vs historical prices

£ million	Current prices	Historical prices	Ratio A/B
	(A)	(B)	
1988/89*	3,370	3,203	1.05
1989/90	4,109	3,426	1.20
1990/91	4,794	3,773	1.27
1991/92	5,514	4,302	1.28
1992/93	6,508	4,940	1.32
1993/94	8,276	5,681	1.46
1994/95	8,626	6,720	1.28
1995/96	9,367	7,875	1.19
1996/97	10,681	8,722	1.22
1997/98	11,801	9,765	1.21
1998/99	12,864	10,993	1.17
1999/00	14,163	11,753	1.21
2000/01	16,357	12,244	1.34
2001/02	17,929	12,449	1.44

* the starting point was 1 April 1988; first year totals are averages for the year 1 April 1988 to 31 March 1989, and thus current and historical price amounts are not identical.

Source: BA annual reports and author's calculations

BA has adjusted gross book fixed assets (including property and equipment) to current values for Cash Value Added calculations (see 7.1 for an assessment of their

approach), although they use new rather than used market values.⁶⁹ For their financial year 1997/98, they used a ratio of 1.26:1 for all depreciating assets, including aircraft on operating lease, which are excluded from Table 8.7. This is only slightly higher than the ratio given here, which casts doubt on whether they actually used new aircraft prices. They calculated the same ratio for 1999/2000 to be 1.16:1, lower than the ratio given here. However, the 1.16 ratio was based on the use of GDP deflators, rather than any consideration of replacement aircraft prices. Table 8.6 shows that the UK GDP deflator has over the past ten years risen somewhat faster than the aircraft cost index, but lower than UK prices in general. Thus one would have expected the BA asset inflation factor to be higher.

SAS is the only airline that has published figures for market and book values of their fleet since the early-1990s. The ratio of market to book value increased from 1.07 in 1991 to 1.45 in 1999, before falling back to 1.08 in 2001 (see also Figure 7.1). This is a similar range to BA, but with a cyclical pattern that appears to be more in step with the economic and airline industry cycles. This is because the prices are adjusted by market, rather than cost trends, and the recent collapse of aircraft prices is reflected in SAS's 2001 ratio.

8.4.2 Fleet: capital flow

The indexation procedure is designed to adjust the value of the stock of capital, from which an annual flow can be derived over the aircraft's remaining useful life. Thus, it is intended to arrive at a realistic valuation to form the basis for leasing the aircraft for a further period of between 1 to 25 years. In BA's case this averaged out at a further 15 to 18 years between 1988/89 and 2001/02.

Market operating lease rates tend to overreact to short-term events, and thus do not adequately reflect the longer term earning power of the majority of the fleet. They might be appropriate to BA's older B737-200s at the time when they were over 20 years old, but they would understate the value of the newer aircraft. It should be remembered that the value of the aircraft should reflect the discounted present value of its future earnings. In a major downturn, such as the one just experienced, earnings are depressed for two or three years, but they increase above trend over the subsequent upturn. Thus, the flow of capital services reflects the market lease rental that the

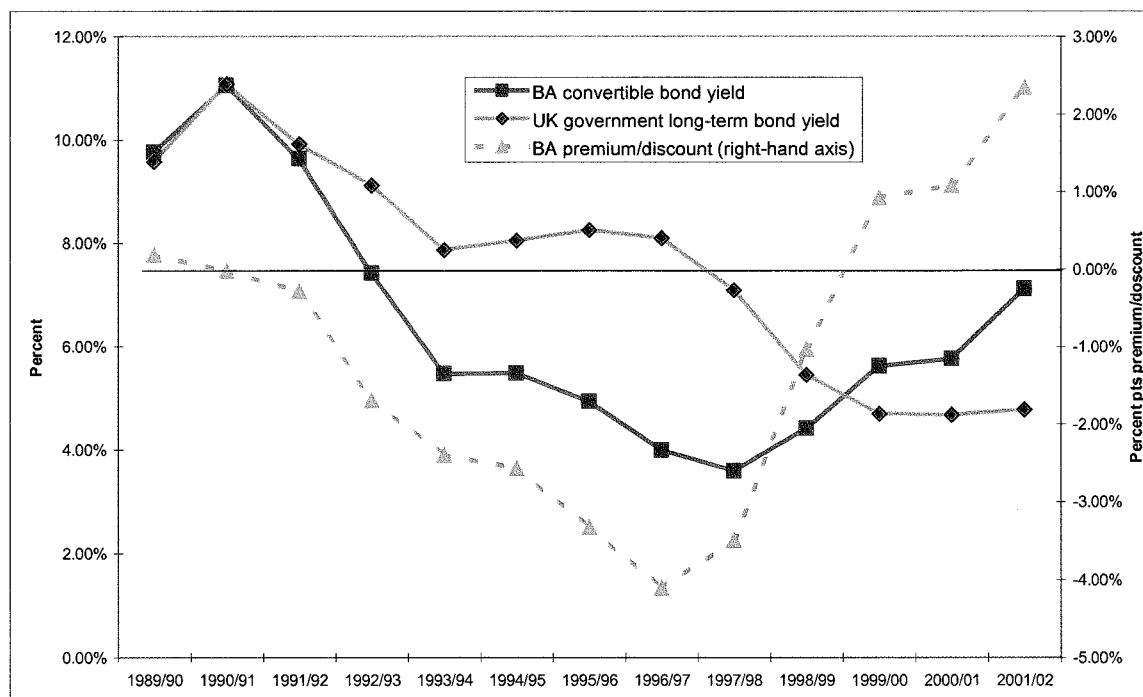
⁶⁹ Their methodology converts assets at current prices into an estimate of economic depreciation using an 'average asset life' of just over 22 years, and thus requires new rather than used prices (see section 7.1 for fuller discussion).

value of aircraft could command, using Equation 5.5 in Section 5.6, and using an appropriate discount rate or cost of capital.

One possible proxy for BA's cost of capital could be the yield on their convertible bond, which was issued at the end of the 1980s, and has the advantage of having a market quotation. Its yield is compared with long-term UK government bonds in Figure 8.7.

The convertible yield differs from straight debt finance in that the holder has an option to convert to BA's ordinary shares. The bond matures in 2005, but so far few holders have opted to convert, since the coupon of 9¾% of the nominal amount was attractive to those that needed a regular income stream. However, the price reflects both BA's debt financing cost and the conversion option, which makes the bond more attractive to debtholders, without really indicating the expected return to equity investors. Its yield should be below the yield on straight debt, and the equity cost should be considerably higher to reflect the higher risks involved. It is therefore doubtful if it could be considered as a proxy for BA's overall cost of borrowing.

Figure 8.7: BA convertible bond yield vs UK government bond yield



Source: Datastream and IMF Financial Statistics

At the time of the Gulf War, BA's convertible yield was very similar to government bonds; but as the equity price recovered it included a built-in potential profit from conversion. Holders thus traded a lower income stream expectation for the likelihood of a profit on conversion to equity. The equity price reached a high of £7.40 in May 1997, compared to the conversion price of £2.34 (adjusted for the 1993 rights issue). The market price of the ordinary shares crossed the £2.43 conversion price threshold in September 1992, and went below the adjusted conversion price again in September 2001. Figure 8.7 does show that BA's cost of finance has increased substantially over the past three years.

The above analysis was useful in determining the premium over LIBOR rates to use for BA's cost of debt. The approach selected to calculate BA's cost of capital in each year, and thus interest rate used in the lease formula, was to apply the Capital Asset Pricing Model (CAPM) to arrive at a weighted average cost of capital (WACC). The cost of debt was taken to be 0.5% over the average six month £ sterling LIBOR (London Interbank Offered Rate). This assumption was necessary because of the lack of detailed information on BA's actual borrowing. The premium was selected as a result of discussions with the BA Treasury in the mid-1990s. The premium was increased by a further 0.5% in 2000/01 and 1% in 2001/02 to reflect the increased risk premium reflected in the bond price.

Table 8.8: Sample calculation of BA's cost of capital

	1994/95
UK £ 6 month LIBOR	6.3%
BA premium	0.5%
BA pre-tax debt cost	6.8%
Less tax allowance	33%
After tax debt cost	4.1%
Risk-free rate*	7.9%
BA's beta	1.25
Equity premium	4.0%
Equity cost	12.9%
Debt:equity	50:50
Nominal WACC	8.5%

* Yield on 20 year UK government bonds

Source: Appendix L

The cost of equity was determined by applying BA's beta and the equity premium in the UK market to a UK 'risk-free' rate. The closest proxy to the latter would be the UK government long-term bond yield (the average yield over BA's financial year). The results for one year (1994/95) are shown in Table 8.8, while the detailed calculations for all years are shown in Appendix L. As a cross-check, the cost of debt

assumed for the year 1999/00 as a whole was 6.4%, very close to the fixed interest euro security issued by BA in April 1999 (6.75%), when market rates were somewhat higher. The real cost of capital was the result of subtracting the UK rate of inflation (RPI) from the nominal cost.

For purposes of productivity calculation, constant £ capital values for BA's own aircraft were calculated, and the lease equivalent of this capital stock of given vintage. The equivalent lease streams were determined so that when discounted over their remaining life at the real cost of capital they would equal the present value of this capital stock. These results are presented in Table 8.9. It could be argued that the more relevant cost of capital is that for debt alone. SAS used the debt cost to discount their operating lease rentals to present values to adjust their assets to market prices. The debt rate might be more appropriate to valuing marginal additions to the fleet, but for large numbers of leased aircraft, the cost of all financing sources are thought to be better.

The largest increases in the annual lease equivalent of owned fleet assets occurred in 1991/92 and 1996/97. In the first year, BA's cost of capital increased. This led to a higher discount rate, and thus higher lease equivalents. In the second year, the lease equivalents were based on a markedly higher fleet value.

Table 8.9: BA owned aircraft fleet value and lease equivalent at constant prices

£ million	Fleet value	Lease equivalent of owned aircraft
1988/89	3,357	346.5
1989/90	3,711	340.3
1990/91	4,223	359.1
1991/92	4,832	478.1
1992/93	5,357	525.2
1993/94	5,881	600.1
1994/95	6,229	613.9
1995/96	6,652	649.8
1996/97	7,486	801.0
1997/98	8,487	842.8
1998/99	9,384	830.3
1999/00	9,898	870.0
2000/01	10,123	896.6
2001/02	10,211	865.8

Source: BA annual reports and author's calculations

Both aircraft on operating lease and those chartered on a very short-term basis have also been included in capital flows, and were added to the figures in Table 8.9. Operating lease rentals were converted to US dollars and deflated to 1988/89 prices using the same P_a deflator as used for owned aircraft. These amounts were then converted back to £ sterling at the 1988/89 US\$/£ exchange rate.

As discussed earlier, the same procedure was applied to aircraft on hire or charter, but only 30% of this cost was taken to be capital in each year. This was based on the share of capital in aircraft operating costs (capital, crew, maintenance and insurance) for the B737-300 for 1996 and 2001.⁷⁰ The 1996 share was somewhat higher, but the lower figure was adopted since some other non-capital costs may have been omitted.

8.4.3 *Property*

The category of assets described as ‘property’ in BA’s balance sheet covers buildings, hangars, offices and related structures. Both freehold and leasehold properties are valued periodically, the latest one being at 31 March 1995 and the previous one being at 31 March 1984. Property rentals are also reported as a separate note to the operating accounts.

In order to obtain current price estimates for property, the 1984 values were inflated using the UK GDP deflator up to 1995, when the new market values were used. This resulted in only a small upward adjustment of just below 1%. Post-1995, the UK GDP deflator was again used to convert the balance sheet values to current prices. An industrial property index would clearly have been better, but the very small adjustment in 1995 showed that the two moved fairly closely in step. Constant price trends were then determined by deflating the whole series by the UK GDP deflator.

In order to obtain a flow of services from property assets, the same approach was adopted as for the fleet, using the same interest rate, but a longer remaining service life. The latter was estimated from the balance sheet in each year, by dividing property depreciation for the year into average book value before depreciation. This ranged from 23 to 42 years over the period 1987/88 to 2001/02.

The lease equivalent of the balance sheet assets in each year was then added to the property rentals for the year (adjusted to 1988/89 prices using the GDP deflator) to obtain the total capital flow for property.

⁷⁰ US Department of Transportation, Form 41, 1996 and 2001. In *The Airline Monitor*.

8.4.4 Equipment

Equipment covers shorter life assets than both aircraft and property. It excludes any spare parts that are specific to aircraft, and includes computers (for office use and such applications as reservations, revenue management and departure control), office equipment, vehicles and equipment for passenger and cargo handling and general maintenance.

The stock of equipment was taken from the balance sheet in 1988/89 and net changes added to this amount over the period, deflated to constant baseline prices using the UK GDP deflator. It is thought that the difference between historical costs and market prices for equipment would not have been large.

In order to arrive at a flow of services from equipment, the same approach was adopted as for the fleet, using the same interest rate, but shorter remaining service lives. The latter was estimated from the balance sheet in each year, by dividing equipment depreciation for the year by average book value before depreciation. This ranged from 7 to 12 years over the period 1987/88 to 2001/02. The lease equivalent of the balance sheet assets in each year was then adopted as the total capital flow for equipment adjusted to 1988/89 prices, with equipment hire or rental being combined with aircraft charter and hire.

8.4.5 Total capital input

Estimates of annual capital flows were combined for the following:

- Owned and finance lease aircraft (see Section 8.4.2)
- Operating leased and chartered aircraft (Section 8.4.2)
- Owned and leased property (Section 8.4.3)
- Owned and leased equipment (Section 8.4.4)

These are shown for the Base Case in Table 8.10, the assumptions for which were discussed in the previous sections. The major changes in capital inputs were dictated by changes in the fleet and its financing.

The assumptions on both aircraft life and cost of capital are critical to the estimates, and both these were changed to see what result they had. Two sensitivity tests were carried out: the shortened the economic life of the aircraft from 25 to 20 years. It was argued for the base case that, although aircraft would not remain in BA's (or other

major airlines') fleet for much longer than 20 years, they could be sold for conversion or operations elsewhere; this could be factored in either as an increased period over which to earn rentals, or through an estimate of residual value at the end of the assumed 20 years (net of conversion costs). The two are equivalent, and the longer period was chosen for ease of calculation.

Reducing the overall life to 20 years takes a more pessimistic view on the ability of aircraft to continue to earn rentals at the discounted rate calculated to equate to its current value, even as it approached 20 years old. This is because of the costs of conversion and other modifications, its lower utilisation and obsolescence brought about by increased labour and fuel prices. An alternative of an economic life of 30 years was also tested.

The other sensitivity test was an increase in the real cost of capital as follows:

- For the cost of debt: 1% over £ sterling 6 month LIBOR (previously a premium of only ½%), with the additional premiums of 0.5% and 1% respectively for 2000/01 and 2001/02 retained.
- For the cost of equity: an equity risk premium of 6% (as opposed to 4%) and a beta value of 1.50 (versus 1.25).

Table 8.10: Constant price BA Capital input and sensitivity

£ million	Base Case	30 yrs	20 yrs	High cost of capital*
1988/89	622	571	729	686
1989/90	657	597	779	724
1990/91	765	697	902	839
1991/92	859	781	1,022	948
1992/93	907	841	1,034	1,011
1993/94	959	887	1,100	1,073
1994/95	946	867	1,101	1,065
1995/96	976	879	1,172	1,100
1996/97	1,149	1,027	1,408	1,289
1997/98	1,193	1,063	1,459	1,349
1998/99	1,215	1,078	1,484	1,380
1999/00	1,294	1,164	1,540	1,473
2000/01	1,353	1,231	1,579	1,540
2001/02	1,295	1,177	1,512	1,482

* 1% above the premium above LIBOR assumed for the base case.

Source: see Appendix M

This brought the real cost of capital up for 1999/00 from 4.8% in the base case to 7.0% for the sensitivity test (the rate assumed in BA's CVA calculation for that financial year: see Section 7.1).

The three sensitivity scenarios are shown in Table 8.10. Extending the economic lives of the fleet reduced capital consumption (for example by 9% in 2001/02), while reducing them led to an increase in 2001/02 capital of 17%. The higher cost of capital raised the 2001/02 estimate by 14%.

8.5 Capital productivity

8.5.1 Aircraft utilisation

Aircraft utilisation is a measure of capital productivity widely reported by most airlines. However, it is a fairly crude measure, since it describes the number of hours per day or year that an aircraft is operated, without differentiating by seats offered or sold, cargo space available or sold, or revenue generated. Fleet-wide averages are also misleading, since levels of utilisation need to be related to operating characteristics such as length of haul.

Utilisation is measured either in block or flying (flight) hours. The former is timed from the time the aircraft moves off stand to the time it arrives at the stand at the destination airport. It thus includes taxi out and taxi in time. The latter measures only the time taken from the beginning of the runway roll to touch down at destination, and thus excludes taxiing time. British Airways tends to publish figures for block hours (AEA, CAA and their annual reports), but also uses flying hours internally. Annual utilisation data is calculated by dividing annual block hours by the number of days that the aircraft are in-service as part of the fleet. This includes days spent in maintenance and overhaul, but excludes:

- Days out of service due to major accidents or conversions
- Days when an aircraft is in the possession of others
- Days out of service due to government action such as grounding by regulatory agencies

Over the past decade, expected delays for flights operated within Europe has led many European airlines to add a 'buffer' to scheduled or published block-to-block times. This allows for delays due to ATC or airport constraints, and gives airlines a chance to

recover lost time over the day. It also allows a comfort factor for connections. Passengers can plan better, but there is a cost in terms of a potential loss of aircraft utilisation. Actual tracks flown by aircraft can change, and this results in changes in both scheduled and operated hours flown by each aircraft.

The net loss from increased sector times can be totalled over the European system and it has been suggested that without these delays the system of flights could have been operated with less aircraft. This presupposes that additional rotations could be operated with the time not needed for the 'buffers'. With a large fleet of similar aircraft types, there should be some saving, but the buffer, although increasing, is still not large in relation to total sector time.

Recent research⁷¹ shows that BA's scheduled time is determined almost entirely by a fixed element and a distance element. In each year between 1994 and 2002, over 98% of the variation in scheduled sector times could be explained by distance plus a fixed time to account for taxiing and holding. This merely reflects the way the BA schedulers put together the schedule. If further delays are anticipated, they will add an allowance to the fixed element, especially on certain routes. If delays decline, or experience shows that, for example, times are reduced through more direct routings or lower taxi times, then the fixed part can be reduced. The regression equations for each year gave the results shown in Table 8.11.

Table 8.11: Average scheduled sector time and speed for BA's European network

	Av. speed (kph)	Av. fixed time (minutes)	
		Minutes	% change
1994	752.8	35.45	
1995	752.8	35.42	-0.1
1996	756.6	35.29	-0.4
1997	755.7	36.63	3.8
1998	749.1	37.38	2.0
1999	754.7	38.51	3.0
2000	742.6	38.43	-0.2
2001	753.8	39.53	2.9
2002	756.6	39.96	1.1

Source: See footnote: Stockman (2002)

⁷¹ Unpublished research using the electronic OAG. Ian Stockman, Air Transport Group, Cranfield University, 2002

Table 8.11 shows that BA increased the fixed part of their schedule time by between 2-4% in the years 1997 to 1999. This added over 3 minutes per sector. Further increases in 2001 and 2002 resulted in the fixed part rising by 4.5 minutes over the whole eight year period. This may not seem very much, but for a fleet of 30 aircraft doing two return flights a day, this would amount to 540 minutes, or 9 hours a day, or an additional 6.6 sectors (applying the average BA sector time in 2002 for European operations).

However, in order to decide whether this saving might be realised in practice, it is necessary to look at the aircraft scheduling process. Schedules require the balancing of a number of different requirements:

- Market demand related
- Network operational factors
- Crew scheduling
- Maintenance schedules

The timing of flights should respond to market demand, offering flights with convenient departure *and* arrival times. For airlines such as BA, there will be both origin/destination or point-to-point traffic on each sector, and connecting traffic. These may have different and conflicting schedule requirements. Business passengers will be more sensitive to the schedule and less to price, while the reverse will generally be true for leisure passengers. BA has always served the business segments, but increasingly so in recent years. This means that their schedule will need to be responsive to business demands, especially those of the higher yield point-to-point traffic.

For European sectors, demand will tend to peak in the early morning outbound, and early evening return. Long-hauls will also need convenient arrival and departure times, to which must be added constraints from airport curfews and time zone differences.

If European ATC and airport delays were to be significantly reduced, would BA be able to use effectively the five or so minutes saved from each sector? That would depend first on the ability to schedule additional flights across the fleet and network, within the day. The day normally stretches from 6am to 11pm, but curfews may reduce this somewhat at some airports. The low cost airlines use the day to the full, and charter airlines even more so (sometimes scheduling departures at very inconvenient times, even before 6am). BA's focus on business traffic may limit the

degree to which they could use the extra aircraft time, but the test would be whether the marginal revenue from operating the additional flight exceeded the extra (variable) costs. If this were positive, then the flight would be making a contribution to covering capital costs.

The operational factors would include weather (bad weather affecting landings and take-offs, headwinds etc), infrastructure (insufficient airport and ATC capacity, runway length, ground facilities etc) and routings. If these were not allowed for in the schedule, then delays would occur, and in extreme cases landings could not be made and diversions take place. These are the factors allowed for in the 'buffer' discussed above.

The remaining two important requirements which determine schedules, crew and maintenance, do not change much over time and can often be changed to accommodate the other scheduling demands.

Would BA's aircraft utilisation tend to fall as their schedule buffers have increased? First, it would if the number of flights that could be operated per day declined as a result of the buffers, and this would be unlikely. Second, if the expected delays materialised, their impact on actual aircraft block times would depend on whether aircraft were held on the departure gate and then given a revised departure time that ensured a smooth flow from taxi out, through take-off, landing and arrival at destination gate. This was the system of flow control that Eurocontrol applied from the mid-1990s onwards. This should have little or no impact on aircraft block times for a given sector.

The other type of delay would be unprogrammed, and occur after the aircraft had left the gate. This might be caused by queues for take-off, holding at destination airport, or lack of gate availability at destination. All these would add time to sector block times achieved, and increase aircraft utilisation overall. However, this cause of increased utilisation would not increase revenue output (ATKs or RTKs) or revenues generated per aircraft.

What is the evidence from BA's reported aircraft utilisation? Two sources of data were examined: BA's annual reports and the AEA statistical appendices to their yearbooks. Both used block times, but the AEA report calendar years and BA financial year to end March. The two were, however, fairly close. A further source, the UK CAA, was also consulted.

Three aircraft types were selected from the BA fleet: B737-400, B757-200 and B747-400. The first two types accounted for a high percentage of total short-haul hours flown at the beginning of the 1990s. The last was the mainstay of the long-haul fleet at the same time, and remained so until very recently.

AEA data was analysed for each year of the period 1990 to 2001, with block hours regressed against stage length for each type. There was a strong correlation for the B737-400 (adjusted R^2 of 0.80), but very poor ones for the B757-200 (adjusted R^2 of 0.25) and B747-400 (adjusted R^2 of 0.19). The average stage had increased significantly over the period for the B737-400, but had changed little for the other two types. There was thus a case for adjusting the B737-400 block hours for increased stage length, using the following regression equation (t statistics in brackets below coefficient):

$$\text{Block hour utilisation} = 1,143 + 1.91 (\text{stage kms}) \dots\dots\dots (8.1) \\ (+ 4.26) \quad (+ 6.16)$$

The resulting adjusted block hours were then indexed on 1992, and compared with the unadjusted figures for the other two types (Table 8.12). These trends for block hours by aircraft type were broadly confirmed by those found in BA's annual reports.

Table 8.12: Index of BA utilisation by aircraft type

	Block hours per annum (index)		
	B747-400	B757-200	B737-400*
1990	106	101	n/a
1991	95	95	n/a
1992	100	100	100
1993	99	99	98
1994	98	106	105
1995	83	104	109
1996	101	112	111
1997	99	106	106
1998	94	107	107
1999	91	106	113
2000	88	102	117
2001	85	103	116

* adjusted using equation 8.1

Source: AEA

It can be seen that the B737-400 utilisation increased by 16% over the ten years, after allowing for longer sector lengths operated. It did not show a decline in utilisation in the second half of the 1990s when delays and buffers were increasing, and the number

of flights per day each aircraft operated was maintained. The sector length operated by the B757-200 had increased between 1991 and 1995, levelling out after that, while its utilisation declined from 1996 onwards. There was thus some evidence, at least for the B757, to support the view that buffering schedules had reduced the number of hours that each aircraft operated on average per day. Since some of these hours may have become unproductive, data on flights per day would also be needed. This was available from the CAA.

The CAA data in Table 8.13 shows that the number of B757 flights operated per day did fall between 1996 and 2001, whereas there was no change during the first five-year period. Between 1996 and 2001, the average time operated per sector declined by 4.8 minutes (0.08 hours, or by 4%), but proportionately less than the drop in the average sector length operated of 12%. Using the fixed and variable elements from Table 8.11 a decline in sector length from 920 km to 811 km would result in a fall in sector time from 1.90 hours to 1.75 hours, or 8%. While the formula is not specific to the B757, its application does show that the average sector time operated has fallen by less than expected, due to not all the delays that were allowed for in the increased buffers materialising. However, the crucial point here is that aircraft utilisation needs to be linked to productive flights, and these did decline in the second half of the period.⁷²

Table 8.13: Operating data for BA's B757-200 fleet

	1991	1996	2001
Aircraft kms (000)	47,813	62,472	50,223
Stage flights	58,021	67,900	61,955
Aircraft hours	92,331	120,583	105,496
ASKs (m)	8,968	10,726	8,639
Average number of aircraft	38	44	42
Average kms per sector	824	920	811
Average hours per sector	1.59	1.78	1.70
Average block hours per aircraft	6.7	7.5	6.9
Average seats per aircraft	188	172	172
Average ASKs per flight (000)	155	158	139
Average flights per day per aircraft	4.21	4.21	4.05

Source: UK CAA UK Airlines

The long-haul B747-400, on the other hand, experienced a decline in average hours operated per year by just over 15% between 1996 and 2001, after a rise of 11% in the

⁷² Ryanair's chief executive has said that the reason the airline does not fly longer sectors in Europe is because they could then only get in two return sectors a day instead of the three they now operate, and that the incremental revenues from these longer sectors would fall short of the incremental costs.

first five year period (Table 8.14). The initial advance was helped by a significant increase in average sector length, and was accompanied by a marked increase in seats per aircraft to result in a 20% rise in aircraft productivity expressed in Available seat-kms (ASKs) per aircraft. But over the last five years more generous seat spacing and the decline in utilisation led to a drop in ASKs per aircraft of 26%.

ASKs per aircraft is a better measure of productivity than hourly utilisation, since it is ASKs that produce the revenue. Utilisation can also be affected by the flown mileage according to permitted routings. For example, since 1991, the opening up of much more direct routings from Asia to and from Europe has led to a lower number of hours per sector (while sector kilometres recorded have been unchanged). South-east and South Asian points could be served from London by taking more direct routes through Chinese airspace. The route most affected was London/Hong Kong, where the scheduled time declined by 75 minutes (one-way) between 1992 and 2001 (by around 10%).

Table 8.14: Operating data for BA's B747-400 fleet

	1991	1996	2001
Aircraft kms (000)	70,351	136,606	204,315
Stage flights	11,988	19,004	28,628
Aircraft hours	90,346	173,341	256,601
ASKs (mn)	26,538	54,933	70,777
Av. number of aircraft	18	32	56
Av. kms per sector	5,868	7,188	7,137
Av. hours per sector	7.54	9.12	8.96
Av. block hours per a/c	13.4	14.9	12.6
Av. seats per aircraft	377	402	346
ASKs per aircraft (000)	1,437	1,724	1,269

Source: CAA UK Airlines

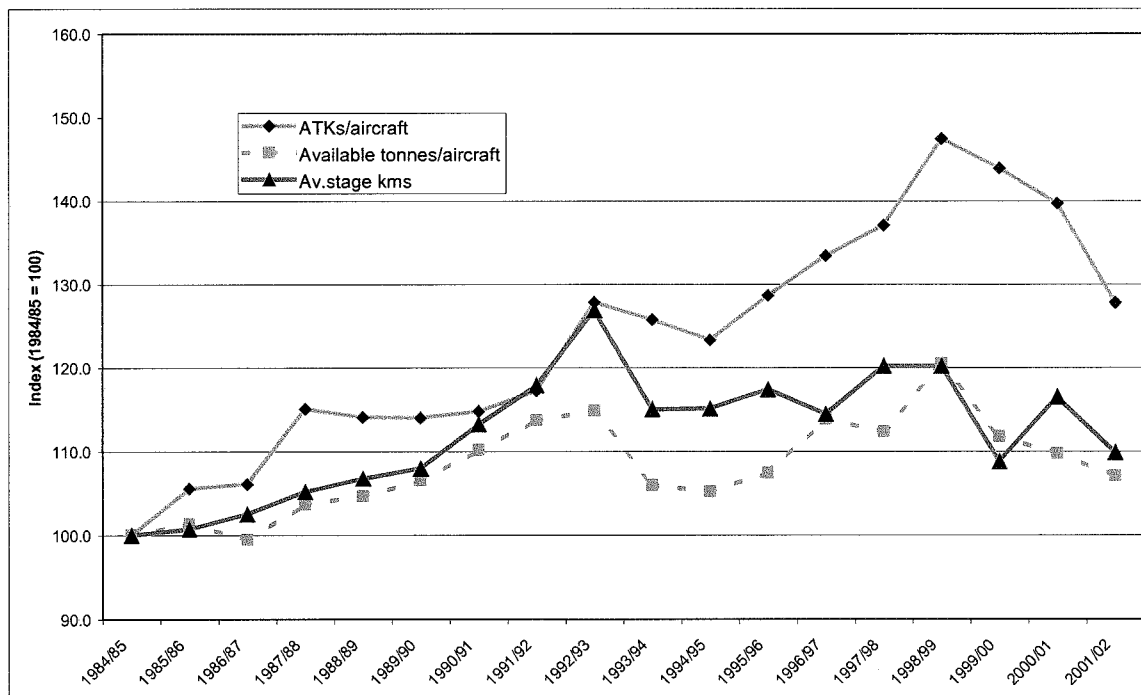
Second, BA discontinued many of their 'tag end' flights, for example between Philadelphia and Pittsburgh and Nairobi and Dar-es-salaam. These added between 40 to 95 minutes to the block hours, and the time saved could not be used for other revenue flights (although average sector length would increase in these cases). These flights were mostly eliminated, and passengers fed to the long-haul sector by alliance partner airlines. Some were served on a non-stop basis, which required less hours than the indirect routing with intermediate stop. This affect tended to push up the average hours flown per sector, while the more direct routes described above would tend to reduce it. The net result was a 2% drop in hours per sector between 1996 and 2001, and probably a similar decline for the first five year period, adjusted for the increase in sector lengths.

8.5.2 Aircraft productivity

An initial idea of capital productivity might be gained from examining trends in average ATKs per aircraft. This ratio does not contain price or value data, but averages efficiency over the whole fleet. A change in fleet mix towards more long haul widebodies would increase the ratio without any underlying change in the true productivity of capital used for supplying a specific city-pair of given stage length. Furthermore, for the figures used here, output changes do not reflect any qualitative improvements in terms of seat density or amenities, and inputs do not include ground and other equipment, without which the aircraft output would not be possible.

Figure 8.8 shows that the average capacity of BA's fleet increased up to 1992/93 (from 31 to 36 tonnes), but has declined overall since then. ATKs per aircraft, however, continued to increase throughout the period, in spite of a small decline in average sector operated. Longer sector lengths allow higher aircraft productivity through higher aircraft utilisation and are generally operated with larger capacity aircraft.

Figure 8.8: Indices of BA fleet size and aircraft productivity



Source: Author's calculations

In the 1960s and 1970s, new aircraft incorporated a larger number of seats, increased lower deck cargo capacity and greater speed and range. This inevitably led to easily identifiable and quantifiable efficiency increases delivered in return for some increases in price. Over the past two decades, however, aircraft size has not grown much on average, but many cost saving improvements have nevertheless been incorporated in the aircraft (eg automated flight deck, modular design for lower maintenance costs).

The decline in both aircraft size and productivity between 1992/93 and 1994/95 can be explained by the acquisition of the remaining shares in Brymon by BA (and thus consolidation of this carrier's assets). This took place between 1992/93 and the following year, and led to the inclusion in the fleet of a number of small turbo-prop aircraft, which depressed the all the averages. The consolidation of quasi-subsidiary, TAT, at the end of March 1995 added further small (ATR) aircraft to the BA fleet.

Part of the upturn in average ATKs per aircraft and average aircraft payload was due to the increase in average weight per passenger, which rose from 75 kg to 80 kg as a result of a directive from the UK CAA. This boosted ATKs by 2.5% in 1995/96.⁷³ The additional allowance for checked baggage of 20 kg was unchanged (see earlier discussion of this in Section 3.2).

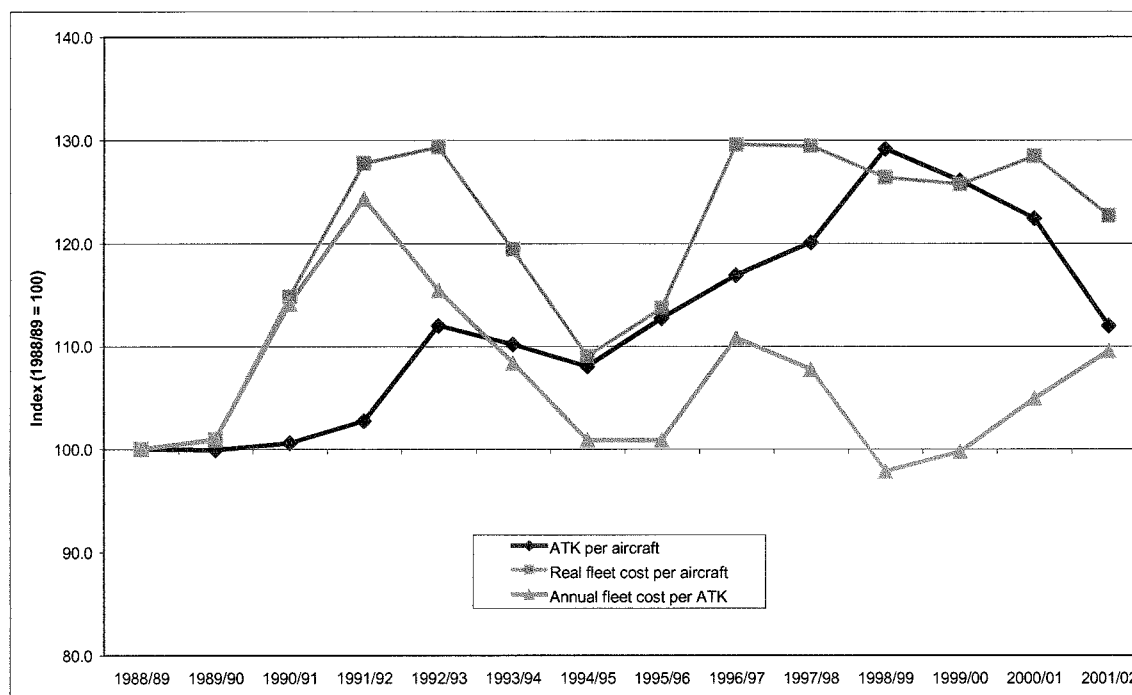
In the latter part of the 1990s, BA was taking delivery of larger jet aircraft and retiring smaller jets (B737-200s) and turbo-props. The latter stemmed from the restructuring of both DBA and TAT, whose turbo-props were gradually retired to focus on medium sized jet aircraft (B737-300s).

The most recent fall in average aircraft size and production over the past three years has been due to the retirement of B747s and B757s and their replacement by smaller aircraft. This was the result of the change in strategy adopted in the late 1990s. Thus between 1998 and 2001, the average number of seats on BA's total long-haul services increase fell from 357 to 316, and on flights within geographical Europe, they declined from 163 seats to 140.⁷⁴ This strategy required the operation of smaller aircraft, and also the shift in emphasis towards business and first class seating. A methodology was proposed for adjusting physical measures of output to take into account quality changes in Chapter 3.

⁷³ BA Annual Report and Accounts, 1995-96, note on page 57.

⁷⁴ AEA Yearbook, appendices for 1998 and 2001.

Figure 8.9: BA's fleet productivity & average lease equivalent cost (constant prices)



Source: BA annual reports and author

Figure 8.9 shows that, apart from the early years when BA benefited from lower interest rates and a good credit rating, average annual capital cost per aircraft has been rising in terms of constant 1988/89 prices. However, until the recent changes to smaller aircraft, ATKs per aircraft have increased at a similar rate, such that the fleet cost per ATK had not showed any overall increase. In the first of two years of especially strong advances in the cost per aircraft, the real cost of capital assumed for BA rose sharply from 5.5% in 1990/91 to 8.5% in 1992/93. In 1996/97, purchases of new aircraft were weighted towards the larger capacity and more expensive models.

However, in addition to the cost of borrowing, the other strong influence on the average cost per aircraft was the pricing policy of the manufacturer (in BA's case mostly Boeing). At times of recession, extremely good deals on new aircraft prices are available (but commercially confidential), and these come through after a time large from contract signature to delivery of between 1-3 years. As the industry recovers, the price discounts disappear, and airlines pay closer to the list prices.

An alternative measure of output to use for aircraft productivity would be RTKs, rather than ATKs. This shows how much sold capacity each aircraft generates, rather than available capacity. However, BA's overall load factor had not varied much over the past 18 years, until 2000/01 ranging from 66% in 1985/86 to 70% in 1995/96. In 2001/02, it fell to 64%, the lowest level for almost 20 years. This means that the trend of aircraft productivity would not have been very different when expressed in traffic terms.

8.5.3 Capital productivity

Capital productivity trends for BA were examined by dividing an index of output by an index of capital input, including owned, leased and chartered aircraft, property and equipment.

The output index was discussed in Section 8.1. The various steps in its calculation were as follows:

- Traffic data was used rather than capacity provided
- The series started with 1988/89 because of assets were only valued at historical cost prior to that date
- Indices for passenger-km traffic, cargo tonne-kms and the RTK equivalent for incidental revenues were combined using revenue shares as weights
- Using an index of passenger-kms, rather than passenger tonne-kms, meant that no adjustment was necessary for average passenger weights (however, some sources such as the ICAO Financial Statistics used in the next chapter only give RTKs)
- No adjustment was made for quality of output⁷⁵

Capital input consumed in each year was calculated and discussed in Section 8.4 above. This can be summarised as follows:

- The starting point was 1988/89, the year in which BA re-valued its fleet to current prices (non fleet assets were also re-valued in 1993)
- Fleet assets were valued at 1988/89 US\$ costs using the PIM method and the application of the US aircraft manufacturers' composite cost index, and average assets for each year were switched back to £ sterling using the baseline 1988/89 \$/£ exchange rate

⁷⁵ This was impossible to do for all years, and will be applied in the cross-sectional analysis for 1999/2000 in the next chapter.

- Owned fleet assets were converted to a flow of capital used in each year by calculating a lease rate that, discounted using a cost of capital, would give a present value identical to its £ constant price value, over the average remaining life of the aircraft (which was available for each year)
- The CAPM was applied in order to determine BA's average cost of capital
- Rented and the capital element of chartered aircraft were switched to US\$ and deflated using the same index as for owned aircraft, and converted back to £ using the baseline exchange rate
- Sterling values for property and equipment were deflated using the UK GDP deflator to constant 1988/89 prices

Indices of output and capital input are shown in Table 8.15, together with the resulting capital productivity for each year. Whereas output increases steadily up to 1988/89 to 1998/99, capital inputs are more cyclical for the reasons discussed in the previous section. It can be seen that BA's capital productivity tracked quite closely the industry's cycle over this period, although the downturn started in 1999/00, or even 1998/99, well before passenger traffic had started slowing (or at least the passenger side).

Table 8.15: BA indices of output, capital input and productivity

	Capital Input*	Revenue weighted output	Capital Productivity
1988/89	100	100	100.0
1989/90	106	108	101.9
1990/91	123	112	90.7
1991/92	138	114	82.7
1992/93	146	127	87.3
1993/94	154	142	92.2
1994/95	152	153	100.6
1995/96	157	167	106.2
1996/97	185	178	96.4
1997/98	192	186	97.2
1998/99	195	204	104.3
1999/00	208	205	98.4
2000/01	217	204	93.9
2001/02	208	182	87.5

* from Section 8.4.5

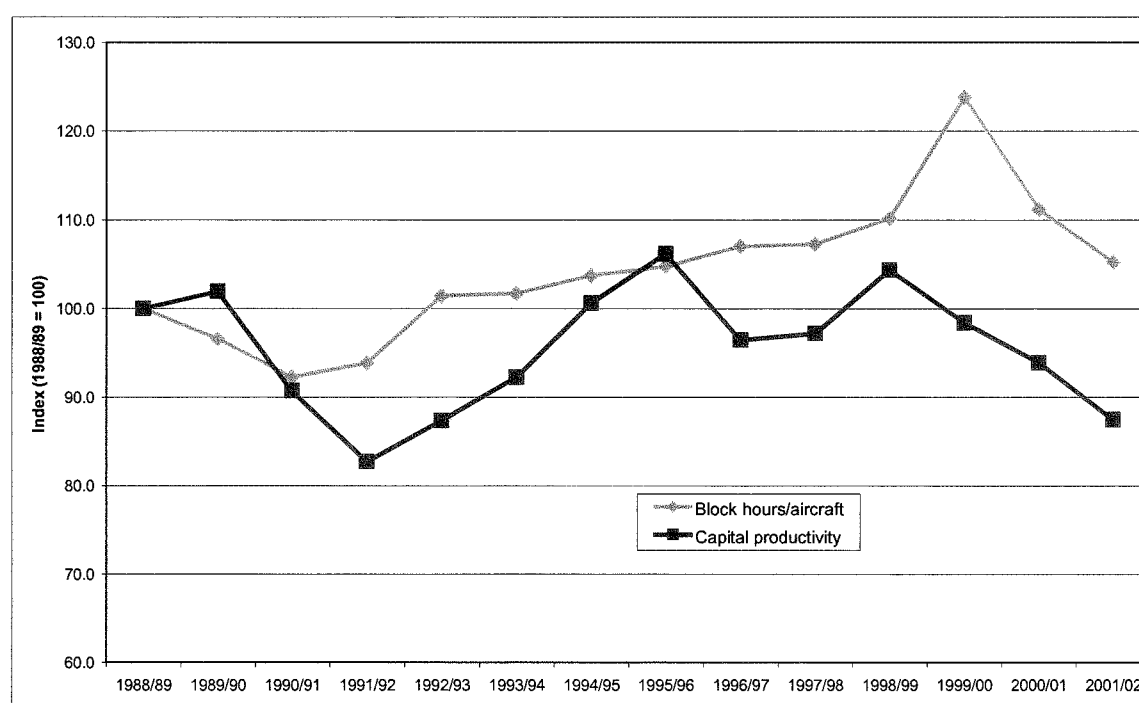
Source: Author

Over the past three years, output first stagnated and then declined sharply, but this is distorted by the gradual introduction of BA's more comfortably configured long-haul aircraft, and smaller short-haul aircraft.

The more productive use of existing capital through more efficient organisation or better-trained staff is probably difficult to achieve in any sizeable way in the air transport industry. Flying crew are already highly trained and improvements may show up more in better quality service than higher output. Increasing aircraft utilisation is also constrained by congested airspace and passenger requirements, although week-end charters can make a small contribution here.

Capital productivity not surprisingly tends to move in step with aircraft utilisation, which should increase output for the same amount of capital. However, as Figure 8.10 shows, this was not so in 1996/97 (when a large increase in capital input occurred) and 1999/2000 (when utilisation appeared to increase sharply).

Figure 8.10: BA capital productivity vs aircraft utilisation



Source: BA and author

It is not clear how far the use of operating leases influences capital productivity. It is difficult to remove price effects to obtain a quantity index. The cost of the operating lease paid by BA or any other airline might be inflated by a profit element, but this might be offset by the lower discount rate and cost of capital incurred by large operating lessors (such as Gecas, owned by General Electric). However, new lease rates are affected by market forces in the same way as new aircraft prices, albeit

without the same time lag, and existing leases have generally been extendible at rentals adjusted for changes in interest rates.

For BA, operating lease rentals and the capital element of short-term chartering of aircraft were just under 30% of the equivalent lease value of the owned fleet and the rental cost at the beginning of the period. This rose to 41% in 1990/91, and then gradually declined to only 14% in 2001/02. Operating leased (and especially chartered) aircraft may need more resources (whether capital or other inputs) than owned aircraft for their scheduling and operation, since they are often not identical to the majority of the fleet.

Aircraft accounted for around three-quarters of the total annual capital consumption at the outset, but this share increased to 80% in 1990/91. It has since oscillated between 77% and 81%. The faster growth in shorter life investments, which are not directly related to aircraft, would tend to depress any measure of capital productivity that did not take into account the output quality improvements that such investments tend to produce.

The capital productivity index was not especially sensitive to changes in either aircraft economic life or cost of capital. Both had the effect of applying a similar change to both base and subsequent years, such that the index was little changed. Thus the capital productivity index was 87.7 in 2001/02 for the 20 year life, 88.3 for the 30 year life, and 84.3 for the higher cost of capital, all compared to the base case of 87.5. However, in absolute terms, however, there was a significant change, as was shown in Table 8.10.

To conclude this section, BA's capital productivity has declined at an average rate of 1.0% a year over the period 1988/89 to 2001/02, with a large fall in the last of these years. Even without the 2001/02 data, it would still have been down by 6% over the remaining 12 years. It followed the economic cycle in the first half of the 1990s, but moved more erratically since 1995/96. However, BA's change of strategy and the movement of daughter airlines into and out of the consolidated accounts have clouded the analysis over that period.

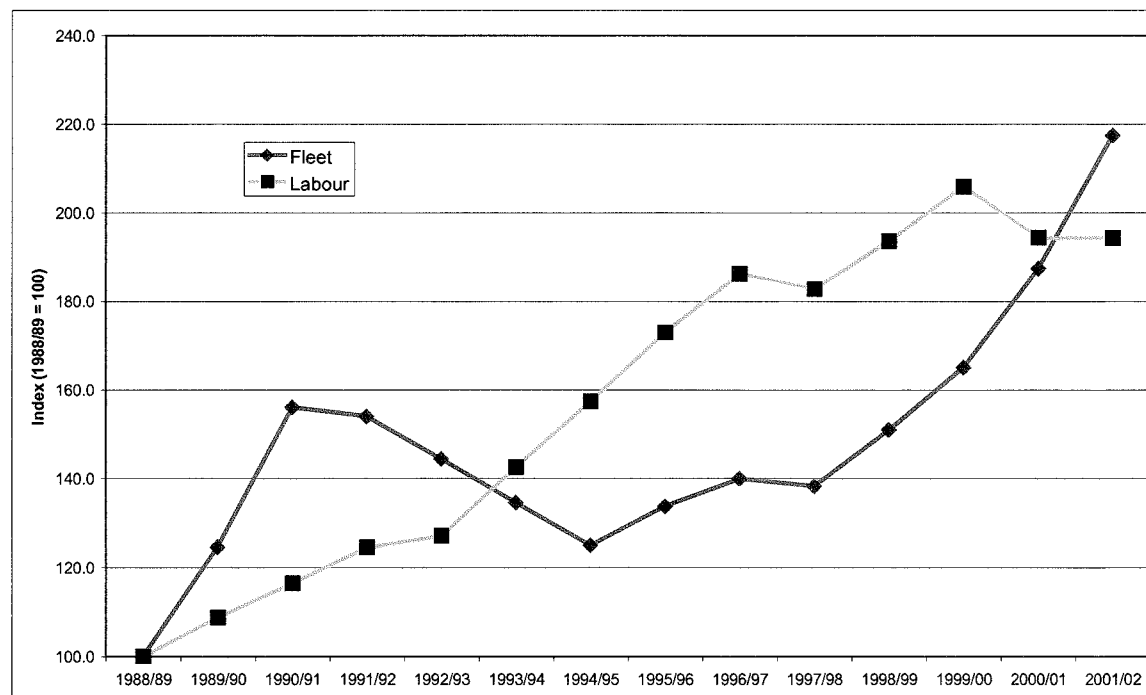
8.6 Labour and Total Factor Productivity (TFP)

8.6.1 Productivity trends

Before comparing labour, capital and TFP, current cost inputs of both capital and labour were contrasted in Figure 8.11. The capital cost index increased very rapidly over two periods: 1988/89 to 1990/91 and from 1987/88 to 2001/02. During both periods, BA experienced significant net increases in the number of aircraft operated. The first period can be explained by both an increase in the share of aircraft on operating lease, which are inherently more costly, as well as a rise in the cost of borrowing, especially in the second year. There was some increase in the share of the fleet on operating lease in the second period, but the driver of higher capital costs was the deteriorating credit rating of BA.

The period of decline in capital costs was characterised by the falling cost of capital, coupled with lower net additions to the fleet. Labour costs have moderated considerably since 1996/97, and especially over the past two years, when BA have placed a strong emphasis on rationalisation and labour cost reduction.

Figure 8.11: BA index of labour and capital inputs at current prices



Source: Author's calculations

Labour productivity was first expressed as the ratio of output (defined in the same way as for capital productivity) to total staff costs (including pensions, but excluding any one-off redundancy payments), deflated by the UK Retail Price Index (RPI). This can be seen in to have increased steadily over the decade following 1988/89, apart from a marked slowdown following the Gulf War. Significant staff reductions in 2000/01 anticipated the market slowdown in the following year, and resulted in a short-lived increase in labour productivity.

Total Factor Productivity (TFP) was then defined as the harmonic mean of labour and capital productivity, weighted by the shares of each in net value added (see Section 2.1 for a discussion of this production function formulation). This measure examines the contribution from only these two main factors of production, and excludes material and other service inputs such as fuel and airport facilities:

$$TFP = (Y/K)^{\alpha} \cdot (Y/L)^{1-\alpha} \dots\dots\dots (8.2)$$

Where Y is a volume index of output, and K and L are volume indices of capital and labour respectively. The weights are the shares in value added of capital (α) and labour ($1 - \alpha$).

Table 8.16: BA capital and value derived labour productivity indices

	Capital Productivity	Labour Productivity*	TFP
1988/89	100.0	100.0	100.0
1989/90	101.9	106.6	104.8
1990/91	90.7	113.1	102.9
1991/92	82.7	114.7	99.0
1992/93	87.3	129.9	108.1
1993/94	92.2	131.9	112.8
1994/95	100.6	133.7	119.2
1995/96	106.2	137.9	124.4
1996/97	96.4	138.8	119.4
1997/98	97.2	153.1	125.8
1998/99	104.3	164.5	135.5
1999/00	98.4	157.4	128.8
2000/01	93.9	170.3	129.0
2001/02	87.5	155.0	119.1

* Index of BA staff costs deflated by UK RPI

Source: Author

It can be seen from Table 8.16 that TFP suffered the same cyclical swings as capital productivity, but in a less extreme way. Labour productivity lessened the downside fall, as management shed jobs to cushion the impact. Capital is clearly more difficult to adapt to cycles, despite the possibility of returning some aircraft on short-term leases. The latter options are not generally exercised during economic and traffic downturns because of fears that adding back this capacity later, to take advantage of any recovery, leads to operational problems and extra costs.

An alternative definition of labour productivity was also used, replacing deflated staff costs by an index of manpower equivalents (Table 8.17). This index tracks the one based on constant price values quite closely, the major difference being the two years following the Gulf War, when the MPE index advanced by 27% compared to 15% for the value based index. Staff costs were reduced proportionally less than staff numbers, implying that lower paid staff took the main impact of the cuts.

Table 8.17: BA capital and MPE labour productivity indices

	Capital Productivity	Labour Productivity*	TFP
1988/89	100.0	100.0	100.0
1989/90	101.9	103.8	103.1
1990/91	90.7	102.9	97.5
1991/92	82.7	113.7	98.5
1992/93	87.3	130.5	108.4
1993/94	92.2	138.5	115.9
1994/95	100.6	144.7	124.9
1995/96	106.2	151.2	131.6
1996/97	96.4	150.9	125.4
1997/98	97.2	153.8	126.2
1998/99	104.3	159.6	133.2
1999/00	98.4	156.4	128.4
2000/01	93.9	163.0	126.0
2001/02	87.5	151.1	117.5

* Index of average manpower equivalent (MPE) for BA group

Source: Author

Whichever labour productivity index is used, BA's TFP first peaked in 1995/96, when it was either 32% or 24% up on 1988/89, depending on whether manpower equivalent or deflated wages were used. Reading from a graph of results from another study whose data only went as far as 1995, BA's TFP was found to have increased by 20% over the same period (Waters et al, 1998). Another study (Oum and Yu, 1998) found that BA's TFP increased by an average rate of 3.0% a year between 1988 and 1995,

compared with the 3.2% determined here for the same period using deflated wages (Table 8.16).

BA's TFP growth thus appears similar to previous studies, although it was impossible to disaggregate this into labour and capital productivity growth separately.

8.6.2 Contribution of capital deepening

Capital's role in overall productivity analysis is also important in allowing the use of labour and other inputs themselves to be more efficient.

In the period leading up to the start date of this analysis, the capital/labour ratio experienced a marked increase from 1982/83 to the date of privatisation (1987). This was due to the shake out of labour, rather than any planned move towards increasing capital per employee. Once this had occurred, capital inputs tended to rise somewhat faster than labour inputs (Morrell, 1999, p96).

A further lay-off of staff in early 1991 as a result of the Gulf War recession led to an increase capital intensity, in spite of a significant reduction in numbers of aircraft operated: this was the result of the withdrawal from all Irish routes and a number of others, and the retirement of seven BAC 1-11s and five Tristar 200s. However, these aircraft were relatively old, and the opportunity cost of the remainder of the fleet increased as a result of a higher real cost of capital.

Table 8.18: BA capital and labour inputs at 1988/89 prices

	Capital (£m)	Labour (£m)	Capital and Labour (£m)	Capital share
1988/89	622	1,035	1,657	37.6%
1989/90	657	1,045	1,702	38.6%
1990/91	765	1,021	1,786	42.8%
1991/92	859	1,030	1,889	45.5%
1992/93	907	1,014	1,921	47.2%
1993/94	959	1,115	2,075	46.2%
1994/95	946	1,184	2,130	44.4%
1995/96	976	1,250	2,226	43.9%
1996/97	1,149	1,327	2,476	46.4%
1997/98	1,193	1,259	2,451	48.6%
1998/99	1,215	1,282	2,497	48.7%
1999/00	1,294	1,345	2,639	49.0%
2000/01	1,353	1,240	2,592	52.2%
2001/02	1,295	1,215	2,511	51.6%

Source: Author

Following the post Gulf War recovery, further capital deepening was not possible, with the real cost of capital declining and lowering capital inputs relative to labour. The extent to which this was possible in any large way in a service industry may, in any case, have been limited, if the airline were to retain its reputation for high service standards. Some investment in automation led to reduced labour requirements, or at least moderated increases. Examples of this were:

- The replacement of B747-100/200 aircraft which required a flight engineer with B747-400s which did not (from Summer 1989)
- Computerisation in areas such as revenue accounting and management information which reduced staff needs
- Self-service check-in

It is noteworthy that BA's Information Technology budget increased from £35 million in 1982/83, or 1.3% of turnover, to £130 million or 2.7% of turnover in 1989/90. This was expected to reach 5% of turnover in 1995.⁷⁶ However, this is a small percentage of fleet assets and many IT or communications applications result in increased service quality rather than greater efficiency. One example of this is issuing passenger service staff with hand-held computers at check-in. It should be added that the air transport industry has been slow to adopt automation in areas such as check-in and ticketing, whereas other industries such as banking have developed faster. Some progress has been held up by the need for industry wide standardisation to be agreed (eg the Automated Ticket and Boarding pass, and electronic ticketing). This is partly because of the continued importance of interline sales.

Capital investment in aircraft also results in a reduction in the use of other inputs, notably fuel, maintenance and overhaul materials, and outsourced services.

8.7 Input and output price developments

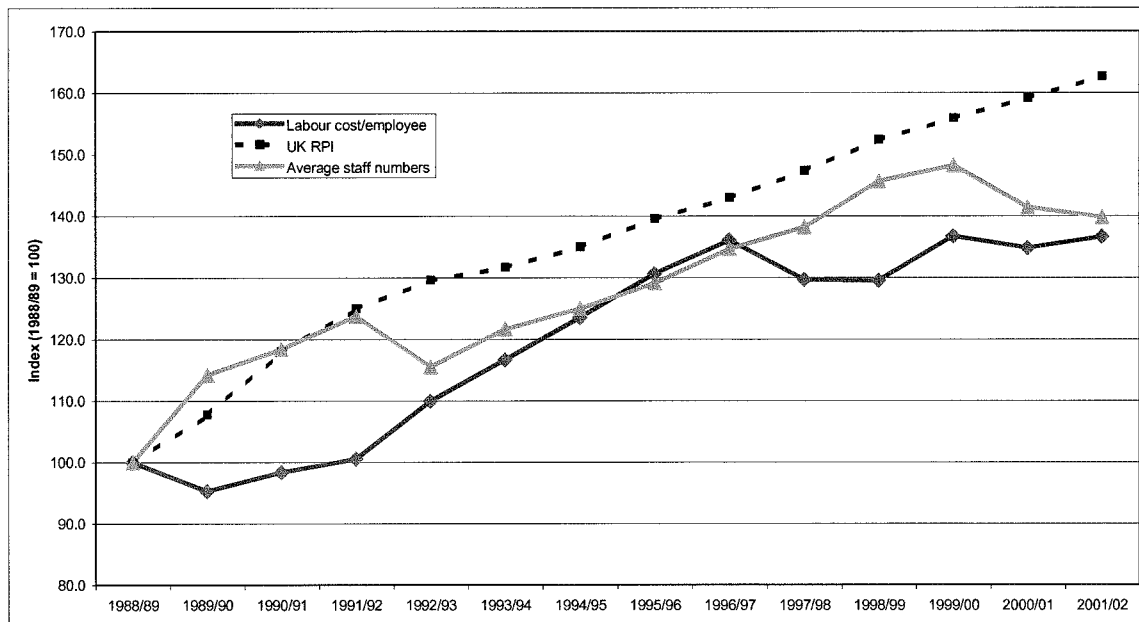
The profitable performance of BA depends, in addition to total factor productivity, on input and output price trends. These are examined in this section before seeing how the two combined to influence BA's profitability in the next section.

⁷⁶ BA Annual Report 1989/90, p.15.

Figure 8.12 gives the picture for labour, comparing BA's average labour cost per employee (labour price) with both employee numbers and the UK cost of living index. The labour price was depressed in the early part of the period because of the Gulf War and the serious losses incurred by BA and the industry in general. BA fared less badly than other airlines and pay increases were awarded soon after the beginning of the recovery in 1993/94. The increase in 1992/93 resulted more from laying off workers who were paid less than average wages.

The increases continued during the profitable period to 1997/98, when a reduction in bonuses and exchange rate benefits led to a fall in price. A threatened pilot strike had been averted in July 1996, and a cabin crew dispute in Autumn 1997 was finally settled with BA achieving the savings that it was seeking.

Figure 8.12: BA employee numbers and average pay



Source: UK Statistics, BA annual reports and author

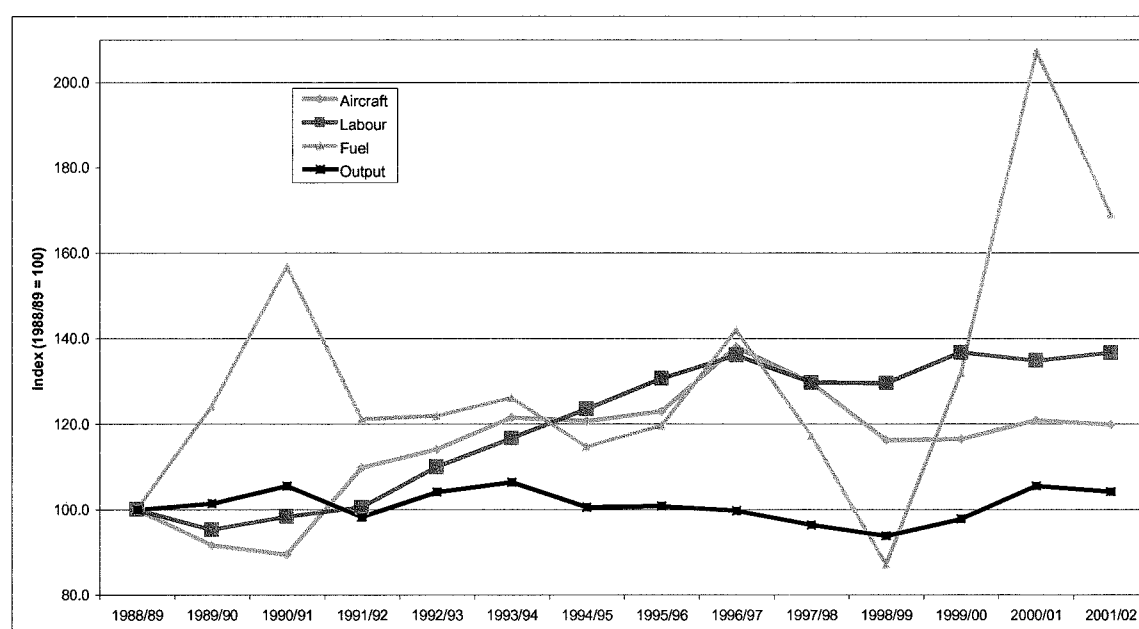
Over the whole period, the average BA wage advanced more slowly than the UK retail price index, although exceeding it during the five-year recovery period to 1996/97.

Labour price developments are compared with those for aircraft (base case) and fuel in Figure 8.13. The aircraft price index combines inflation in the cost of new aircraft with the cost of capital. The trend for aircraft dipped more markedly following the Gulf War recession, and again after 1996/97. The second downturn was driven more by lower long-term interest rates than new aircraft prices, which continued to increase

up to 2001. Fuel prices were more erratic, with a large increase prior to and during the Gulf War, and between 1988/89 and 2000/01.

The other inputs that account for a sizeable share of the total are distribution and airport and ATC services. The former's price has certainly dropped substantially over the past few years.⁷⁷ Airport charges are unlikely to have increased per landing or per passenger: charges at BA's main bases of Heathrow and Gatwick were regulated over the entire period, and these have fallen in current prices. Increases at other airports may have offset these to some degree.

Figure 8.13: BA's input and output price indices



Source: BA annual reports and author

Output prices (average revenue per RTK) are also shown in Figure 8.13. These hardly changed overall, with some rise more recently. This was partly due to growing competition in all world regions making it harder to pass through to the customer the input price rises shown above. It was also because of a trading down from full fare to discount fare in the economy cabin, and from first to business and business to economy in the other cabins. For BA, the average trip length did not change significantly and so this did not affect yield.

⁷⁷ Moves towards direct distribution reduced the amount of these inputs, and also increased the efficiency with which distribution is handled overall.

8.8 BA's economic and financial performance

This section provides the final link between the analysis of productivity and input price trends and BA's financial performance over the period. Financial performance can be measured in a number of ways. Here it is proposed to use operating profitability, after deducting interest charges. Interest paid on loans, finance leases and other forms of debt is normally excluded from operating results, and presented as a financial item, net of interest received. This has become anomalous with the growing use of operating lease, the charges for which implicitly include interest and are shown under operating costs (Morrell, 2002, p.60).

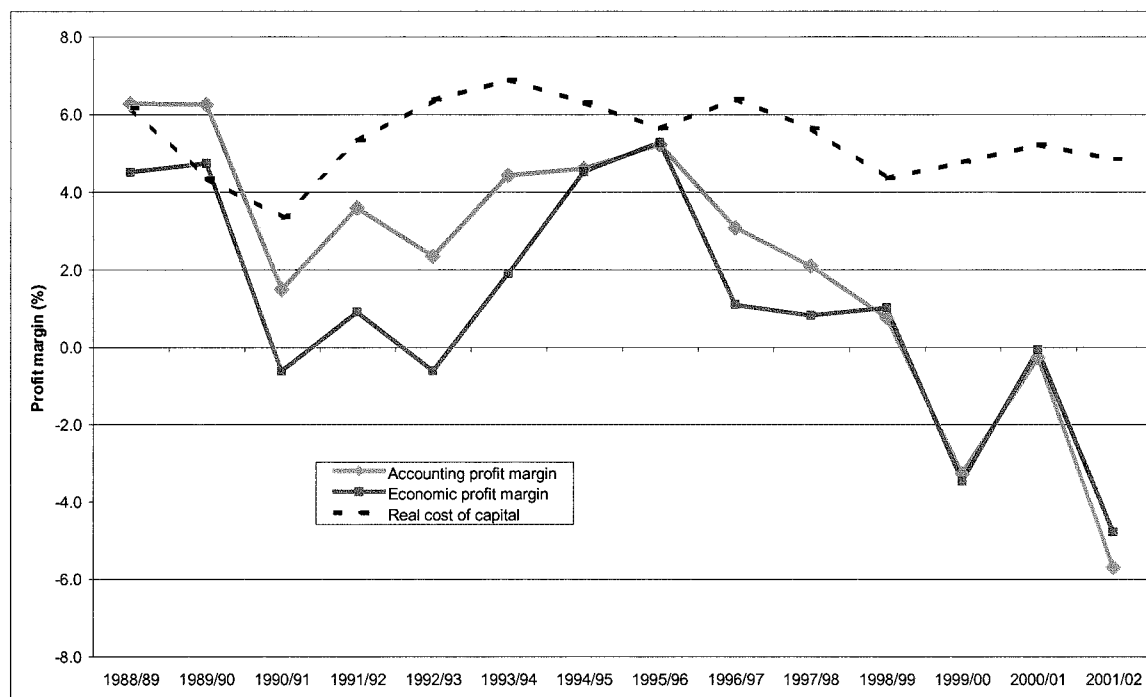
One problem with deducting total interest paid from operating profit is that part of interest charges relate to financing investments rather than fixed assets.⁷⁸ These are associated companies and trade investments, which are not part of the airline's operations. For this reason, interest charges have been allocated to BA's own operations and to investments in proportion to their average net book values over the financial year. Fixed assets were initially running at around 95-97% of total long-term net assets. However, with the acquisition of US Air and Qantas shares (both minority interests), the percentage fell to just above 90%, before stabilising at 96% with the sale of the US Air shares in May 1997.

BA's operating performance is shown in Figure 8.14 as operating margin (total operating revenue operating costs that include the allocated share of interest paid). This is compared with the same margin, but with accounting depreciation and allocated interest removed and the lease equivalent capital consumption inserted. The latter reflects an economic depreciation charge and associated interest expense. Operating and other short-term lease rentals remain as operating expenses for both calculations.

The two margins are close together in the later years, which means that the lease equivalent capital consumption was close to the accounting depreciation and allocated interest. The current cost of assets certainly moved much closer to their book values, and the depreciation and lease rental lives were broadly similar. The interest rate used for the equivalent lease calculation must have also moved closer to the actual amounts that BA were paying.

⁷⁸ It is assumed that current assets are exactly financed by current liabilities (in fact they more than cover current assets).

Figure 8.14: BA's accounting and economic profit margin (base case)



Source: Author's calculations

Where the two lines diverged was in the years of Gulf War economic recession and its aftermath (1990/91 to 1993/94). The economic margin assumed that the lease equivalent amounts were based on variable interest rates (year to year averages). It can be seen that the real cost of capital increased significantly over this period: this was not because of any rise in nominal interest rates, and indeed they were declining somewhat at that time. It was because of the reduction in inflation rate from 9.5% in 1990/91 to 1.6% in 1993/94. This led to an increase in the real cost of capital.

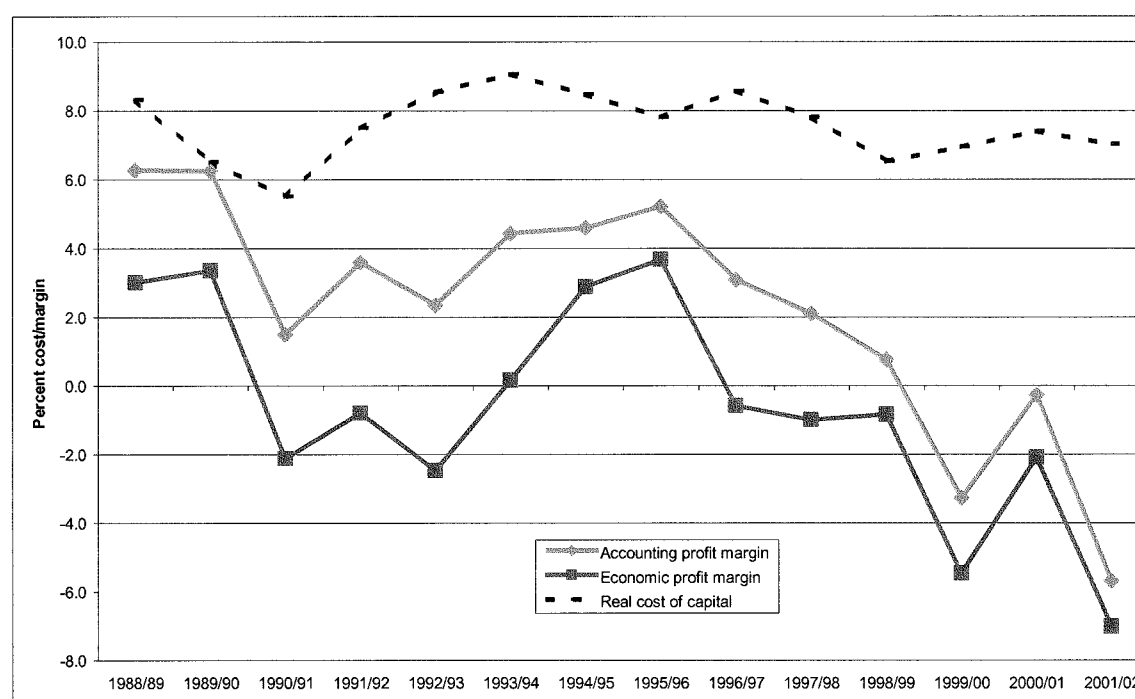
The accounting margin includes an allowance for interest costs, but not all of that was based on debt at variable interest. Some of it would be at the higher fixed interest rates prevailing in the late 1980s, but some would be based on borrowing in Japanese Yen at low interest rates.

This result suggests that accounting practice and the calculation of true economic costs were not too far out over this period (see Section 5.2.1). Thus economic and accounting profit margins were reasonably in agreement. However, the economic margin needs to be compared with the weighted average cost of capital, which in percentage terms is equivalent to BA's CVA concept described in Section 7.1. As can be seen from Figure 8.14, of the 14 years analysed, BA only exceeded their real cost

of capital in one of them, with the last four years all falling short of an economic return on assets.⁷⁹ The interesting finding is that the results were so poor during the upswing phase of the economic cycle, from 1996/97 until the start of the current downturn (early 2001).

High fuel prices accounted for the poor results for the last three of those years. Higher labour productivity helped in one of the years, but was fairly flat overall. Similarly, capital productivity gave no advantages, and TFP hardly grew over this period. However, on the output side, yields were declining from 1996/97 to 1998/99, and the meagre increases in the following two years were not sufficient to compensate for higher fuel prices. BA did not have the possibility of grounding more fuel inefficient aircraft at this time, and any change to more fuel-efficient (and twin-engined aircraft on long-haul routes) had to be gradual.

Figure 8.15: BA's accounting and economic profit margin (higher cost of capital)



Source: Author's calculations

The sensitivity test which lengthened the economic life of the fleet to 30 years would have improved the picture and resulted in the economic margin exceeding the cost of capital in 2 years (1989/90 and 1995/96), rather than only one. Conversely, a shorter life of 20 years would have made the situation even worse, with the margin covering

⁷⁹ CVA would only have been positive in one out of the 14 years.

the cost of capital in none of the years. The assumption of a higher cost of capital (both equity and debt) had the effective of lowering the economic margin and raising the return threshold (Figure 8.15).

If BA were consistently producing a lower return than the market had been looking for, how could the airline have continued to raise money for investments? The answer is first the fact that the market return was backward looking, and showed what investors had been happy with in the past, based on their expectations at that time. Ideally, the rate used here would be the forward-looking cost of capital, but there is no way of determining it. Further work on equity premiums and the beta ratio (used here as the basis for equity cost of capital and thus WACC) might reveal that even past values are too high. Second, investors are putting money into the industry and BA not only on their expectations of BA or industry profits but also on expectations about asset (aircraft) values. There are few mobile assets of this nature in the international arena, and there will continue to be those who expect to get the timing right so as to make money on the asset alone.

8.9 Summary and conclusions

This chapter has contained a detailed analysis of BA's productivity, input price and profit performance over the years 1988/89 to 2001/02. The starting point was chosen as the year when BA re-valued its fleet assets, enabling these assets to be converted to current or constant, rather than historic, prices in all subsequent years (the PIM method). The most recent year includes the first results from BA's major strategic change and the impact of 9/11 and the economic downturn that was beginning even before that date.

First, various operating parameters were examined to provide a background to the analysis. Variables such as average stage length and passenger trip length changed remarkably little over the period. These normally need to be corrected for in cross-sectional studies of airlines, but this was not necessary for BA. However, output quality was examined, and an adjustment was made for changes in average passenger weights for those output indices using passenger RTKs, which did not seem to be justified by changes in the loads carried.

Second, BA made significant changes to their strategy in 1998, which resulted in orders for more B777s and A320 family aircraft (smaller than the aircraft that they had relied on until then), and the cancellation of five firm B747-400 orders. This also

meant that the mix of output moved to more comfortable seating configurations and higher average seat pitch. Trends in passenger-kms or seat-kms would not reflect these changes. A method of allowing for this by standardising aircraft on one seat pitch was proposed, and this will be applied in the cross-section analysis in the next chapter.

Labour productivity has grown strongly over the period as a whole, increasing by an average of 3.4% a year. This was helped by capital deepening, the capital share in total constant price inputs rising from 37.6% at the beginning of the period to 51.6% in 2001/02. There was a period following the Gulf War recession when further capital investment was put on hold (with a time lag before it impacted the balance sheet), but otherwise investment was strong throughout.⁸⁰ Older B757s and the whole B747-100 and -200 fleets were retired, as were all the B737-200s. These aircraft had been the mainstay of both short and long-haul operations in the 1980s.

Capital productivity has declined over the period as a whole by an average of 1.0% a year. This was partly the result of a switch to smaller, less productive aircraft in the past three years. Taking the first ten years only to 1998/99 would result in a small advance in capital productivity of 0.4% a year. Adjusting for higher quality seat mix in the past three years would give continued, albeit low, growth in this indicator.

There are few published studies of capital productivity for airlines, which overlap the period studied here. Oum and Yu (1998) examined the period 1986 and 1993 (going up to 1995 for their output index and input prices, but not their partial productivity indices). From their graph of capital productivity trends by airline, it appears that BA's ratio declined from around 1.15 in 1986 (indexed on American Airlines in 1990 as 1.00) to just below 1.00 in 1993. This is equivalent to a decline of around 2.5% a year, after adjusting for stage length and output mix. The nearest period available from the analysis here is 1988/89 to 1993/94, when capital productivity fell at an average annual rate of 1.6%. The difference is, however, not surprising given the difference in approach between the two, especially in terms of capital inputs.

In spite of declining capital productivity, investments in new aircraft give far fewer benefits in terms of output quantity, and more quality improvements such as increased range, and environmental benefits. The latter also bring fuel improvements, and some reduction in labour input has been possible. BA's investment in new aircraft over the period has averaged 13.7% a year in terms of current prices, and 10.8% a year in

⁸⁰ A further lull in investment will take place over the next few years in order to strengthen the balance sheet post-9/11.

constant prices. These are high rates, and it is thus not surprising that capital productivity has not grown, since output growth could never have matched this rate.

TFP (with labour's contribution using deflated wages rather than MPE) has increased over the period as a whole by an average of 1.4% a year. This again is low in comparison to rates achieved in the 1960s and 1970s, and not sufficient to accommodate declining yields and increased input prices. Broadening the analysis to include other inputs might reveal a further stimulus, especially from distribution in recent years. Oum and Yu (1998) estimated BA's TFP to have grown by an average rate of 3.0% a year between 1988 and 1995. This compares with the result from this research for the same period of 3.2% a year. Encaoua (1991) had estimated BA's TFP to be growing at a somewhat lower rate of 2.2% a year for the earlier period from 1981 to 1986, which is a shorter period spanning a major economic downturn.

Input prices increased generally compared with declining output prices. The average cost of staff increased significantly following the Gulf War recovery, but has not increased and even declined somewhat in the past five years. Its increase has tended to be lower than the UK retail price index, partly as a result of the absence of profit related bonuses in recent years.

Aircraft prices increased more slowly than labour prices over the whole period, helped by marked reduction following the Gulf War recession, and again after 1996/97. The second downturn was driven more by lower long-term interest rates than new aircraft prices, which continued to increase up to 2001. Fuel prices were more erratic, with a large increase prior to and during the Gulf War, and between 1988/89 and 2000/01. It should be mentioned that very low operating lease rates would have been offered post Gulf War and again post-9/11, but major international airlines are locked into higher rates and could not normally take advantage of these prices to any significant degree.⁸¹

Economic and accounting profit margins were reasonably in agreement over most of the period. However, the economic margin needs to be compared with the weighted average cost of capital. Of the 14 years analysed, BA only exceeded their real cost of capital in one of them, with the last four years all falling well short of an economic return on assets. The interesting finding is that the results were so poor during the upswing phase of the economic cycle, from 1996/97 until the start of the current

⁸¹ It should be noted that the US Chapter 11 bankruptcy code allows airlines to force across the board reductions, and renegotiate lease and loan terms. United Airlines (one of BA's major competitors on the North Atlantic) was doing this in late 2002, following its entry into Chapter 11.

downturn (early 2001). This was due to static TFP, an escalation in fuel costs, and declining, or at best small increases in yields.

9 Productivity for cross-section of airlines

9.1 Introduction

In the previous chapter, a detailed analysis of BA over the past 14 years fulfilled part of the objectives of this thesis in applying a new methodology to the measurement of capital productivity. Various alternatives were examined, and conclusions drawn on BA's performance. This chapter addresses the thesis objectives in applying the new methodology to a sample of different airlines. As for the BA time-series analysis, the intention was to compare airlines using published information.

The approach to the measurement of outputs and capital inputs that was developed in earlier chapters has been applied to a cross-section of major international airlines in North America, Europe and Asia. This was also based on index number theory as for the time-series analysis in the previous chapter. However, it should be stressed that the application of index numbers to different airlines presents an additional problem in that there is no logical progression of comparison from one year to the next (chaining). One airline can be chosen as a yardstick against which all others are measured, but care needs to be taken that an alternative selection would not alter the outcome. It is also not possible to use deflated monetary outputs or inputs to get quantities or volumes for productivity measures in the same way as for time series.

The data is for the calendar year 1999, and various financial years for which the majority of months fall largely in 1999. The following airlines have been included, followed by their two-letter codes (which will be used in some of the charts), with their financial year-ends in brackets:

North America:

American Airlines - AA (31 December)
Delta Air Lines - DL (31 December)
Northwest Airlines - NW (31 December)
United Airlines - UA (31 December)

Europe:

Air France - AF (31 March)
British Airways - BA (31 March)
KLM - KL (31 March)
Lufthansa - LH (31 December)

Asia:

Cathay Pacific Airways - CX (31 December)

Japan Airlines - JL (31 March)

Singapore Airlines - SQ (31 March)

Thai Airways International - TG (30 September)

As stated in the first chapter, the year was chosen so as to avoid the turbulence of the most recent year for which data is available (2001/02) and the problems that Asian airlines faced during the earlier years of 1997 and 1998. All the airlines are network carriers and amongst the largest in their region. There was considerable competition between these airlines, especially on long-haul routes. Because of the bilateral nature of traffic rights on such routes, competition tended to be between US and Asian carriers on transpacific routes, US and European carriers on transatlantic routes, and European and Asian carriers on Europe/Asia. The US airlines had a very large home market in which they competed with each other. On the other hand, Asian domestic and intra-regional markets were still relatively protected in 1999. Intra-EU routes had already been opened up to competition since 1993, although some home markets (eg France) were still dominated by the country's major national carrier.

The concepts and measures described earlier rely on both physical and monetary quantities. These also need to be provided on a consistent basis for the same operations. Wherever possible, the core airline operations have been the focus of this study, and not the broader diversified group that was used in the last chapter (see Appendix N). For many airlines, there is not a large difference. For most of the US airlines in the sample, there is very little difference between the two. The one exception is American Airlines, which sometimes includes data for its American Eagle commuter airline division. It has been possible to exclude these operations, which are entirely domestic and use small jet and turbo-prop aircraft, and therefore are not strictly comparable to the major network carriers.

For the European airlines, BA and KLM consolidate wholly-owned regional or commuter airlines: Citiflyer Express and British Regional for BA, as well as Deutsche BA and, in 1999, TAT. For KLM, they included KLM uk, Transavia, and KLM cityhopper. These subsidiaries have been excluded for both airlines.

The Lufthansa Group consolidated their regional 100% owned subsidiary, CityLine, which has been excluded. The group also owned two substantial airline related businesses: LSG and Globeground (see Table 3.2 for their turnover in 2001). LSG, the services company, was in 1999 and is still focusing on contract catering for many

other industries apart from airlines and it seemed appropriate to exclude it from a comparison of airlines, which at most have smallish in-flight catering facilities at their main base. The smaller Globeground, involved in ground handling, was excluded because it only reported 3% of revenues (DM10m) contracted with other Lufthansa group companies. Thus for the Lufthansa group, only the mainline passenger services, Lufthansa Cargo and Lufthansa Technik, were included, even though this required data for separate companies to be combined to reflect a comparable mix of businesses to the other airlines in the sample.

In Asia, Singapore Airlines presents a different picture, depending on whether their ground handling and maintenance subsidiaries are included or not (they later evolved into a similar organisational structure to Lufthansa, when they split off cargo into a separate company). For the purposes of this research, ICAO data for the financial results of the airline (SIA) was used, but an estimate was made for the aircraft maintenance and handling work that was undertaken by the subsidiaries for the airline. The findings of previous recent airline productivity work had not made this important adjustment.⁸²

The sources of data used for revenues and balance sheet items were principally the ICAO Financial Digest of Statistics (Series F). All airlines in the sample reported, but the Lufthansa return provided no accompanying traffic data and some of their financial figures were missing. Thus for Lufthansa, the airline annual report for 1999 was the main financial source used. Traffic data was also taken from the same publication, cross-checked against the ICAO Traffic Statistics and IATA WATS reports, from which passenger-kms were added.

Labour costs and staff numbers were obtained mainly from the ICAO Fleet and Personnel Digest of Statistics Series FP (with the exception of Air France), cross-checked against airline annual reports. It was important to make sure that this data only covered airline, rather than group operations, and thus was consistent with the other items. Similarly, consistency was ensured between traffic and financial data, and between fleet size (eg excluding commuter aircraft) and all other figures.⁸³

⁸² Oum and Yu, 1998, omitted Lufthansa's 1995 data from its comparison, following its reorganisation the previous year. This was the last year of the series they studied. They used Singapore Airlines' airline employment of just under 13,000 staff, omitting any of the further 13,500 staff who worked in subsidiary companies in 1995.

⁸³ None of the previous studies of international airlines have addressed these problems, which did not arise for those which only considered US airlines.

9.2 Output

As concluded in Section 3.6, traffic based measures of output work better than value based ones, and are amenable to quality and other adjustments. Revenue tonne-kms were chosen for this analysis, rather than revenues or available tonne-kms. It was first necessary (based on the experience with BA) to examine the average weight per passenger assumption used to arrive at RTKs.

As can be seen from Table 9.1, of the 12 airlines in the sample only four used the standard ICAO/IATA 90 kg for each passenger and their checked and carry-on baggage. The low value for Japan Airlines reflects the significant number of domestic passengers in total passenger and cargo RTKs (just over 17% in 1999), who do not take much baggage. JAL used 75 kg for their domestic passengers and an average of 92.8 kg for international passengers. Of the remaining airlines that used more than 90 kg, only Lufthansa applied a higher average weight to international passengers: 100.3 kg versus 98.0 kg for domestic traffic. This difference was very small, and so it could be concluded that any variations in weight assumption across the sample were based on overall averages.

Table 9.1: Average passenger weights and RTK shares

FY1999	Average weights (kgs) per Passenger	Passenger tonne-kms as % Total RTKs
KLM	100.3	58.5
Lufthansa	100.2	54.4
Singapore Airlines	95.2	52.2
Cathay Pacific	95.2	51.3
American Airlines	90.7	84.1
Northwest Airlines	90.7	76.0
Thai Airways	90.1	66.2
Air France	90.0	60.5
British Airways	90.0	65.5
Delta Air Lines	90.0	85.6
United Airlines	90.0	80.3
Japan Airlines	89.1	61.2

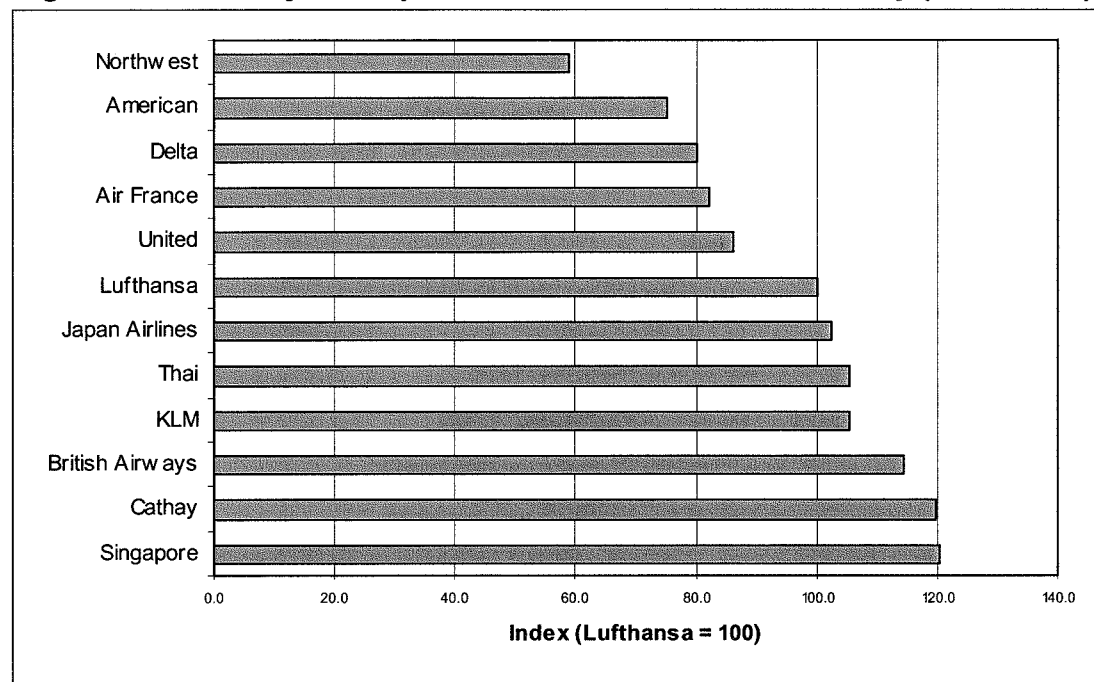
Source: ICAO Financial Statistics, 1999 and IATA WATS 1999

For the purpose of this analysis, it was decided to standardise weights by taking 95 kg per passenger for international and 85 kg for domestic passengers. This seemed a reasonable assumption without having survey data available, which would provide data both on the average weight of passengers (likely to be higher in the US compared

with Asia), and the weight of bags, which might also be lower than the 25 kg assumed here on some short-haul international flights. The higher figure for domestic traffic than used by Japan Airlines would possibly inflate that airline's RTKs, but the higher weight per passenger of the US airlines would probably justify the higher figure assumed for this region.

A second adjustment to output was made by considering the seating comfort for the aircraft types operated by each airline. There is a maximum number of seats allowed for safety reasons, and an index has been calculated by comparing the actual number of seats offered on each aircraft with this maximum, and taking an average across the fleet as a whole, weighted by revenue hours flown. The results are shown in Figure 9.1 (see Appendix O for the detailed calculations).

Figure 9.1: Quality of output based on aircraft seat density (1999/2000)



Source: Author's estimates (from Appendix O)

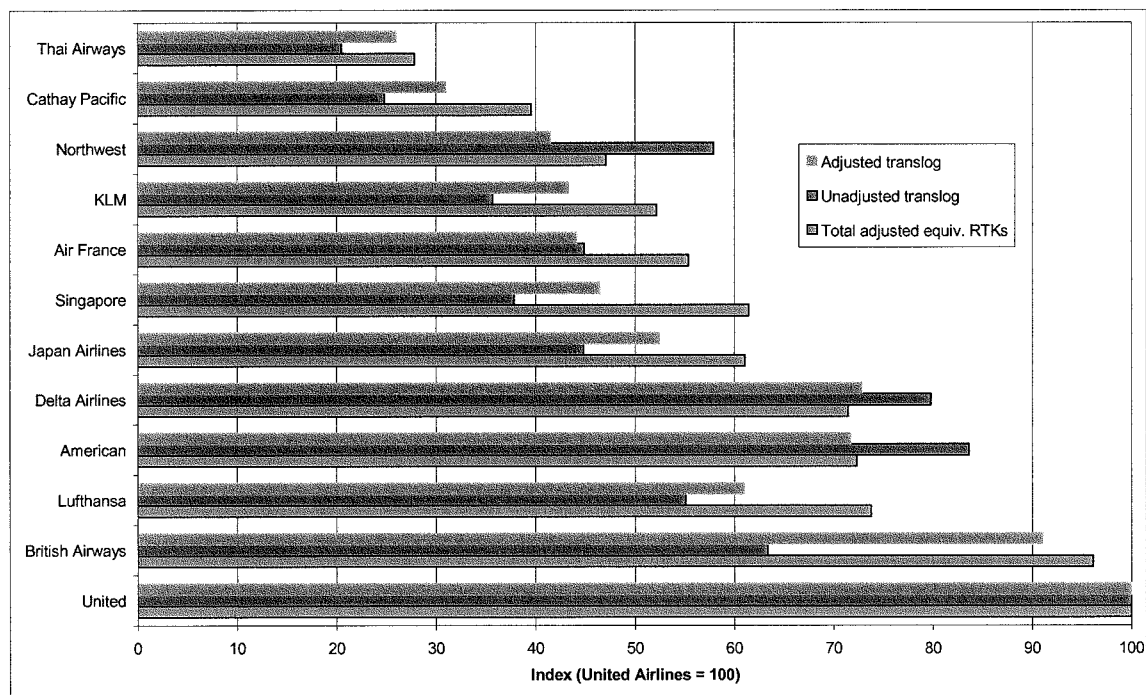
The airlines with more longer haul flights, such as Singapore and Cathay Pacific, would be expected to have a higher ratio, and they also have a reputation for above average service quality (which requires higher inputs). British Airways had, by 1999/2000, started to implement its new strategy. This involved moving towards a fleet mix of smaller aircraft and a higher proportion of business class seats. This already shows in their position in Figure 9.1.

The US airlines have a high proportion of domestic flights and thus would be expected to have higher seat densities and thus lower indices. However, the US airline Northwest also operates international B747-400 services with more seats than both Asian and European airlines.

Output has been measured in terms of RTKs for scheduled passengers, cargo and mail, and charters (as reported to ICAO). Incidental revenues have been measured in one of two ways:

- Incidental revenues have been divided by the average price paid for all categories of traffic (RTK yield) to arrive at equivalent RTKs (see also Section 8.1.3)
- Incidental revenues (PPP US\$) have been combined with RTK traffic in a multilateral translog index, using their share in total revenue as the weight

Figure 9.2: Output indices based on 1999/2000 data



Source: Appendix O

The first method simply sums RTKs by type of output and equivalent RTKs for incidental revenues to produce a figure of total RTKs. The second method combines each type of output (passenger, cargo, and incidental activities) into a multilateral translog index (as discussed in Section 2.2.1).

Figure 9.2 shows the various ways of expressing overall output, indexed on the largest airline in the sample, United. All three include incidental revenues, in terms of equivalent RTKs for one of the bars in the chart, and using incidental revenues directly in the two translog indices. The former has the advantage of providing a physical output measure that is not sample specific. The two translog indices would change if the sample were increased or reduced in size, since it calculates the index in relation to sample means. It is also only available in index form, which means that absolute differences cannot be compared in units with some meaning. However, for cross-sectional or panel data it provides index numbers which conform more to input and output substitution based on the production function.

The adjusted translog index includes both passenger weight and cabin comfort adjustments, as does the equivalent RTK total. BA gain on both of these adjustments, while the US airlines, especially Northwest and American lose. Singapore and Cathay gain from seat comfort, while Japan Airlines gains from the higher passenger weights used.

9.3 Capital inputs

It was not possible to take an identical approach to fleet values to that taken for the BA time series in Chapter 8, since none of the other airlines in the sample had recently re-valued their fleets to current market prices. Published accounts showed only their fleet at historical prices, and depreciated values. So each fleet was valued for the purposed of this comparison at current or replacement value, based on the range of aircraft values reported by Avmark (see Appendix P). January 2000 values were used, since these were little changed from January 1999 estimates.

The Avmark range is from the oldest to the newest aircraft, and so, for example, the value of the BA fleet (excluding non-mainline subsidiary airline aircraft) would lie between US\$10.2 billion to US\$18.0 billion. A point estimate was determined by taking the average age of the BA fleet as a whole (9.0 years) and assuming that a new fleet would be valued at the higher amount and a 25 year old fleet at the lower amount. The actual value was then estimated to be 9/25th up from the lower end of the band. A similar approach was taken for the other airlines.

It was important to include only aircraft placed on the balance sheet. The capital input or 'consumption' for those aircraft on operating leases (off-balance sheet) was taken

to be the actual lease rentals paid over the year.⁸⁴ A comparison was then made with the net book value of the fleets, as shown in the ICAO Financial Statistics (and for Lufthansa annual reports). These were averaged over the financial year, and converted to US dollars at the exchange rates reported.

Table 9.2 highlights the problem in using accounting net book values as a basis for capital consumption. There was a large variation in market to book value ratios across the sample, with Singapore Airlines showing the largest difference. This was because of their policy to write aircraft down on their books at a rapid rate. Lufthansa have also in the past written down aircraft rapidly, applying a life of only 10 years to 5% residual value until 1992, when it was increased to 12 years and 15% (Morrell, 2002, p.26). At the other extreme is BA, which has re-valued all its aircraft in 1988, and apply a period of between 20-25 years for their fleet, broadly in line with US airlines.

Table 9.2: Fleet on balance sheet: market to book and depreciation rates

FY1999	<i>Market (ex spares) to book values</i>	<i>Depreciation rate (% pa)</i>
Singapore	1.94	6.64
Lufthansa	1.83	4.63
Northwest	1.65	4.04
KLM	1.55	4.07
Thai	1.46	3.77
Air France*	1.45	5.22
Cathay	1.39	4.36
American	1.26	4.45
United	1.10	3.84
Delta*	1.06	6.20
Japan	1.06	3.20
BA	1.05	4.62

* depreciation rate for all fixed assets; *Source: Author and ICAO*

The market values in Table 9.2 exclude spares, and thus the differences would be greater if they were included. Thai Airways report the net book value of their aircraft related spares to be around 10% of fleet net book value.⁸⁵ For the larger airlines this should come down to between 5-10%. A provision for spares has been added to the dollar fleet values: 10% for total fleets of up to 150 aircraft; 8% for 151 to 300 aircraft and 6% for larger fleets than 300 aircraft.

⁸⁴ An alternative approach would be to combine these aircraft with the owned ones, and treat them in the same way. This would assume that operating lease contracts could be continued over the whole life of the aircraft.

⁸⁵ Thai Airways International. Annual Report for 2000/01, p.50

Capital input was then calculated using the formula discussed in Section 5.6, which requires inputs of both remaining service or economic life and interest rate. The former was initially set at 25 years less the average age of the fleet in 1999, with the interest rate set at 50 basis points over the six month US dollar LIBOR (London Interbank Offered Rate), or 6.4% for 1999. Using the average age for the fleet as a whole did not seem to give a very different result to summing the capital flow for each aircraft type and the average age for that type (this was checked for BA and American Airlines).

The Weighted Average Cost of Capital (WACC) would have been preferable, but this was only available for one or two airlines for different periods. British Airways were using a nominal WACC of 9.5% in pound sterling terms, which is well above the rate used here based in dollar terms (6.4%). This difference, however, is larger than might be expected from the UK/US interest rate differentials.

As expected, there was a relatively high correlation between average aircraft size (in terms of available tonnes) and capital input per aircraft (excluding GPE capital). This implied few economies of scale from larger aircraft. The regression equation (adjusted R^2 of 0.88) applied to the data in Table 9.3 was:

$$\text{Capital/aircraft} = -5.05 + 0.326 (\text{available tonnes/aircraft})$$

(-3.7) (9.1)

Table 9.3: Capital input per aircraft vs aircraft size

FY1999	Capital input/aircraft*	Tonnes/aircraft	Predicted capital input*
Singapore	14.2	53	12.2
Japan	11.3	48	10.7
Cathay	11.3	54	12.5
KLM	8.8	36	6.8
Thai	8.5	45	9.7
Air France	6.0	32	5.4
BA	6.0	40	7.9
Lufthansa	4.9	34	5.9
United	3.9	27	3.7
American	3.0	23	2.5
Northwest	2.9	27	3.8
Delta	2.8	23	2.6

* US\$ lease equivalent, excluding GPE capital, but including operating leases;

Source: Appendix R

Singapore Airlines' capital input was higher than predicted because of its newer aircraft. However, Cathay and Lufthansa also had younger fleets than the average, but

a very low share of their fleet on more expensive operating leases. BA was just below the average age for their fleet and also had a low share on lease. KLM has a high percentage of operating leased aircraft (as does Thai whose high lease share could not be allowed for in this analysis due to lack of data). Northwest had a very old fleet, and thus lower unit capital input than predicted, while Delta and American both had around 30% on operating lease and United an even higher share (40%).

A question arises as to whether there are any distortions arising from the conversion of currencies. The denominator of the capital productivity ratio is an index based on equivalent lease amounts expressed in US\$, using PPP rates of exchange with local currencies. For owned assets, US dollar valuations were used, but for operating lease amounts, reported local currency amounts could have been converted to US\$ using PPP \$ exchange rates (except for Thai Airways, for which PPP rates were not available). However, since these were already incurred in US\$, they would have first been converted to local currencies using market exchange rates. So where operating leases were a significant portion of capital inputs, a distortion would have occurred if market and PPP US\$ rates differed appreciably.

For example, for Japan Airlines, every US\$100 of operating lease rentals was converted to yen at the market rate of exchange (Y110.6), and this amount of Y11,060 would have been translated back into US\$ at the PPP \$ rate of Y161, giving only US\$60. Thus Japan Airlines' (and to a much lesser extent BA's) lease rentals would have been understated here if PPP rates had been used; so market dollar exchange rates were used to convert the 'local currency' equivalents back to the US\$ amounts in which they were incurred (and thus also to PPP dollars).

The share of operating lease cost to total capital input for all US airlines was above 25%. Of the other airlines, Japan had a lease share of 51%, followed by KLM with 46% and Air France with 36%. BA had only 17% and Lufthansa 7%. Singapore and Cathay had 10% and 3% respectively.

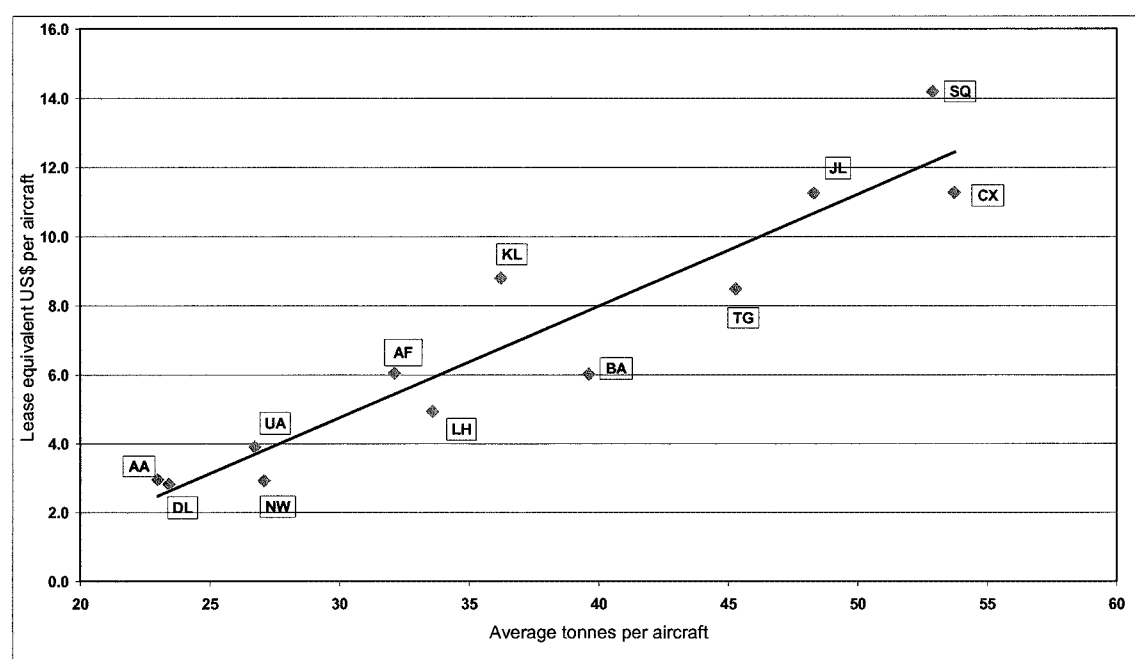
It was also impossible to treat ground property and equipment (GPE) in the same way as in the previous chapter, since re-valuations were not reported by ICAO, which requests airlines to report on a historical cost basis. Their average age was also not known, and so the lease equivalent cost of these assets was estimated by multiplying the lease equivalent of aircraft and spare parts by the ratio of net book values of GPE to the net book value of the fleet. This could be justified by the fact that assets with longer lives than aircraft (eg hangars, buildings etc) would offset those with shorter lives (eg computer equipment and vehicles). However, this assumption could inflate

capital inputs for any airlines that might have rented much of their longer life GPE. Operating lease rentals were then combined with the lease equivalent costs of the fleet, property and equipment to give the total capital consumed over the year.

The lease equivalent values for the fleet (excluding GPE) were divided by the average number of aircraft operated, and compared with average aircraft payload for each airline (Figure 9.3).

There was a reasonably good correlation between the two, as might be expected. Singapore Airlines recorded higher average values per aircraft due to their significantly lower average age of fleet of only five years compared to an average of almost 10 years for all airlines (and Northwest the opposite). KLM were also higher than expected, but this was because of a higher number of aircraft on operating lease than others (which tend to be more expensive).

Figure 9.3: Capital input per aircraft versus aircraft size (1999/2000)



Source: Appendix R

Thai Airways also operate a large share of their fleet on operating lease. This arose following the Asian financial crisis, when Thai did a large number of sale and leaseback deals to reduce their balance sheet debt. However, it was impossible to obtain an accurate number of aircraft on operating lease, and so these lease rentals were capitalised by multiplying by seven (see Section 5.6), and then treated as if they

were owned. Thai was also the only airline for which PPP exchange rates were not available.

9.4 Capital Productivity

Capital productivity was determined by dividing the output measures discussed in Section 9.2 by the capital inputs presented in the previous section. The two ratios were:

- Adjusted RTKs (including equivalent incidental revenues) divided by lease equivalent US\$ input of capital
- Translog index of outputs weighted by revenue shares divided by index of capital input (calculated as for the above bullet point)

It should be noted that productivity should be the ratio of two quantities, free from any input price distortions. The numerators, whether indexed on one airline (United) by means of the translog multilateral procedure, or in terms of adjusted RTKs do not contain any price distortions. The denominators are expressed in monetary terms for the first of the above ratios, but their starting point was the US dollar values of capital equipment and US dollar interest rates. They are based on identical prices for each aircraft type. This has the advantage of freeing the comparison from price or exchange rate distortions, and providing a proxy for volume inputs that *took into account the age and efficiency of the fleet*.

Sources of advantage that a particular airline might have from lower aircraft price or lower interest rates should not show up in productivity ratios, but be determined separately, along with other input prices. However, information on actual prices paid by airlines is not available, nor is detailed data on debt interest by currency of borrowing. The former would in any case have to be treated together with maintenance and training inputs that usually depend to some extent on the contract with the manufacturer for a new aircraft. The WACC approach is not free from such problems, but it does allow assumptions to be made about each individual airline's own debt and equity cost of capital.

The first method of calculation is shown in Table 9.4, both before and after indexing the amounts in RTKs per US dollar input on the 1999 value for United Airlines. It can be seen that without any adjustment for passenger weight and quality, Lufthansa

and Northwest achieved the highest productivity, and Japan Airlines the lowest. Adjusting for standard passenger weights narrowed the overall range (by bringing Japan Airlines closer to the average), but leads to some change in rankings.

Table 9.4: Capital productivity: equivalent RTK methods

FY1999	Quality adjusted Index	Passenger weight adjusted index	Unadjusted index	Quality adjusted RTKs/US\$ lease equiv. capital input
Lufthansa	116.9	105.1	107.1	10.70
BA	116.3	95.9	92.0	10.64
KLM	115.0	100.8	102.5	10.52
Singapore	113.3	92.4	91.5	10.37
Cathay	103.2	84.7	83.9	9.44
Thai	101.6	88.6	85.4	9.29
Air France	100.0	100.4	96.9	9.15
United	100.0	100.0	100.0	9.15
Delta	96.4	102.7	104.0	8.82
Northwest	92.1	117.7	117.6	8.43
Japan	85.5	75.9	73.1	7.83
American	82.6	92.2	93.0	7.56

* Passenger RTKs adjusted for both seat comfort and passenger weight

Sources: Appendices Q, R and S

Adding the seat pitch adjustment significantly increases the spread of outcomes, and also the ranking: three out of four Asian carriers with their longer stage lengths and higher quality of service all move above United, while the US carriers fill the bottom four positions. Lufthansa still do well and are joined by BA, with their recent focus on quality and their high share of passengers in total output. The final column of Table 9.4 shows the data before indexation. This option is not available for the translog procedure, and it does have an advantage of producing a ratio that has meaning by itself, rather than just in relation to other airlines. This is because it has units, in this case RTK output per unit of US\$ capital input.

One explanation for Japan Airlines' low ranking could be the fact that it had the highest share of non-fleet assets in its capital input, but did not generate very large incidental revenues. Either or both of these may have been misreported, and would need further investigation. At the other extreme were Singapore and Thai that reported low non-fleet assets, and the former (but not Thai) low incidental revenues. The US airlines tend to report low non-fleet asset shares (less than 10%), and the Europeans somewhat higher at 10-20%.

Table 9.5: Comparison of different approaches to capital productivity

FY1999	Adjusted translog index	Adjusted equiv. RTKs index	Unadjusted translog index
BA	115.3	116.3	80.9
United	100.0	100.0	100.0
KLM	99.5	115.0	81.9
Delta	98.4	96.4	107.8
Lufthansa	96.2	116.9	86.8
Thai	95.2	101.6	74.9
Singapore	86.0	113.3	70.1
American	82.1	82.6	95.8
Northwest	81.3	92.1	113.4
Cathay	81.2	103.2	65.0
Air France	80.0	100.0	81.4
Japan	73.2	85.5	62.6

Sources: Appendix R

The use of the multilateral translog approach to computing outputs and thus capital productivity gives a very different result (Table 9.5). Those airlines with a high share of air cargo move down the unadjusted ranking, and the more passenger oriented airlines move up. This is because the translog procedure applies revenue shares as weights, and air cargo generates less revenue per RTK than passenger services. KLM and Air France all fare badly using the translog outputs because of their high cargo shares (41% and 39% of total RTKs respectively), and Lufthansa drops in the ranking for the same reason (46%). The Asia carriers, Singapore Airlines (48% of RTKs were cargo) and Cathay (49%) did worst of all.

Revenue weights have been used in other recent studies (eg Oum and Yu, 1995 and 1998). Their justification rests on whether air cargo is inherently less capital and labour intensive than passengers. In other words, does cargo consume less input per unit of output? For the carriers considered here much of the cargo is containerised, with a growing part of that arriving at the airport in agent-packed aircraft compatible unit load devices. This means that these airlines do not have the handling costs that the high-value, high-priority, integrated carriers have. Furthermore, cargo does not need the in-flight and airport services that passengers demand. There are thus strong arguments for concluding that cargo requires less input, certainly of labour, and also of capital. Capital is still needed in terms of aircraft, even though this is often shared with the passenger part of output.

Table 9.6: Adjusted aircraft productivity vs stage length

FY1999	Adjusted RTKs/aircraft (000)	Av. stage kms	Capacity tonnes/aircraft
KLM	183.90	2,027	36
Singapore	149.19	3,969	53
Japan Airlines	149.05	2,434	48
Cathay Pacific	118.04	3,479	54
British Airways	89.22	1,839	40
Thai Airways	81.94	1,712	45
Air France	75.01	1,404	32
Lufthansa	67.57	1,200	34
United	64.76	1,785	27
Delta	39.18	1,367	23
Northwest	26.07	1,456	27
American	33.64	1,906	23

Sources: Appendices Q, R and S

Average stage length, together with aircraft size, could be important determinants of capital productivity, since the economies of scale both from manufacturer and from operation should show up in greater output per aircraft or per unit of input. However, there was almost no correlation between capital productivity (using whichever formulation) and each of these two operating characteristics. This was presumably because of the significantly higher capital input required to operate the larger aircraft over longer sectors. However, if aircraft numbers, rather than lease equivalents, were taken as the denominator in the productivity ratio, then there was a better correlation with aircraft capacity, although not with average stage length (see Table 9.6).

Table 9.6 shows adjusted RTKs (without revenue weighting) per aircraft against average stage length and capacity tonnes per aircraft, and those airlines operating longer sectors do not necessarily achieve higher aircraft efficiency. There is more of a tendency for those with larger aircraft to do better. However, American performs worse than expected from its average stage length of almost 2,000 km, penalised for operating smaller aircraft already in high-density configuration.⁸⁶ KLM performs well, despite operating smaller aircraft over medium length sectors, partly because of having the highest load factor of the sample.

Airlines operating their aircraft for a greater number of hours per day on average might be expected to obtain higher capital productivity, for the same reason as for longer stage lengths. While there is again some degree of correlation between RTKs

⁸⁶ In the year following the year used for this analysis, American increased the seat pitch of their economy class seats from between 78-81cm to 86-92cm. This involved removing 6.4% of their economy class seats. Airline Business, March 2000.

per aircraft and aircraft utilisation, the same does not hold for capital productivity, as seen in Table 9.7.

Table 9.7: Capital productivity versus aircraft utilisation

FY1999	Adjusted translog index	Aircraft utilisation (hours per day)
BA	115.3	10.3
United	100.0	10.7
KLM	99.5	11.1
Delta	98.4	10.5
Lufthansa	96.2	9.8
Thai	95.2	8.9
Singapore	86.0	11.7
American	82.1	10.0
Northwest	81.3	9.5
Cathay	81.2	12.4
Air France	80.0	11.6
Japan	73.2	10.3

Sources: Appendices Q, R and S

Oum and Yu (1998, p.85) found that their index of aircraft efficiency (translog output index divided by numbers of aircraft weighted by their value shares) was closely related to aircraft utilisation. This was not evident from their graph for 1993, which did not specify the source for aircraft utilisation. KLM's average utilisation was shown as 14.5 hours a day (AEA data for 1993 gave an overall average of just under 11 hours for KLM, close to their 1999 average shown in Table 9.7).

Oum and Yu (1998) produced an aircraft efficiency index that was adjusted for network characteristics. This approximated to an index of capital productivity, and their averages for 1993 showed the European carriers (1.139) to be ahead of the Asian (1.082) and North American airlines (0.920). Unweighted regional averages from Table 9.7 give the European airlines 97.8, the US airlines 90.5 and the Asian airlines trail at 83.9. The major reason for the change in ranking is the inclusion of seat quality, which penalises the US carriers, although the time lag and method of calculation also clearly resulted in Asian airlines performing worse. Asian carriers faced a major downturn in the intervening period, which the other regions did not experience. Baily and Zitzewitz (2001) showed the European airlines' capital productivity on average to have been only 92% of the US airline average, but this again did not adjust for quality.

Capital productivity, using the translog adjusted form, was tested against changes in both interest rate and aircraft economic life assumptions. The base case assumption of

25 years for the useful life was increased to 30 years, and reduced to 20 years, to evaluate its impact on productivity. An increase in useful life tends to increase productivity in absolute terms for all airlines (through reductions in capital inputs), especially those which own a higher proportion of their fleet and can thus make the most from this change. Thus, KLM and the US airlines get less advantage from this change, which is shown in relative terms to United Airlines in Table 9.8.

The benefits from a lengthening of economic life will go to the operating lessors that own the aircraft. On the other hand, a reduction in economic life hits airlines such as BA and Thai harder with few operating leased aircraft, and KLM gains relative to these and United. Cathay also falls back in relative terms, since it owns most of its fleet.

Table 9.8: Capital productivity (translog) indices vs aircraft economic life

FY1999	25 years	30 years	20 years
BA	115.3	119.1	109.9
United	100.0	100.0	100.0
KLM	99.5	97.7	102.4
Delta	98.4	99.0	97.5
Lufthansa	96.2	100.6	90.1
Thai	95.2	100.8	87.7
Singapore	86.0	89.6	81.1
American	82.1	83.5	80.1
Northwest	81.3	82.2	80.0
Cathay	81.2	85.5	75.4
Air France	80.0	79.9	80.2
Japan	73.2	71.5	76.1

* Note: Cost of capital (US\$) = 6.4%; Source: Appendix T

Table 9.9 shows the sensitivity of capital productivity to changes in cost of capital assumption. Higher interest rates tended to reduce the difference between the highest and lowest performance in the sample. United and Cathay moved down the ranking as interest rates increased, while KLM increased its relative position, although there was little change in the overall rankings.

The sensitivity tests were applied only to owned assets. Leased assets were treated as capital costs that were fixed under contract, although in practice interest rates might have been adjusted during the year. Furthermore, in the discussion above, those airlines with a high percentage of leased assets tended to do worse than those that did not. The question then arises as to whether operating leased aircraft should be capitalised (as BA have done for CVA calculations in Section 7.1). If the purpose of the analysis, as it is here, is to compare the efficiency of aircraft (and other assets) on

the basis of real resources used, then the answer is yes. An owned and leased aircraft of the same type and vintage would command the same future rental streams and thus value (other things being equal). They should therefore be treated in the same way.

Table 9.9: Capital productivity (translog) indices vs US\$ cost of capital

FY1999	Cost of capital = 6.4%	Cost of capital = 7.4%	Cost of capital = 8.4%
BA	115.3	113.8	112.4
United	100.0	100.0	100.0
KLM	99.5	100.3	101.0
Delta	98.4	98.2	97.9
Lufthansa	96.2	94.5	92.8
Thai	95.2	93.1	91.1
Singapore	86.0	84.6	83.3
American	82.1	81.5	81.0
Northwest	81.3	81.0	80.6
Cathay	81.2	79.5	78.0
Air France	80.0	80.1	80.1
Japan	73.2	74.0	74.8

* Note: Aircraft economic life = 25 years; Source: Appendix T

The main argument here for not capitalising them is that more serious distortions might be introduced. The application of the 7x rule by both BA and SAS does not work so well for medium and long-haul aircraft (see Appendix F), quite a few of which were leased by a number of airlines in the sample.

If, however, the purpose of the analysis were to examine the economic return on capital assets against the rates that the market expects (as will be the focus in the last section of this chapter), then it would probably be better not to capitalise leases. Investors are looking for their target return on an airline's own assets, and not leased ones, which might be considered as another input, the capital for which is financed by a third party (eg ILFC or Gecas). It is thus for the operating lessors to examine the economic return on these assets.

9.5 Labour productivity

Labour productivity was calculated by dividing equivalent RTK output (two methods) by numbers of employees (manpower equivalents). In this way, price was removed from both numerator and denominator of the productivity ratio. Using PPP\$ or US\$ wage inputs would have incorporated the price advantage that low wage countries such as Thailand enjoy. However, because the measure of capital productivity had

adjusted output to a common seat pitch, it was necessary to revise the numbers of employees to match the higher or lower output. Capital input would not change, since an identical fleet would be operated.

On the other hand, labour inputs would be sensitive to volume of output, in particular cabin crew, sales, ticketing and promotion and airport handling staff. So the share of these categories of staff was determined from the annual IATA statistics,⁸⁷ and applied to the original total number of employees for each airline, which was revised pro rata according to the change in RTKs as a result of the passenger weight and seat comfort adjustments.

Table 9.10: Labour productivity indices (two output measures)

FY1999	Translog RTKs/employee	Adjusted RTKs/employee
Japan Airlines	240.0	280.4
Singapore	213.1	280.6
Cathay Pacific	196.8	250.1
KLM	151.0	174.6
British Airways	142.7	143.9
Lufthansa	126.1	153.2
United	100.0	100.0
Delta	95.2	93.3
Thai Airways	95.2	101.5
Northwest	90.7	102.8
Air France	84.2	105.3
American	80.4	80.9

Source: Calculations from Appendix Q, R and S

From Table 9.10 it can be seen that Japan Airlines (a high wage cost country for Asia) achieved the highest labour productivity using the translog measure, ahead of Singapore Airlines, which was highest in terms of the simpler adjusted RTK measure, after inclusion for both of part of their ground handling and engineering subsidiary staff numbers and costs.⁸⁸ BA and KLM were ahead of other European rivals on both measures, after taking into account their higher quality output (and revised employee numbers).

⁸⁷ IATA World Air Transport Statistics, 44th edition, June 2000

⁸⁸ This was done by estimating numbers and costs of SATS and SIA Engineering staff working on SIA airline contracts. S\$523m was the estimated value of this work, which accounted for 38.6% of the turnover of the two subsidiaries: this % was used to estimate staff numbers, whose cost was based on the average cost per employee of SIA as a whole.

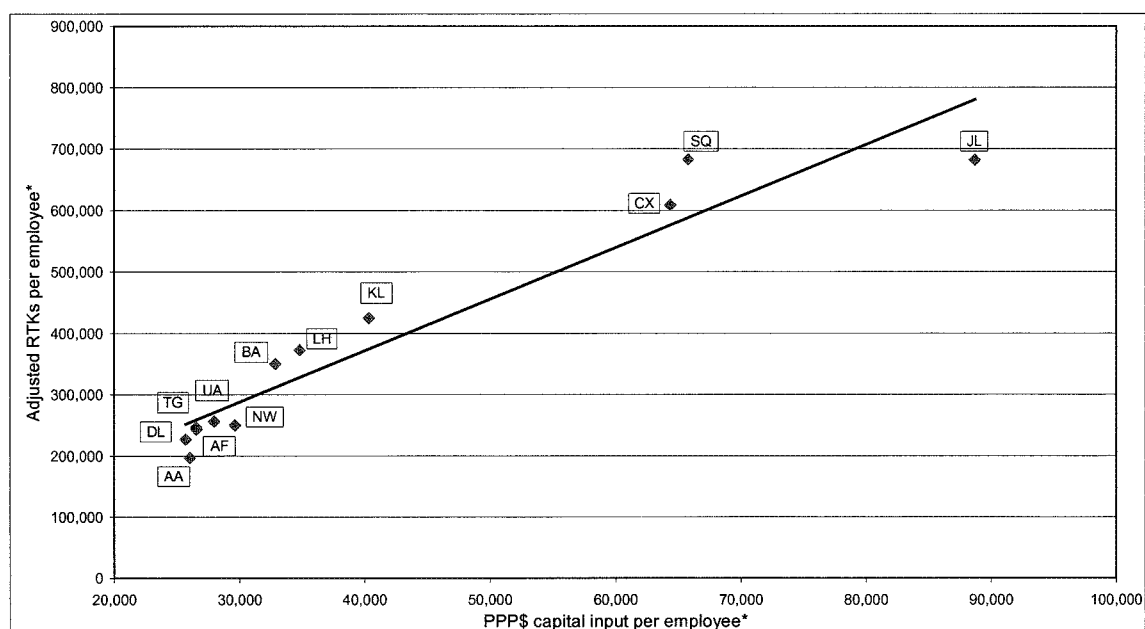
Capital intensity, expressed as the lease equivalent capital per employee, should be an important driver of labour productivity (Figure 9.4). The best-fit regression line had an adjusted R^2 of 0.91.

$$\text{Adjusted RTKs per employee} = 35,847 + 8.40 \times (\text{Lease equivalent capital per employee})$$

(+ 1.0) (+ 10.3)

This surprisingly good correlation is also shown in Figure 9.4 (with the best-fit line from the above equation). Singapore does much better than expected, having a high quality product and using labour efficient large aircraft over longer sectors. It can be seen that British Airways, KLM and Lufthansa achieved slightly higher labour productivity than would be expected by their capital intensity, and Northwest, American and Japan Airlines slightly worse.

Figure 9.4: Labour productivity and capital intensity (1999/2000)



* employee numbers revised as result of quality changes in RTKs, Source: Appendix S

KLM achieved a relatively high load factor, but probably has the most hub-oriented operation of all the non-US airlines, and has been shown to have higher capital inputs than most of the others through its heavy involvement in operating leases. Northwest has lower capital input from operating old aircraft, while Thai's capital input may be distorted by the process of capitalising its operating leases.

Japan Airlines was significantly more capital intensive than the other airlines, and also would have been expected to generate higher labour productivity than it did. This

may have been because of more restrictive work practices, or perhaps through needing higher numbers of employees than were estimated to contribute to its higher levels of service.

9.6 Total factor productivity

Total factor productivity was determined by dividing a quantity index of output by a weighted average of input quantities, or alternatively expressed as the weighted product of capital and labour productivities:

$$TFP = (Y/K)^{\alpha} \times (Y/L)^{1-\alpha} \dots\dots\dots (9.1)$$

Where Y is a volume index of output (both the adjusted RTK and adjusted translog indices), and K and L are volume indices of capital (US\$ lease equivalent index) and labour (employee number index) respectively. The weights are the shares in value added of capital (α) and labour ($1 - \alpha$). Both inputs and outputs are free of any input price distortions, since capital inputs have been calculated on the same aircraft price and interest rate basis for each airline.

Together with BA, three of the Asian airlines perform best on Total Factor Productivity (TFP), mainly through their above average labour productivity (Table 9.11). Thai performed worse than other Asian carriers, but operates over shorter sectors. Air France scored badly both on capital and labour productivity, operating below average sized aircraft over relatively short stage lengths.

Table 9.11: Capital, labour and TFP (translog indices)

FY1999	Capital productivity	Labour productivity	TFP
BA	115	143	129
KLM	99	151	126
Singapore	86	213	125
Cathay Pacific	81	197	121
Japan Airlines	72	240	119
Lufthansa	96	126	113
United	100	100	100
Delta	98	95	96
Thai Airways	95	95	95
Northwest	81	91	88
Air France	80	84	83
American	82	80	81

Source: Calculations from Appendices Q, R and S

The US carriers as a whole performed worse than the European airlines; this was the opposite of the conclusion from a study by Baily and Zitzewitz (2001, p.448), which concluded that, based on 1995 data, the European airline sample achieved on 75% of the level of US carriers. However, they took a larger sample of European airlines, which included Swissair, Iberia, Alitalia, and SAS, whose TFPs may have been below the sample used here. They also disregarded air cargo, which would have significantly penalised three out of four of the European carriers.

United and Delta did best of the four US airlines: they combined higher capital productivity with higher labour productivity than the others, but also suffered less through the seat comfort adjustment. The US carriers are less capital intensive than airlines from the other two regions, and this lessens the importance of capital productivity for them (see Figure 9.4).

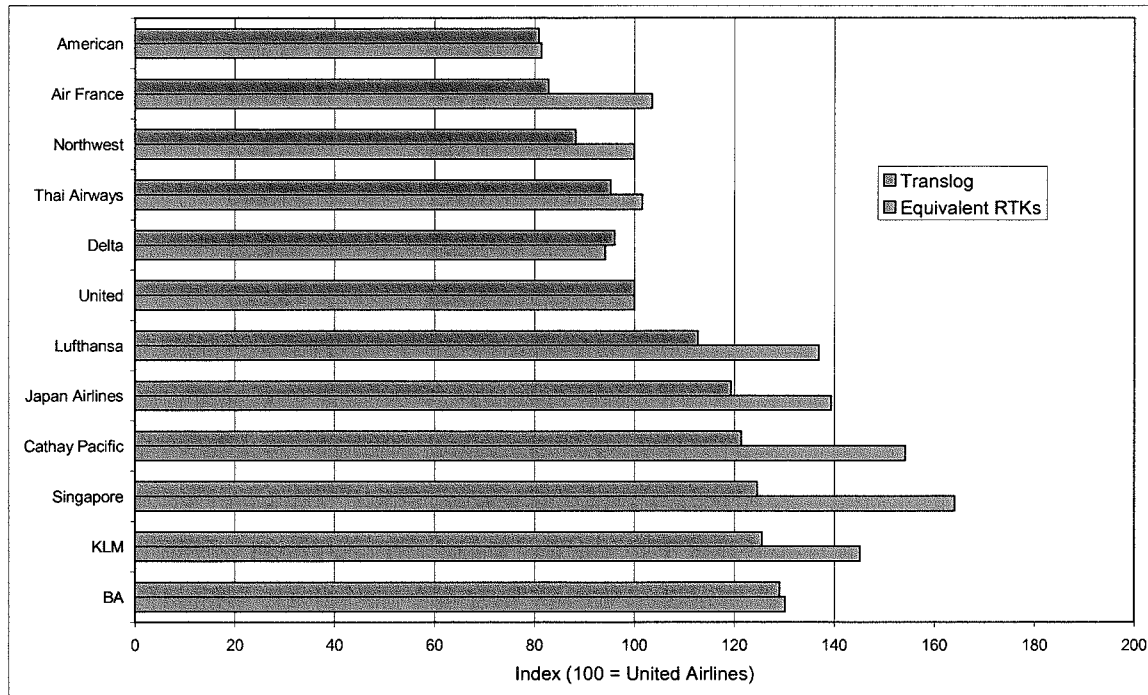
From the above equation, Lufthansa, Japan Airlines and to a lesser degree, BA, do better than predicted, while Thai does much worse. It does seem quite critical to achieve a high overall load factor (including cargo), rather than just a high passenger load factor. For the translog index, this would not be so important.

Oum and Yu (1995) found that the four European airlines were around 10% below the four US airlines included here (an average of their 1992 indices, KLM not being shown for 1993). As already discussed, this study did not take into account quality, and the same authors in their 1998 study admitted that their 'efficiency results were likely to be biased against airlines that produce consistently higher quality of service than average carriers' (Oum and Yu, 1998, p.205). The latter study's individual TFP airline rankings of the airlines included here showed Singapore Airlines to perform best, followed by KLM, Cathay Pacific and then United and Northwest. All these featured high in the ranking in Table 9.11. BA was the exception, which ranked top here, and close to the bottom in the 1998 study. One possible explanation for this is BA's poor record for reporting financial data to ICAO.

An alternative way of arriving at a TFP index is shown in Figure 9.5, and compared with the translog index shown in Table 9.11. This takes RTK output, adjusted for passenger weights and seat comfort, and compares this directly with that of United Airlines, in a similar way to chaining time series data. Input data are calculated in the same way as for the translog index. This gives a broader range of outcomes because the translog tends to compress outlying points. The airline ranking does not change significantly, with Air France moving up three places and KLM, Cathay and Singapore one place in the table. Lufthansa moves up one place to join BA, which

drops well back as a result of its low air cargo involvement (which now gets more weight), and the US carriers now occupy the bottom four places.

Figure 9.5: TFP comparison of output approaches



Source: Appendix S

None of the operating characteristics in Table 9.12 were very closely correlated with the translog TFP productivity index, with overall load factor the highest with an adjusted R^2 of only 0.55. Passenger load factor was much more similar across all the airlines, and thus was poor in its correlation with TFP. On the other hand, when the other form of TFP was used (adjusted RTKs with no translog weights), overall load factor variations explained 68% of variations in TFP, and together with stage length (kms) 84%:

$$\text{Adjusted RTK TFP} = -73.4 + 2.54 (\text{Overall Load Factor}) + 0.014 (\text{Stage kms})$$

$$(-2.3) \quad (+4.9) \quad (+3.3)$$

This result is not surprising, and it can be concluded that these two factors would be fairly good predictors of this measure of TFP. The error in predicting the coefficient of each of them is not increased by multicollinearity, since the two independent variables are very poorly correlated with each other.

Table 9.12: Airline traffic and operating characteristics

FY1999	Aircraft capacity tonnes	Overall load factor	Average stage kms	Average trip kms
Japan Airlines	48.3	67.7	2,434	3,093
BA	39.6	67.3	1,839	3,867
Singapore	52.9	71.1	3,969	5,512
Cathay Pacific	53.7	72.0	3,479	4,539
KLM	36.3	77.3	2,027	4,773
Lufthansa	33.6	71.1	1,200	2,889
United	26.8	57.5	1,785	2,569
Delta	23.5	58.2	1,367	1,728
Thai Airways	45.3	69.7	1,712	2,626
Northwest	27.1	61.7	1,456	2,349
Air France	32.2	61.7	1,404	3,123
American	23.0	53.5	1,906	2,338

Source: Calculations from Appedices Q, R and S

It is impossible to compare the results described in this section with those of previous studies because of the very different approach adopted here. Oum and Yu (1998) only go up to 1995, when they found TFP for the Asian airlines ahead of the US carriers (but not by a big margin compared to the best US performer, United), and most European airlines fared worst. The two quality adjustments to output made in this section have reduced the relative performance of the US carriers, and tended to enhance that of the Asian airlines (as well as BA). Oum and Yu (1998, p.115) stated that their stochastic frontier work had contradicted their TFP results for two airlines in particular, BA and Thai Airways. Two possible explanations were given for the, the first being airport congestion (not a major factor for Thai), and the other the fact that service quality was not incorporated in their TFP methodology.

9.7 Input prices and operating performance

In the previous sections, comparisons have been drawn with volume indices of productivity, both partial and for labour and capital combined. It was not possible to obtain data for all carriers' fuel efficiency, and even less data is available for the volumes of other inputs consumed. In this section, the financial results will be assessed for FY1999, taking into account labour input prices and various measures of operating performance.

The financial results have been obtained from the same sources as the operating revenues, namely the ICAO Financial Statistics and airline annual reports. From these, an accounting operating ratio can be calculated as:

$$\text{Operating ratio (\%)} = (\text{Operating revenues} \times 100) \div \text{Operating expenses}$$

Operating expenses here have been broadened to include net interest paid.⁸⁹ This ratio has then been converted to 'economic' terms by taking out net interest and accounting depreciation from operating expenses and adding back the lease equivalent capital inputs that were calculated in Section 9.3. These were converted to local currencies using US\$PPP exchange rates, and combined with the other amounts that were also reported in local currencies. This reduced the possibility of exchange rate distortion.

Table 9.13: Economic versus accounting operating ratios (%)

FY1999	Economic	Accounting
KLM	111.5	115.1
Delta	111.4	107.5
Thai Airways	108.1	111.6
United	104.5	106.3
Air France	104.2	105.8
Northwest	103.0	104.5
American	101.7	106.6
Singapore	96.6	110.7
BA	95.7	96.5
Cathay Pacific	93.6	108.8
Lufthansa	92.9	99.0
Japan Airlines	92.3	100.0

Source: Appendix Q

A tendency for a reduction in operating ratio for most airlines from the accounting to the economic formulation was due to the inclusion of an interest charge, whereas in the accounts any interest paid was offset against interest received. It could also be because some aircraft were written off in the accounts, but could still command a lease value, and were thus given an economic opportunity cost. The third reason would be the higher market values of the fleet that were used for lease equivalent calculations, compared to net book values. KLM, Singapore and Cathay all fell into this category (Table 9.13), with significant reductions in the ratio. The operating ratio should reflect the following productivity and price outcomes:

- Output prices (yield)
- Total labour and capital productivity
- Fuel and other input productivity

⁸⁹ Interest paid, rather than net interest paid, would have been preferred, but data was not available from this source.

- Labour prices
- Capital prices
- Other input prices

Only the first, second and fourth items from the above list could be calculated here. Fuel productivity and price paid was available for some airlines, and it is likely that this would have varied quite considerably across the sample, after allowing for offsets from hedging.

Capital prices were standardised for all airlines, both regarding the prices paid for aircraft and the cost of capital incurred. The sensitivity of capital inputs to changes in cost of capital were explored in Section 9.4, but the problems remain of obtaining actual prices paid by airlines, after tax interest rates paid on debt, and the equity premium that each national stock market requires.

Finally, other non-fuel inputs, which still amount to some 30-40% of total input costs, cannot be analysed either in volume or price terms through lack of data. Some cost breakdowns are available from annual reports, but the ICAO reports group costs into function rather than input categories. With some increase in the degree of outsourcing, this uncertainty becomes greater, since airlines will not divulge prices paid for catering, ground handling, IT and other services. Even airport and ATC services, for which more data is published, are difficult to incorporate into single dimension measures of volume and price.

Table 9.14 shows some of the factors or ratios that might have had an impact on the economic operating ratio. Output price is reflected in the degree to which an airline had achieved a higher or lower yield than that predicted from the average trip length of its passengers alone. Only the input price of labour can be given. Overall (passenger and cargo) load factor is also shown, but none of the network characteristics such as average sector or trip length or average aircraft capacity were closely correlated with either TFP or operating ratio.

The US carriers were faced with the highest wage rates of the sample, and operated a higher percentage of more labour intensive shorter haul routes, resulting in the lowest labour productivity scores. Given the higher weight of labour, their TFP was also reduced. However, Delta produced a high economic operating ratio, despite not having above average load factors or passenger yields. Northwest and American offset low productivity with above average fares. United's positive operating ratio was the result of only average yield and productivity, but they were let down by high

wages and low load factors. Its subsequent decline to Chapter 11 bankruptcy shows how delicate the balance is in the airline industry between success and failure. The only indication here of its problems two years on is the fact that it had the highest average wage in the sample. This and its inability to do anything about it because of union control was a major factor in its downfall.

Table 9.14: Possible factors explaining variations in economic operating ratio

FY1999	Economic operating ratio %	TFP	Average Wage PPP\$	Passenger yield*	Overall load factor %
KLM	111.5	119	50,718	111.7	77.3
Delta	111.4	95	64,240	94.6	58.2
Thai Airways	108.1	96	16,862	47.2	69.7
United	104.5	100	69,403	97.0	57.5
Air France	104.2	88	51,561	112.6	61.7
Northwest	103.0	83	68,386	128.3	61.7
American	101.7	81	64,649	119.3	53.5
Singapore	96.6	125	48,505	111.5	71.1
BA	95.7	126	39,341	99.1	67.3
Cathay Pacific	93.6	121	56,825	78.0	72.0
Lufthansa	92.9	113	47,741	84.1	71.1
Japan Airlines	92.3	129	65,759	69.5	67.7

* actual yield expressed as a percentage of the yield predicted from average passenger trip length

Source: Appendices Q, R and S

Interestingly, BA were a low wage carrier compared to almost all the others in the sample, and (apart from Thai) the Asian majors do not pay low wages. However, Cathay and Singapore employed a sizeable number of expatriates, which would have raised their average, and Japan Airlines pay very generous allowances for travelling to/from work. All these airlines tend to have high productivity and high load factors, but (apart from Singapore) low yields, especially in relation to their higher quality product. This has been taken into account in seat comfort and output, but not through the higher inputs of services not covered in this analysis (such as in-flight meals, airport lounges etc).

Thai Airways managed to achieve a relatively high operating ratio in spite of average productivity and very low yields. It did, however, have an advantage of very low wages.⁹⁰ It also had some quite lucrative incidental activities such as limousine services and duty-free.

⁹⁰ Something other airlines have been trying to take advantage of: for example, Qantas hires significant numbers of its cabin crew for long-haul services in Thailand.

BA's poor financial performance in 1999/2000 was recorded against a background of low wages and high total factor productivity, while it had a somewhat low load factor but reasonable yields. Its PPP US\$ exchange rate was about 7% higher than its market £/\$ rate. This means that those expenses incurred in US dollars (other than capital, which has been converted at PPP rates) should have been converted to somewhat lower local currency amounts. Capital and labour account for a lower proportion of total inputs than many others due to outsourcing, and thus the services bought in (and not analysed here) would have made an appreciable difference. As stated above, some of these would have necessarily have been more costly to meet above average service quality.

Fuel prices were only available for one or two individual airlines. The last report on this by ICAO for 1997 estimated aircraft fuel prices in US cents per litre to have been 9% higher in Europe compared to North America, and 24% higher in the Asia/Pacific region.⁹¹ This would have supported the more favourable economic operating ratios for US carriers in Table 9.14. The same report gave landing and associated airport charges per departed tonne, but this data needed to be treated with caution, especially for the North American region, since the cost of passenger terminals appeared to have been omitted. However, European airports looked more expensive than Asian ones.

9.8 Summary and conclusions

This chapter has applied the approaches described in earlier chapters and partially applied to one airline (BA) in the last chapter to 12 international airlines (including BA). The analysis goes a step further than the time series ratios for BA by adjusting output for an important dimension of quality, namely seat comfort. Data has been collected for the financial year 1999, from a number of sources, but attempting to focus solely on the airline and closely associated activities such as aircraft maintenance.

Output was measured by RTK equivalents, where incidental revenues were converted to RTKs by applying the average yield for airline operations. These were added to passenger, cargo, mail and charter RTKs to arrive at a total of physical output, which was then indexed across the sample, with 100 being output for United Airlines. An alternative approach was used which produced a multilateral translog index using the revenue shares of each of the types of output as weights.

⁹¹ Regional differences in international airline operating economics, 1997. ICAO Circular 280-AT/117, Table 4-3, p.26.

Capital consumption was measured, by taking the lease equivalent of the current market value of the fleet and spares for each airline (market values taken from Avmark for January 2000). This was combined with operating lease rentals in US dollars, and GPE lease equivalents to arrive at a total US\$ value of capital consumption, which was then indexed on United Airlines. The market value for identical vintages and types of aircraft was taken to be the same, as was the interest rate used (6 month US\$ LIBOR plus 50 basis points). All airlines were assigned a 25-year economic life for their fleet. Thus no input price specific differences were included in what was designed to be a volume or quantity index. The high market to book ratio of fleet assets for many airlines confirmed the need to focus on current market rather than historical values.

BA performed best on capital productivity, once their higher quality output had been allowed for. They also recorded reasonably high labour productivity to come out top on TFP. However, this would not alone be sufficient to produce a high economic operating margin, even with their relatively low wage rates. Yield and load factor are also important, and other inputs that can account for up to half of total inputs. Their new strategy should not result in much of a decline in their relative position in terms of capital productivity (quality adjusted), but the key to their success lies in achieving high enough yield to pay for the more labour intensive market segment that they are focusing on. This also requires investment, but more on quality aspects of service, rather than growth per se.

United score second on capital productivity, but along with other US airlines are not as capital intensive as, for example, the Asian carriers. However, for a more labour intensive carrier, they paid the highest average wage to their employees, and their overall load factor was second lowest. Neither factor would have positioned them well for the slump and decline in fares that was to come. The capital intensity of Cathay and Singapore is a major factor behind their high labour productivity, but their capital productivity is poor.

Air France did worst of the European sample, with both low capital and labour productivity, but high yields, perhaps from more protected markets in which they operated. Lufthansa did much better on both capital and labour, but worse than BA on both scores: their low yield was offset by higher load factor. KLM had the second highest TFP and high labour productivity. It achieved the highest economic operating ratio, thanks to above average yields (somewhat surprising, given the highly competitive transfer markets they operate in) and load factors.

A large percentage of variation in TFP (84%) was accounted for by variations in overall load factor and sector distance. US carriers do not score highly on load factor, since they do not carry much cargo in the lower deck holds of their passenger flights. They also operate over shorter sectors, such that they came in the bottom half of the TFP results, using both approaches. Furthermore, their seat comfort quality of output was well below Asian and most of the European carriers in the sample. This finding is the reverse of previous studies where US carriers were well ahead of European airlines and just behind Asian airlines.

There was no evidence of increasing returns to scale for TFP from larger aircraft. There was some tendency for airlines operating larger aircraft to have higher capital productivity, and capital per employee explaining a large part of the variation across the sample in labour productivity.

One assumption in the analysis was the identical cost of capital, or interest rate, assumed for the lease equivalent of owned assets for all the airlines in the sample. Using the US\$ LIBOR rate was appropriate to assets which up to now have been priced in US dollars. However, the risk premium of 0.5% might vary between airlines, only three of which were majority owned by their governments (Air France, Singapore Airlines and Thai Airways). Thus the evaluation would be improved by using estimates of risk premium or WACC for each airline.

Certain problem areas should be highlighted:

- The lack of data on leased aircraft, for Thai Airways
- The difficulty in including the relevant parts of group subsidiaries for Lufthansa, and to a lesser extent Singapore Airlines.

Both these problems were addressed, but the results for these airlines may not have been entirely consistent with the others. All the data was carefully checked where possible with other sources, and outliers identified and investigated. A number of errors were corrected, for example the aircraft rental figure reported by BA to both the UK CAA and ICAO. This was almost double that found in their annual report, and was explained by the inclusion of finance-leased aircraft (which should have been reported under depreciation and interest costs).

10 Conclusions

10.1 Research findings and conclusions

10.1.1 Aims and theoretical framework

The aim of the research was to develop and apply improved measures of capital productivity using published data, and to evaluate the role of capital investment and productivity in overall airline performance. As well as contributing to total factor productivity, capital productivity is a partial measure, and the investment upon which it is based should improve the productivity of other inputs to the production process, in particular labour and fuel.

The starting point for the research was the theory of the firm, and the production function which describes the relationship between inputs and the output of goods or services. Economic theory can be applied separately to different outputs, each of which has its own production function. However, airlines produce two outputs jointly, passengers and freight, and this results in a step up in complexity. The shape of the production function is in any case difficult to determine without econometric modelling, itself fraught with problems. It is for this reason that many previous studies of airline productivity have applied index number theory to the estimation of productivity ratios. Thus the relationship between inputs and outputs is evaluated at various points along the production function, without the need to estimate an equation which describes the whole function. This is the approach that has been taken here, combined with some econometric modelling to determine which factors affect the index numbers.

There has been considerable work undertaken on index number theory that relates multiple inputs to multiple outputs. This has resulted in formulations with regard to the weights used that meet a number of criteria (eg the product test), as well as satisfy assumptions on the behaviour of firms under conditions of competition. The so-called 'exact' indices (such as the translog multilateral index) lie somewhere between the better known Laspeyres and Paasche indices, and the use of sample means results in their being specific to a particular set of observations.

Observations over time for one airline can be indexed as a chain, while still meeting the above requirements. However, with cross-sectional comparisons for one or more year it is necessary to apply an index formulation that relates the weight of one airline's inputs and outputs to the sample mean, rather than to one particular airline in

the sample. The best type of index number for this purpose is the translog multilateral index, which uses sample means as well as a logarithmic relationship between inputs and outputs. This is considered to conform better to the overall shape of the production function.

This research uses both simple indices as well as the translog multilateral formulation to compare one airline over time (BA), and also a sample of 12 airlines for 1999/2000. Before these analyses could be undertaken, the definition and measurement of airline outputs was assessed.

10.1.2 Measures of output

The core airline business is the processing and carriage by air of both passengers and air cargo. Most flights are on a scheduled basis, but there is a large charter business in Europe, although these specialist airlines were excluded from the empirical work in this thesis. However, airlines also use specialist staff in performing work for other airlines, especially in ground handling, aircraft maintenance and flight catering. These are combined as incidental revenues. The latter type of output is only reported in monetary terms, while the other forms can be given either in traffic (passenger, cargo, or total tonne-kms) terms or in terms of revenues.

Productivity ratios should ideally be in volume or physical terms, without any related input or output price distortions. The majority of output can be summed as revenue tonne-kms (RTKs), or units of traffic (after standardising for average passenger and baggage weights), but that would not include incidental revenues. Thus one approach was to convert these incidental revenues into equivalent RTKs. This was done by using the average revenue per RTK obtained from the traffic output. This has been declining through competitive pressures, and it would seem reasonable to apply similar pressures to the value of the work performed by one airline for another. Thus a total of RTKs and equivalent RTKs could be calculated.

A second approach was to combine the various types of output into an index that reflected the weights of each component. Economic theory states that these should be proportional to their marginal products, assumed to be revenue shares under the assumption of constant returns to scale. Passenger, cargo and incidental revenues were indexed using the multilateral translog procedure, using the revenues generated as weights.

One major shortcoming of previous studies was the absence of any differentiation of product or output quality. A high quality product usually involves greater resource inputs and therefore should be recognised. On the passenger side, this was done by comparing the actual seating configuration for each aircraft type with the maximum number of seats that could be accommodated in all economy class layout. The percentage difference was averaged across the fleet, and the figure of passenger traffic used in total output was increased by it. Air cargo quality might also vary between airlines in terms of priority or handling characteristics, but data is not available to make any adjustments. Furthermore, excluding specialist cargo operators such as El Al or Fedex from the sample lessened the likelihood of distortion.

10.1.3 Measures of capital input

Most of the previous productivity studies have examined panel data. They distinguished between fleet capital and ground, property and equipment (GPE). A fleet quantity index was constructed by deflating the product of numbers of aircraft and operating lease rate by an aircraft price index. This was a translog multilateral index based on lease prices for a number of categories of aircraft. This approach correctly produced a volume index, but suffered from two problems, neither of which were addressed. The first was the use of so-called 'market' lease rates as a proxy for market price. It was shown here that these were often not consistent with their present market values, in that they did not conform with an annual capital flow whose discounted present value would equate to that value. This would be true, even if the age of the aircraft were taken into account. Second, in previous studies, the aircraft's age was not taken into account, and it was not always clear whether the lease rates used were for new or old models. Finally, the credit risk of the airline is not taken into account in published lease rates. Publishers of market lease rates stated that they were less volatile than aircraft values, and this may be because the shorter one and two year leases re-negotiated in downturns are not reflected in their standard 5-year lease rate data.

The approach here for the time-series analysis of BA was to separate capital into fleet and GPE (fleet accounting for a large part of the total). The fleet was then divided into on and off-balance sheet aircraft. Those on the balance sheet were valued at current (rather than historic prices) in 1988, and this US dollar amount was taken as the starting year for the analysis using the Permanent Inventory Method (PIM). Additions were adjusted to base year (1988/89) prices using a US dollar index which combined labour and materials for US aircraft manufacturing. This ensured that each additional aircraft could be valued as if manufactured in the base year, but having

exactly the same capabilities as the delivered model. US dollar values could then be converted back to pounds sterling at base year exchange rates.

BA capital flows were then determined using a formula that equates the present value of future lease streams with the sterling values determined above. The period used for the future streams was the economic life of 25 years less the average age of the fleet as a whole. The real cost of capital was calculated by applying the Capital Asset Pricing Model (CAPM), with the cost of debt varying according to £ sterling LIBOR market interest rates, plus a risk premium of 0.5% for most years. The cost of equity took initial assumptions of a UK equity risk premium of 4% and a beta of 1.25. The UK RPI inflation rate was subtracted from the nominal cost in each year.

GPE capital inputs for the time-series analysis were split into property and equipment, and based on the constant value balance sheet amounts in pounds sterling. These were estimated from two years when re-valuations had taken place, and the UK GDP price deflator. The capital flow was determined using the lease formula and the expected lives based on the depreciation period shown in the annual reports.

The approach for the cross-section analysis has also been to separate capital into fleet and GPE, and the fleet was then divided into on and off-balance sheet aircraft. Those owned or on finance lease (on balance sheet) were valued according to Avmark market values (considered much more reliable than lease rates), with a point estimate made for the total fleet based on their average age. The BA approach could not be followed, since neither current nor constant price values were available. The stock of capital was then converted into a flow by using the lease formula which gives the annual rental stream that when discounted would equal the present value of the fleet over its remaining economic life. This was determined to be 25 years for both short- and long-haul aircraft (with sensitivity tests performed for 20 and 30 years respectively). The interest rate assumed was the six month US\$ LIBOR rate (asset values were in US\$ here, unlike the switch back to local currency in the BA time series), plus 0.5% to allow for a good credit borrower. This approach differed from that taken in previous studies in correctly including the present value of all future income streams that the aircraft would generate, and also in taking into account the aircraft's age and credit risk (the latter was assumed to be identical for all airlines, but the WACCs could be calculated for each airline in the sample).

GPE capital inputs for the cross-section analysis were taken to be the share of fleet capital inputs that was represented by the ratio of net book value of GPE to the total

net book value. This was considered the best way to deal with these assets, in the absence of data on type of asset by vintage.

Operating leased aircraft were not capitalised but treated as an annual flow of capital. If the purpose of the analysis, as it is here, is to compare the efficiency of aircraft (and other assets) on the basis of real resources used, it might have been better to capitalise them, and treat them in the same way as owned aircraft. However, insufficient data was available to do this accurately, and the 7x annual rentals rule was thought to be too imprecise. On the other hand, the comparisons here of economic return with that expected by investors might exclude these aircraft, since they are the object of an expected rate of return from aircraft lessors, and not airline investors.

10.1.4 Capital productivity: BA time-series

Capital productivity for the BA time series was the ratio of output (in various formulations) to capital input, as described above. The selected output index combined passengers, cargo and incidental or third party work using revenue weights. Capital productivity declined between 1988/89 and 2001/02 at an average rate of 1.0% a year. If the past three years of strategic change and aircraft downsizing were removed, then the average annual rate would have been a positive 0.4%. For this analysis, no account was taken of the quality improvement, especially over the past three years, and preliminary estimates of seat pitch changes suggest that this would have resulted in positive, but very small, growth in capital productivity over the period as a whole.

Previous studies showed BA's capital productivity to be declining faster than estimated here, but they had not allowed for quality of service in output, and had used lease rates as a proxy for the price of capital inputs. Furthermore, only one study used data that went as far as 1995 (Oum and Yu, 1998), with most based on much earlier periods.

However, BA's fleet assets (including new seats and interior re-fits for aircraft) were increasing at the rate of just under 11% a year in real terms, and this led to more capital intensive operations, with capital's share of constant price value added rising from 37.6% in 1988/89 to 52.2% in 2000/01, before falling back to 51.6%. This helped BA achieve much improved productivity ratios of fuel and labour, but did mean that capital productivity itself scarcely increased over the period.

BA's new strategy would not appear to lead to a decline in capital productivity, once the higher average quality of service is taken into account. But it is probably more labour intensive, and investment became more directed to quality than growth.

10.1.5 Total Factor Productivity: BA time-series

TFP (with labour's contribution using deflated wages rather than MPE) has increased over the period as a whole by an average of 1.4% a year. This again is low in comparison to rates achieved in the 1960s and 1970s, and not sufficient to accommodate declining yields and increased input prices. Broadening the analysis to include other inputs might reveal a further stimulus, especially from distribution in recent years.

No previous studies used data that went beyond 1995. Oum and Yu (1998) estimated BA's TFP to have grown by an average rate of 3.0% a year between 1988 and 1995. This compares with the result from this research for the same period of 3.2% a year. Thus the differences in capital productivity between this research and the Oum and Yu study became offset by differences in other partial productivities to give very similar results for TFP over this period. While the two results are similar, the approach proposed here to capital productivity is considered to be an improvement on previous studies. However, some of the techniques used for combining labour and capital inputs and airline outputs (the translog multilateral procedures) are common to this and previous work.

Input prices increased generally compared with declining output prices. The average cost of staff increased significantly following the Gulf War recovery, but has not increased and even declined somewhat in the past five years. Its increase has tended to be lower than the UK retail price index, partly as a result of the absence of profit related bonuses in recent years.

Aircraft prices increased more slowly than labour prices over the whole period, helped by marked reduction following the Gulf War recession, and again after 1996/97. The second downturn was driven more by lower long-term interest rates than new aircraft prices, which continued to increase up to 2001. Fuel prices were more erratic, with a large increase prior to and during the Gulf War, and between 1988/89 and 2000/01. It should be mentioned that very low operating lease rates would have been offered post Gulf War and again post-9/11, but major international airlines are locked into higher rates and could not normally take advantage of these prices to any significant degree.

Economic and accounting profit margins were reasonably in agreement over most of the period. However, the economic margin needs to be compared with the weighted average cost of capital. Of the 14 years analysed, BA only exceeded their real cost of capital in one of them, with the last four years all falling well short of an economic return on assets. The interesting finding is that the results were so poor during the upswing phase of the economic cycle, from 1996/97 until the start of the current downturn (early 2001). This was due to static TFP, an escalation in fuel costs, and declining, or at best small increases in yields.

10.1.6 Capital productivity and TFP: airline cross-section

This part of the research analysed a cross-section of 12 international airlines (including BA) for the year 1999/2000 (the closest financial year to calendar 1999). The analysis goes a step further than the time series ratios for BA by adjusting output for an important dimension of quality, namely seat comfort. For both the BA time-series and this cross-section, only airline operations were included, with sizeable related businesses such as handling and general catering excluded.

The approach to measuring output was similar to the BA time-series, but with the passenger part of output adjusted so as to standardise the seat configurations in an all economy layout (with no change in load factors). The various outputs were combined in both translog form, and the sum of equivalent RTKs (without revenue weighting). Capital stocks were estimated at 1999 market prices by applying Avmark US\$ valuations for that year to each of the aircraft types and models in the fleets. Capital flow was then calculated in the same way as for BA, but using a common 6.4% as the cost of capital (0.5% over the six month US\$ LIBOR average for the year).

As with the BA analysis, it was decided to use the actual annual rental expense as the capital input from those aircraft not placed on the balance sheet (operating leases). The alternative of capitalising them and treating them in the same way as other aircraft would have been preferred for the capital productivity analysis, but not for the comparison of overall economic return with investor expectations. However, insufficient data was available to do this for the BA analysis, and the same approach was also taken for the airlines analysed in 1999.

The lease equivalents of non-fleet assets were estimated by taking their share in net book values of tangible assets and applying it to the fleet lease equivalents. Actual lease rentals in US\$ were used as capital inputs for those aircraft on operating lease:

this was not part of the airlines' own capital, and insufficient data was available to capitalise them with any degree of precision.

BA performed best on capital productivity, once their higher quality output had been allowed for. They also recorded reasonably high labour productivity to come out top on TFP. However, this would not alone be sufficient to produce a high economic operating margin, even with their relatively low wage rates. Yield and load factor are also important, and other inputs which can account for over 50% of total inputs.

United score second on capital productivity, but along with other US airlines are not as capital intensive as, for example, the Asian carriers. The capital intensity of Cathay and Singapore is a major factor behind their high labour productivity, but their capital productivity is poor.

Air France did worst of the European sample, with both low capital and labour productivity, but high yields, perhaps from more protected markets in which they operated. Lufthansa did much better on both capital and labour, but worse than BA on both scores: their low yield was offset by higher load factor. KLM had the second highest TFP and high labour productivity. It achieved the highest economic operating ratio, thanks to above average yields (somewhat surprising, given the highly competitive transfer markets they operate in) and load factors.

A large percentage of variation in TFP (84%) was accounted for by variations in overall load factor and sector distance. US carriers do not score highly on load factor, since they do not carry much cargo in the lower deck holds of their passenger flights. They also operate over shorter sectors, such that they came in the bottom half of the TFP results, using both approaches. Furthermore, their seat comfort quality of output was well below Asian and most of the European carriers in the sample. This finding is the reverse of previous studies where US carriers were well ahead of European airlines and just behind Asian airlines.

There was no evidence of increasing returns to scale for TFP from larger aircraft. There was some tendency for airlines operating larger aircraft to have higher capital productivity, and capital per employee explaining a large part of the variation across the sample in labour productivity.

Oum and Yu (1998) gave regional averages of capital productivity for 1993, showing the European carriers (1.139) to be ahead of the Asian (1.082) and North American airlines (0.920). Unweighted regional averages from this research show the European

airlines in 1999 to have been 97.8, the US airlines 90.5 and the Asian airlines trail at 83.9. The major reasons for the change in ranking were the time lag and inclusion of seat quality, which penalises the US carriers, although method of calculation also clearly resulted in Asian airlines performing worse. Asian carriers faced a major downturn in the intervening period, which the other regions did not experience. Baily and Zitzevitz (2001) showed the European airlines' capital productivity on average to have been only 92% of the US airline average, but this again did not adjust for quality.

10.2 Key contributions to field

This thesis applies economic and financial theory to the air transport industry, using a combination of index numbers and econometric techniques. It also applies an in-depth understanding of airline economics to the development of new approaches to the measurement of both inputs and outputs to the production process. These can be of value to academics through their application to airline productivity studies and other analyses. They can also be of value to industry for productivity studies and benchmarking against other airlines. The following summarises their main areas of contribution.

10.2.1 Output quality measure

Its contribution to measures of airline output is in the adjustment of passenger so as to allow for differences between airlines in both seat comfort and the mix of seats by class or cabin. A means of measuring this is proposed, taking the percentage difference between the actual number of seats available per flight and a hypothetical all-economy class configuration. Thus output for those airlines offering a high quality of service is increased by more than for those that already have high-density seating. This measure was calculated for a cross-section of major international airlines in 1999, and the results were cross-checked with a survey of passenger ratings of the same airlines according to in-flight comfort. The two were closely correlated. The measure can either be incorporated into output quantities (the approach taken here), or it can be used as an explanatory variable in econometric studies of productivity or costs.

10.2.2 Capital flow measure

This research has improved on the measure of capital flow used in previous airline productivity studies, by getting a more accurate reflection of an asset's discounted

future earning potential over the remainder of its useful life (using published data). Most previous studies have used market operating lease rates, which have been shown at most times not to reflect that potential.

Second, this research has allowed an airline's credit rating or cost of capital to be incorporated into the analysis of productivity, which the use of a standard lease rate does not. This can be estimated in a number of ways, and both the CAPM weighted average cost of capital and LIBOR with risk premium approaches have been applied here.

Third, the approach adopted here has explicitly taken into account the average age of the fleet or individual aircraft types in the fleet in calculating capital inputs.

Fourth, a consistent approach to the conversion of historic price to constant or current price valuation of fleet assets is proposed by applying the materials and labour composite price index of aircraft manufacture. This provides a true replacement cost, and avoids revaluing an aircraft (especially one whose production has been discontinued) with a new aircraft of higher quality or technology.

10.2.3 General

Finally, the thesis contributes to a better understanding of the field of airline economics and finance as a result of the author's detailed knowledge of these two areas. Some technical know-how was also required in the discussion of aircraft operational lives and maintenance procedures. This extended from familiarity with international reporting standards and definitions to operational and maintenance procedures and constraints.

As is always the case with economic studies of this nature, a balance has to be struck between complexity of modelling and an understanding of the processes and basic data. In order to increase the usefulness of this research to the industry, the balance here may have been pitched more towards the latter than the former.

10.3 Areas for further research

As with any area of economics, there are many areas that need further investigation and analysis. The most obvious of these is in the area of other inputs to the production process than capital and labour. Some work has been done on fuel, but

there are major gaps that have not been properly addressed in previous studies, and were not researched here due to lack of published data. Survey work would be required to examine the following:

- Volume and price changes for airline distribution, and a comparison of airline efficiency in this area
- Airport and ATC services purchased, also involving qualitative aspects

Focusing on capital productivity itself, further work would be needed to shed light on GPE assets and rentals, which would involve a closer look at aircraft maintenance and overhaul (becoming more capital intensive) and IT. This relates to incidental services, and more information is clearly needed on the volume and price of services that are outsourced to others, as well as contracted in from others. This covers ground handling, maintenance, flight catering and many other functions, and it would be interesting to see how capital or labour intensive these services are.

Capital allowances and taxation, which vary by country, would have an impact on both investment and productivity, and little work has been done to date in this area.

Finally, no account has been taken here of external benefits or disbenefits that result from airline outputs. Environmental costs are increasingly being quantified, and older aircraft tend to produce noisier and more polluting outputs. These could be addressed through a tax that completely ‘internalised’ these costs. This would then be dealt with in the approach taken here as a price effect. Alternatively, the output from operations of, say, an older B747-100 could be reduced to take account of environmental quality, and those RTKs produced by, say, a quieter, cleaner, B747-400 could be increased in relative terms. Such adjustments were, however, beyond the scope of this thesis.

References

- Baily, Martin N. and Schultze, Charles L. (1990). The productivity of capital in a period of slower growth. In: *Brookings Papers on Economic Activity*, edited by Martin Baily and Clifford Winston, 369-406
- Baily, Martin N. and Zitzewitz, Eric. (2001). Service sector productivity comparisons of TFP. In: *New developments in productivity analysis*, edited by Hulten, Dean and Harper. University of Chicago Press, 446-464
- Balk, Bert M. (1998). *Industrial price, quantity and productivity indices: the micro-economic theory and application*. Kluwer Academic Publishers.
- Barrington, Colm. (1998). Operating leasing. In: *Aircraft Financing*, eds Littlejohns and McGairl. Third edition, Euromoney Books, 58-70
- Bauer, Paul W. (1990). *Decomposing TFP growth and the presence of cost inefficiency*, The Journal of Productivity Analysis, 1, 287-299
- Bishop, Matthew and Thompson, David. (1992). *Regulatory reform and productivity growth in the UK's public utilities*, Applied Economics, 24
- Black, Fisher. (1982). *The trouble with econometric models*. Financial Analysts Journal, March/April, 29-37
- Black, Fisher. (1986). *Noise*. The Journal of Finance, 41, July
- Boeing. (1992). *Current market outlook: world market demand and airplane supply requirements*. Boeing Commercial Airplane Group
- Boeing. (2002). *Current market outlook*. Boeing Commercial Airplane Group
- Bowen, Brent, Headley, Dean E. and Luedtke, Jacqueline. (1992). *A quantitative methodology for measuring airline quality*, JAAER, Winter, 27-33
- Brunning, E.R. (1991). *Market liberalization and operation efficiency in the international aviation industry*. International Journal of Transport Economics, 28, 259-274
- CAA (1984). Airline competition policy. CAP500, Civil Aviation Authority, London
- CAA (2002). *UK Airline Statistics, 2001*, Civil Aviation Authority, London, July
- Caves, D.W., Christensen, L.R. and Diewert, W.E. (1982). *Multilateral comparisons of output, input and productivity using superlative index numbers*, Economic Journal, 92, 73-86
- Caves, D.W., Christensen, L.R. and Trethaway, M.W. (1981). US trunk carriers 1972-1977: a multilateral comparison of total factor productivity, In: *Measuring Productivity in Regulated Industries*, eds T.G. Cowing and R.E. Stevenson, New York: Academic Press.
- Charles, R. and Ghobrial, A. (1995). An assessment of the changes and performance of the avionics industry. In: *Handbook of Airline Economics*, edited by Darryl Jenkins. Aviation Week (McGraw-Hill), 603-609

- Christensen, L.R. and Jorgenson, D.W. (1969). *The measurement of US real capital input, 1929-1967*. The Review of Income and Wealth, Series 15(1), 293-320
- Clark, Paul. (2001). *Buying the big jets; fleet planning for airlines*. Ashgate.
- Deakin, B. and Seward, T. (1969). *Productivity in transport*, Cambridge University Press, UK
- Doganis, Rigas. (1991). *Flying off course*. Harper Collins
- Doganis, Rigas, Alamdari, F. and Lobbenberg, A. (1995). *Efficiency of the world's major airlines: a comparative study of 26 airlines from Asia/Pacific, North America and Europe*, Department of Air Transport, Cranfield University, Research Report 4, March
- Doganis, Rigas and others. (1998). *User costs at airports in Europe, S.E. Asia and the USA, 1997-1998*. Air Transport Group, Cranfield University. Revised Study Report 6, February
- Ehrlich, I, Gallais-Hamono, G, Lin Zhiqiang & Lutter, R. (1994) *Productivity growth and firm ownership; an analytical and empirical investigation*. Journal of Political Economy, 102(5)
- Encaoua, David. (1991). *Liberalizing European airlines: cost and factor productivity evidence*. International Journal of Industrial Organisation, 9
- Edvinsson, Leif and Malone, Michael S. (1997). *Intellectual capital: Realizing your company's true value by finding its hidden brainpower*. HarperBusiness
- Fisher, Franklin M. (1987). *Pan American to United: the Pacific division transfer case*. Rand Journal of Economics, 18(4), Winter
- Forsythe, Peter. (2001). *Total factor productivity in Australian domestic aviation*. Transport Policy, 8
- Forsythe, P.J., Hill, R.D., and Trengrove, C.D. (1986). *Measuring airline efficiency*, Fiscal Studies, 7 (1), February
- Gillen, David W., Oum Tae Hoon, and Tretheway, Michael W. (1990). *Airline cost structure and policy implications*, Journal of Transport Economics and Policy, January, 9-34
- Good, David H. and Rhodes, Edwardo L. (1991). *Productive efficiency, technological change and the competitiveness of US airlines in the Pacific rim*. Journal of the Transportation Research Forum, XXXI(2)
- Good, David H., Nadiri, M.I., Röller, Lars-Hendrik and Sickles, Robin C. (1993). *Efficiency and productivity growth comparisons of European and US carriers: a first look at the data*, The Journal of Productivity Analysis, 4, 111-125
- Good, David H., Röller, Lars-Hendrik and Sickles, Robin C. (1995). *Airline efficiency differences between Europe and the US: Implications for the pace of EC integration and domestic regulation*, European Journal of Operational Research, 80

- Gordon, Robert J. (1990). *Commercial aviation*, Chapter 4 from *The Measurement of Capital Goods Prices*, University of Chicago Press
- Goury, C. P. (1999). *An analysis of aircraft resale values based on historical transactions prices*. MSc Thesis, Cranfield University, September
- Griliches, Zvi. (1987). Productivity: measurement problems. In: *The New Palgrave: a dictionary of economics*, eds Eatwell, Milgate and Newman.
- Gust, Christopher and Marquez, Jaime. (2000). *Productivity developments abroad*. US Federal Reserve Bulletin, October, 665-681
- Haanappel, P.P.C. (1994) *Airport slots and market access: some basic notions and solutions*, Air & Space Law, XIX (4/5), 198-199
- Hai, N. (1994). *An evaluation of scheduled airline traffic rights*. MSc thesis, Cranfield University, England
- Hill, Peter. (1988). *Recent developments in index number theory and practice*, OECD Economic Studies, 10
- Hulten, Charles R., and Wykoff, Frank C. (1981). The estimation of economic depreciation using vintage asset prices. *Journal of Econometrics*, April, 367-396.
- Hulten, Charles R., and Wykoff, Frank C. (1996). Issues in the measurement of economic depreciation: introductory remarks. *Economic Inquiry*, 34(1).
- Hulten, Charles R., Dean, Edwin R., and Harper, Michael J. (2001). New developments in productivity analysis. *National Bureau of Economic Research*, University of Chicago Press
- IATA. (1996). *Corporate air travel survey 1996*. Aviation Information and Research, London.
- IATA/KPMG. (1992). *Accounting policies, disclosure and financial trends in the international airline industry*. A survey conducted by KPMG in association with IATA, August
- IATA/KPMG. (1996a). *Airline accounting guideline No.3: components of fleet acquisition cost and associated depreciation*. International Air Transport Association. Exposure draft, effective 1 May
- IATA/KPMG. (1996b). *Airline accounting guideline No.4: recognition of revenue*. International Air Transport Association. Exposure draft, effective 1 May
- Jha, R. and Sahni, B.S. (1992). *Towards measuring airline technical efficiency: the case of the Canadian airline industry*. *International Journal of Transport Economics*, 19, 45-53
- Key, Stephen L. ed. (1989), *The Ernst and Young guide to mergers and acquisitions*. John Wiley & Sons, New York
- Kendrick, J.W. (1991). Total factor productivity - what it does and does not measure. In: *Technology and Productivity: The Challenge for Economic Policy*, Organisation for Economic Co-operation and Development, Paris, 149-156

- Kendrick, J.W. and Creamer, D. (1961). *Measuring company productivity*, The Conference Board Studies in Business Economics, 89
- Li, Michael Z. F., Oum Tae H and Zhang Yimin. (2002). *Tobin's q and airline performance*. Paper presented at 6th ATRS Conference in Seattle, July
- McFarland, Henry. (1988). *Evaluating q as an alternative to the rate of return in measuring profitability*. The Review of Economics and Statistics, LXX, November
- McGowan, F. and Seabright, P. (1989). *Deregulating European airlines*. Economic Policy, 8, 284-344
- McKinsey & Co. (1977). *Airline personnel productivity - a comparative study*, Amsterdam
- McKinsey Global Institute. (1996). *Capital productivity*, Washington, DC, June
- Milne, I. R. (1994). *Bridging the GAAP*. An Airline Business special report, July
- Morrell, Peter. (1999). *The role of capital productivity in British Airways' financial recovery*, Journal of Transportation World Wide, 4(2), 84-99
- Morrell, Peter. (2002). Capital productivity and the role of capital intensity in airline labour productivity. In: *Handbook of Airline Economics*, edited by Darryl Jenkins. Aviation Week (McGraw-Hill), 487-500
- Morrell, Peter, Alamdari, Fariba and Lu, Cherie. (2000). *Measures of strategic success: a comparative study of 24 airlines from Asia/Pacific, North America and Europe*. Air Transport Group, Cranfield University, Research Report 8
- Morrell, Peter S. and Taneja, Nawal K. (1979). *Airline productivity redefined: an analysis of US and European carriers*. Transportation, 8, 37-49
- Nicholson, Walter. (1985). *Microeconomic theory: basic principles and extensions*. Third Edition, The Dryden Press
- Nickell, S. J. (1978). *The investment decision of firms*, James Nisbet and Cambridge University Press
- Ng, Charles K. and Seabright, Paul. (2001). *Competition and productive efficiency: evidence from the airline industry*. The Economic Journal, 111, July, 591-619
- OAG. (1998). *Business travel lifestyle survey 1998: charting the trends of the international business traveller*.
- OECD (2001a), *Measuring capital: a manual on the measurement of capital stocks, consumption of fixed capital and capital services*, Paris, February
- OECD (2001b), *Measuring productivity: a manual on the measurement of aggregate and industry level productivity growth*, Paris, July
- Oum, Tae H., Tretheway, Michael W., and Waters, W.G.II. (1992). *Concepts, methods and purposes of productivity measurement in transportation*, Transportation Research, 26A(6), 493-505

- Oum, Tae Hoon and Yu, Chunyan. (1995). *A productivity comparison of the world's major airlines*, Journal of Air Transport Management, 2(3/4), September/December
- Oum, Tae Hoon and Yu, Chunyan. (1998). *Winning airlines: productivity and cost competitiveness of the world's major airlines*. Kluwer Academic Publishers.
- Ozment, John and Morash, Edward A. (1998). Assessment of the relationship between productivity and performance quality in the US domestic airline industry. *Transportation Research Record*, 1622, 22-30
- Pearson, Roy. (1976). *Airline efficiency*, Transport Studies Group, Polytechnic of Central London, London
- Pike, Richard, and Neale, W. (1999). *Corporate Finance and Investment: Decisions & Strategies*, London: Prentice Hall Europe
- Pitt, Ivan L. and Norsworthy, John R. (1999). *Economics of the US commercial airline industry: productivity, technology and deregulation*. Kluwer Academic Publishers.
- Robinson, Joan. (1954). The production function and the theory of capital. *Review of Economic Studies*, 21(2), 81-106
- Serafimidis, Panagiotis. (2001). *Airline strategies for mitigating jet fuel price risk*. MSc Thesis, Cranfield University
- Sickles, Robin C., Good, David H. and Getachew, Lullit. (2002). Specification of distance functions using semi- and nonparametric methods with an application to the dynamic performance of eastern and western European air carriers. *Journal of Productivity Analysis*, 17, 133-155.
- Smith, E. and Beeching, R. (1948). *Measurement of the effectiveness of the productive unit*. London, British Institute of Management
- Solow, Robert M. (1957). *Technical change and the aggregate production function*, Review of Economics and Statistics, 39(3), August
- Swierenga D.A. and Crandall, M. (1982). Revenues, costs and productivity. In: *Airline Economics*, ed, George James, Lexington
- Turner, Sheelah and Morrell, Peter. (2002). *An evaluation of airline cost of equity capital and its determination using beta values*. Paper to 6th ATRS World Conference, Seattle, July 14-16
- Waters, W.G., Oum, Tae Hoon, and Yu, Chunyan. (1997). *Productivity, prices and profitability trends in the world's major airlines, 1986-95*. Paper presented to 1st Air Transport Research Group Conference in Vancouver, British Columbia, June
- Windle, Robert J. (1991). *The World's Airlines. A cost and productivity comparison*, Journal of Transport Economics and Planning, XXV(1), January
- Windle, Robert J, and Dresner, Martin E. (1992). *Partial productivity measures and total factor productivity in the air transport industry: limitations and uses*. Transport Research - A, 26A(6,) 435-445

Bibliography

- Air Transport Association of America. (1974). *US airline industry costs and productivity, 1963-1973*, Washington, DC, May
- Baltagi, B.H., Griffin, J.M. and Rich, D.P. (1995). Airline deregulation: the cost pieces of the puzzle, *International Economic Review*, 36, 245-258
- Barla, P. and Perelman, S. (1989). Technical efficiency and airlines under regulated and deregulated environment. *Annals and Public and Co-operative Economics*, 60, 103-124
- Blades, D.W. (1991). Capital measurement in the OECD countries: an overview. In: *Technology and Productivity: The Challenge for Economic Policy*, Organisation for Economic Co-operation and Development, Paris, 157-168
- Brown, Murray. (1966). *On the theory and measurement of technical change*, Cambridge University Press
- Butler, Gail F. and Keller, Martin R. eds. (1999). *Handbook of Airline Finance*. Aviation Week.
- Cunningham, Lawrence F., Slovin, Myron B., Wood, Wallace R and Zaima, Janis K. (1988). *Systematic risk in the deregulated airline industry*, Journal of Transport Economics & Policy, 22(3)
- Diewert, E. (1976). *Exact and superlative index numbers*, Journal of Econometrics, 4
- Faraday, J. (1971). *The management of productivity*, Management Publications, London
- Hall, Simon (ed). (1989). *Aircraft Financing*, Euromoney Publications
- Hallerstrom, Nils and Melgaard, Jan. (1997). *Risk and return in aircraft backed loans*, The Avmark Aviation Economist, January
- Haskell, J. and Szymanski, S. (1992). *The effects of privatisation, restructuring and competition on productivity growth in UK public corporations*, University of London and London Business School, May
- Jenkins Darryl. Ed. (1995). *Handbook of Airline Economics*. Aviation Week. First Edition
- Jenkins Darryl. Ed. (2002). *Handbook of Airline Economics*. Aviation Week. Second Edition
- Littlejohns, Andrew and McGairl, Stephen. (1998). *Aircraft Financing*, 3rd edition, Euromoney Books
- Miller, David M. (1984). *Profitability = productivity + price recovery*, Harvard Business Review, 3
- Nellis, Joseph G. and Parker, David. (1992). *The essence of business economics*, Prentice Hall

- Neven, D. and Röller, L.H. (1996). *Rent sharing in the European airline industry*. European Economic Review, 40, 933-940
- Oum, Tae Hoon and Yu, Chunyan. (1997). *Cost competitiveness of major airlines: an international comparison*, Paper presented to Air Transport Research Group Conference, Vancouver, 25-27 June
- Oum, T.H., Zhang, A. and Zhang, Y. (2000). Allocative efficiency and social value of the aircraft leasing industry, *International Journal of Transport Economics*, 27(2)
- Solow, Robert M. (1956). *The production function and the theory of capital*. Review of Economic Studies, 23/2, 101-108
- Straszheim, Mahlon R. (1969). *The international airline industry*, Washington DC, The Brookings Institute
- Sudarsanam, Puliur S. (1992). *Market and industry infrastructure and corporate cost of capital*, Journal of Industrial Economics, XL(2), June
- van Ark Bart, and Pilat Dirk. (1993). Productivity levels in Germany, Japan and the United States: differences and causes. In: *Brookings Papers on Economic Activity*, 2, 1-69
- Winston, Clifford. (1993). *Economic deregulation: days of reckoning for micro-economists*. Journal of Economic Literature, XXXI, September

Appendix A: Output measures used in previous studies

<i>Paper Author(s)</i>	<i>Airlines Analysed</i>	<i>Period Covered</i>	<i>Output Measure(s)</i>	<i>Method of Weighting</i>
Baily & Zitzewitz (2001)	9 US, 8 European, 5 Brazilian and 2 Korean	1995	Revenue passenger-kms	None
Bauer (1990)	12 US airlines	1979-1981	Passenger ton miles and cargo ton miles; load factor and stage length also used	Translog, with revenue weights
Bishop & Thompson (1992)	British Airways + non-airline	1970-1990	Net tonne-kms performed	Insufficient information
Brunning (1991)	73 international passenger airlines	1987	Average stage length	None
Caves, Christensen & Tretheway (1981)	US Trunks	1972-1977	Total revenue tonne kms	Multilateral translog, Revenue shares
Ehrlich & others (1994)	23 international airlines	1973-1983	Passenger-miles (first, coach & charter), Freight ton-miles, Mail ton-miles	Multilateral translog
Encaoua (1991)	5 European airlines	1981-1986	Sched. Pax-kms, FTKs, Mail TKs and non-sched. TKs	Revenue shares
Forsythe (2001)	Australian domestic airlines	1981/82 - 1998/99	RPKs at normal & promotional fares, Cargo RPKs	Multilateral translog
Forsythe, Hill & Trengrove (1986)	17 international airlines	1983	RPKs, deflated revenues (Y fares)	Weights not explained
Gillen, Oum & Tretheway (1985)	Canadian airlines	1964-1971	Available tonne-kms (standardised)	Not required
Good & Rhodes (1991)	37 Pacific Rim airlines	1976-1986	RPKs (Freight & charter tonne-kms later dropped)	None
Good, Nadiri, Röller & Sickles (1993)	8 US and 4 European airlines	1976-1986	Sched. Passenger-kms (?) and all other outputs; prices (fares) adjusted for stage length	Multilateral translog
Good, Röller & Sickles (1995)	8 US and 8 European airlines	1976-1986	Pax and Cargo RPKs	Revenue shares
Haskel & Szymanski (1992)	British Airways + non-airline	1972-1988	Incidental revs deflated by PPP	Multilateral translog
Jha & Sahni (1992)	6 Canadian airlines	1979-1986 (Q)	Pax and Cargo RPKs	Revenue shares
Morrell & Taneja (1979)	14 US and 14 European airlines	1975	Incidental revs deflated by PPP	None
Ng & Seabright (2001)	12 European + 7 US airlines	1982 - 1995	Route tonne-kms	None
Oum & Yu (1995)	23 international airlines	1986-1993	ASKs and ATKs; kms flown per flight and seasonal dummies	None
Sickles, Good & Getachew (2002)	16 Western and Eastern European airlines	1977-90	Net value added	None
Swierenga & Crandall (1982)	US Trunk & Local Service	1972, 1979	Pax-TKs, FTKs & PPI adjusted incidentals	Multilateral index
Windle (1991)	14 US & 27 other countries	1983	Sched. Pax TKs, FTKs, Mail TKs and non-sched. TKs	Multilateral translog
Windle & Dresner (1992)	14 US & 27 other countries	1970-1983	Incidental revs deflated by PPP	Revenue shares
			RTKs and ATKs	Various (including Malmquist Index)
			Revenues broken down by pax (first, coach & charter), cargo (sched. & charter), other	Deflated by price changes
			Sched. Pax-kms, FTKs, Mail TKs and non-sched. TKs	Multilateral translog
			Sched. Pax-kms, FTKs, Mail TKs and non-sched. TKs	Revenue shares
			Mail TKs and non-sched. TKs	Multilateral translog

Appendix B: Capital input measures and methodology used in previous studies

<i>Paper Author(s)</i>	<i>Airlines Analysed</i>	<i>Period Covered</i>	<i>Capital Input Measure(s)</i>	<i>Methodology/weighting</i>
Baily & Zitzewitz (2001)	9 US, 8 European, 5 Brazilian and 2 Korean	1995	Current value of physical capital stock; depreciated over remaining life (no IT or GPE)	None
Bishop & Thompson (1992)	British Airways + non-airline	1970-1990	Real value of capital stock	Törnqvist index
Bunning (1991)	73 international passenger airlines	1987	Imputed flow using depreciation rates	Revenue/cost shares
Caves, Christensen & Tretheway (1981)	US Trunks	1972-1977	Depreciation, interest, rentals, insurance, maintenance & tax (ICAO data)	Econometric models, OLS, MLE
Ehrlich & others (1994)	23 international airlines	1973-1983	Numbers of a/c in 8 categories x annual lease costs, deflated by aircraft price index	Aircraft price index uses translog weighting and lease costs
Encaoua (1991)	5 European airlines	1981-86	Numbers of a/c in 9 categories x annual lease costs	Multilateral index procedures
Forsythe (2001)	Australian domestic airlines	1981/82 – 1998/99	Ground equipment: investment flows and country GDP price deflators Volume measures of 8 functional cost categories	Combined with above using cost share weights Not clarified.
Forsythe, Hill & Trengrove (1986)	17 international airlines	1983	Capital, fuel, labour and other costs converted to quantity indices by various deflators; capital derived from Oum & Yu (1995)	Cost shares
Good & Rhodes (1991)	37 Pacific Rim airlines	1976-1986	Total capital costs adjusted to standard airline price index	Törnqvist multilateral index; cost shares
Good, Nadiri, Röller & Sickles (1993)	8 US and 4 European airlines	1976-1986	Av. no. of aircraft times seat capacity Total number of aircraft, and % widebody, % turboprop	DEA Econometric models (GLS)
Good, Röller & Sickles (1995)	8 US and 8 European airlines	1976-1986	Ground equipment: expenditures and country GDP price deflators	Divisia multilateral index and stochastic frontier
Jha & Sahn (1992)	6 Canadian airlines	1979-1986 (Q)	No. of aircraft, price index and interest based on government & corporate long-term bonds. Capital expenditure deflated by aircraft & parts price index (CANSIM)	Econometric models
Morrell & Taneja (1979)	14 US and 14 European airlines	1975	Equivalent man-years of labour	Econometric model
Ng & Seabright (2001)	12 European and 7 US airlines	1982 - 1995	No. aircraft x av. Avmark lease rates; pre-1987 based on 1-1.5% of jet value (PPI adjusted)	None
Oum & Yu (1995)	23 international airlines	1986-1993	No. of aircraft times lease price	Translog multilateral index
Sickles, Good & Getachew (2002)	16 Western and Eastern European airlines	1977-1990	GPE stock (PIM) using GPE service price	DEA
Swierenga & Crandall (1982)	US Trunk & Local Service	1972, 1979	Capital costs deflated by av. interest rate index	None
Windle (1991)	14 US & 27 other countries	1983	9 aircraft types, lease prices	Multilateral index
Windle & Dresner (1992)	14 US & 27 other countries	1970-1983	GPE stock (PIM) using GPE service price Same as Windle (1991)	Weighted by lease costs Same as Windle (1991) & econometric models

Appendix C: International Accounting Standard Guidelines on depreciation

The International Accounting Standard relating to depreciation is IAS 16, and it was last updated at the beginning of 1995. It can be summarised from the IASB Web Site as follows:

- Property, plant and equipment should be recognised when (a) it is probable that future benefits will flow from it, and (b) its cost can be measured reliably.
- Initial measurement should be at cost.
- Subsequently, the *benchmark treatment* is to use depreciated (amortised) cost but the allowed alternative is to use an up-to-date fair value.
- Depreciation:
 - Long-lived assets other than land are depreciated on a systematic basis over their useful lives.
 - Depreciation base is cost less estimated residual value.
 - The depreciation method should reflect the pattern in which the asset's economic benefits are consumed by the enterprise.
 - If assets are revalued, depreciation is based on the revalued amount.
 - The useful life should be reviewed periodically and any change should be reflected in the current period and prospectively.
 - Significant costs to be incurred at the end of an asset's useful life should either be reflected by reducing the estimated residual value or by charging the amount as an expense over the life of the asset.
- Revaluations (*allowed alternative*):
 - Revaluations should be made with sufficient regularity such that the carrying amount does not differ materially from that which would be determined using fair value at the balance sheet date.
 - If an item of PP&E (property, plant and equipment) has been re-valued, the entire class to which the asset belongs must be re-valued (for example, all buildings, all land, all equipment).
 - Revaluations should be credited to equity (revaluation surplus) unless reversing a previous charge to income.
 - Decreases in valuation should be charged to income unless reversing a previous credit to equity (revaluation surplus).
 - If the revalued asset is sold or otherwise disposed of, any remaining revaluation surplus either remains as a separate component of equity or is transferred directly to retained earnings (not through the income statement).
- If an asset's recoverable amount falls below its carrying amount, the decline should be recognised and charged to income (unless it reverses a previous credit to equity).
- Gains or losses on retirement or disposal of an asset should be calculated by reference to the carrying amount.
- Required disclosures include:
 - Reconciliation of movements.
 - Capital commitments.
 - Items pledged as security.
 - If assets are revalued, disclose historical cost amounts.
 - Change in revaluation surplus.

Appendix D: Aircraft price adjustment formula (Southwest Airlines)

PURCHASE AGREEMENT NO. 1810 relating to BOEING MODEL 737-7H4 AIRCRAFT (Southwest Airlines, Form 10K, 31 December 1999)

Attachment B to
6-1162-RLL-933R7
Page 1

PRICE ADJUSTMENT DUE TO
ECONOMIC FLUCTUATIONS
AIRCRAFT PRICE ADJUSTMENT
(July 1992 Base Price)

1. Formula.

The Aircraft Price Adjustment will be determined at the time of
Aircraft delivery in accordance with the following formula:

$$Pa = (P) (L + M - 1)$$

Where:

Pa = Aircraft Price Adjustment.

$$L = .65 \times \frac{ECI}{116.2}$$

$$M = .35 \times \frac{ICI}{115.9}$$

P = Aircraft Basic Price (as set forth in Article 3.2 of this
Agreement).

ECI = A value using the "Employment Cost Index for workers in aerospace manufacturing" (aircraft manufacturing, standard industrial classification code 3721, compensation, base month and year June 1989 = 100), as released by the Bureau of Labor Statistics, U.S. Department of Labor on a quarterly basis for the months of March, June, September and December, calculated as follows: A three-month arithmetic average value (expressed as a decimal and rounded to the nearest tenth) will be determined using the months set forth in the table below for the applicable Aircraft, with the released Employment Cost Index value described above for the month of March also being used for the months of January and February; the value for June also used for April and May; the value for September also used for July and August; and the value for December also used for October and November.

ICI = The three-month arithmetic average of the released monthly values for the Industrial Commodities Index as set forth in the "Producer Prices and Price Index" (Base Year 1982 = 100) as released by the Bureau of Labor Statistics, U.S. Department of Labor values

(expressed as a decimal and rounded to the nearest tenth) for the months set forth in the table below for the applicable Aircraft.

In determining the value of L, the ratio of ECI divided by 116.2 will be expressed as a decimal rounded to the nearest ten-thousandth and then multiplied by .65 with the resulting value also expressed as a decimal and rounded to the nearest ten-thousandth.

In determining the value of M, the ratio of ICI divided by 115.9 will be expressed as a decimal rounded to the nearest ten-thousandth and then multiplied by .35 with the resulting value also expressed as a decimal and rounded to the nearest ten-thousandth.

Month of Scheduled Aircraft Delivery -----	Months to be Utilized in Determining the Value of ECI and ICI -----
January	June B, July B, Aug. B
February	July B, Aug. B, Sept. B
March	Aug. B, Sept. B, Oct. B
April	Sept. B, Oct. B, Nov. B
May	Oct. B, Nov. B, Dec. B
June	Nov. B, Dec. B, Jan. D
July	Dec. B, Jan. D, Feb. D
August	Jan. D, Feb. D, Mar. D
September	Feb. D, Mar. D, Apr. D
October	Mar. D, Apr. D, May D
November	Apr. D, May D, June D
December	May D, June D, July D

The following definitions of B and D will apply:

B = The calendar year before the year in which the scheduled month of delivery as set forth in Paragraph 1 occurs.

D = The calendar year during which the scheduled month of delivery as set forth in Paragraph 1 occurs.

2. If at the time of delivery of an Aircraft Boeing is unable to determine the Aircraft Price Adjustment because the applicable values to be used to determine the ECI and ICI have not been released by the Bureau of Labor Statistics, then:

2.1 The Aircraft Price Adjustment, to be used at the time of delivery of each of the Aircraft, will be determined by utilizing the escalation provisions set forth above. The values released by the Bureau of Labor Statistics and available to Boeing 30 days prior to scheduled Aircraft delivery will be used to determine the ECI and ICI values for the applicable months (including those noted as preliminary by the Bureau of Labor Statistics) to calculate the Aircraft Price Adjustment. If no values have

been released for an applicable month, the provisions set forth in Paragraph 2.2 below will apply. If prior to delivery of an Aircraft the U.S. Department of Labor changes the base year for determination of the ECI or ICI values as defined above, such rebased values will be incorporated in the Aircraft Price Adjustment calculation. The payment by Buyer to Boeing of the amount of the Purchase Price for such Aircraft, as determined at the time of Aircraft delivery, will be deemed to be the payment for such Aircraft required at the delivery thereof.

2.2 If prior to delivery of an Aircraft the U.S. Department of Labor substantially revises the methodology used for the determination of the values to be used to determine the ECI and ICI values (in contrast to benchmark adjustments or other corrections of previously released values), or for any reason has not released values needed to determine the applicable Aircraft Price Adjustment, the parties will, prior to delivery of any such Aircraft, select a substitute for such values from data published by the Bureau of Labor Statistics or other similar data reported by non-governmental United States organizations, such substitute to lead in application to the same adjustment result, insofar as possible, as would have been achieved by continuing the use of the original values as they may have fluctuated during the applicable time period. Appropriate revision of the formula will be made as required to reflect any substitute values. However, if within 24 months from delivery of the Aircraft the Bureau of Labor Statistics should resume releasing values for the months needed to determine the Aircraft Price Adjustment, such values will be used to determine any increase or decrease in the Aircraft Price Adjustment for the Aircraft from that determined at the time of delivery of such Aircraft.

P.A. No. 1810
K/SWA
SA-8

Appendix E: Example of aircraft valuation report for Southwest Airlines

Source: SEC Filing for Pass through certificates, 19 October 2001

BK ASSOCIATES, INC.

1295 Northern Boulevard
Manhasset, New York 11030
(516) 365-6272 - Fax (516) 365-6287

October 15, 2001

Ms. Laura Wright
Vice President Finance & Treasurer
Southwest Airlines
2702 Love Field Drive
Dallas TX 75235-1611

Dear Ms. Wright:

In response to your request, BK Associates, Inc. is pleased to provide this opinion of the current Base Value on each of 29 commercial jet transport aircraft, identified as the Southwest 2001-1 Aircraft Collateral Pool (Aircraft). The Aircraft are further identified in the attached Figure 1 by type, serial number, manufacture date, engine model and maximum takeoff weight.

Set forth below is a summary of the methodology, considerations and assumptions utilized in this appraisal.

CURRENT FAIR MARKET VALUE

According to the International Society of Transport Aircraft Trading's (ISTAT) definition of FMV, to which BK Associates subscribes, the quoted FMV is the Appraiser's opinion of the most likely trading price that may be generated for an aircraft under the market circumstances that are perceived to exist at the time in question. The FMV assumes that the aircraft is valued for its highest and best use, that the parties to the hypothetical sale transaction are willing, able, prudent and knowledgeable, and under no unusual pressure for a prompt sale, and that the transaction would be negotiated in an open and unrestricted market on an arm's length basis, for cash or equivalent consideration, and given an adequate amount of time for effective exposure to prospective buyers, which BK Associates considers to be 12 to 18 months.

BASE VALUE

Base value is the Appraiser's opinion of the underlying economic value of an aircraft in an open, unrestricted, stable market environment with a reasonable balance of supply and demand, and assumes full consideration of its "highest and best use". An aircraft's base value is founded in the historical trend of values and in the projection of future value trends and presumes an arm's length, cash transaction between willing, able and knowledgeable parties, acting prudently, with an absence of duress and with a reasonable period of time available for marketing.

VALUE METHODOLOGY

As the definition suggests, Base Value is determined from historic and future value trends and is not influenced by current market conditions. It is often determined as a function of the original cost of the aircraft, technical characteristics of competing aircraft, and development of new models. BK Associates has determined from analysis of historic data, a relationship between aircraft age and its value as a percentage of original value for the average aircraft. These data form the basis for base value and forecast value determinations but must be adjusted to reflect the value of engine and gross weight options and other features of the aircraft.

LIMITING CONDITIONS AND ASSUMPTIONS

BK has neither inspected the Aircraft nor their maintenance records but relied upon information supplied by you and from BK's own database. In determining the base value of each Aircraft, the following assumptions apply to the Aircraft:

1. Each Aircraft has half-time remaining to its next major overhaul or scheduled shop visit on its airframe, engines, landing gear and auxiliary power unit.
2. The Aircraft is in compliance under a Federal Aviation Administration approved airline maintenance program, with all airworthiness directives, mandatory modifications and applicable service bulletins currently up to industry standard.
3. The interior of the Aircraft is in a standard configuration for its specific type, with the buyer furnished equipment and options of the types and models generally accepted and utilized in the industry.
4. The Aircraft is in current flight operations.
5. The Aircraft is sold for cash without seller financing.
6. The Aircraft is in average or better condition.
7. There is no accident damage.

CONCLUSIONS

Our base value opinion stated herein is given after consideration of the significant event of terrorism that occurred within the United States on September 11, 2001. During the ensuing days since that event, we have begun to see how our industry has been adversely affected. Passenger demand for air travel has dropped dramatically causing airlines to reduce flight schedules and ground significant quantities of their fleets. In response to this initial industry reaction, BK Associates has selectively reduced our opinion of aircraft current fair market values. Today, we are unsure of the long-term effect on aircraft values and will continue to review the industry status. Since our base values, as provided in this appraisal letter, are derived from historical value trends and are not immediately influenced by current supply and demand issues, we have not affected base values at this time.

Based on the above methodology, considerations and assumptions, it is our opinion that the current base value of each of the Aircraft as of today is as shown in Figure 1 attached hereto.

BK Associates, Inc. has no present or contemplated future interest in the Aircraft, nor any interest that would preclude our making a fair and unbiased estimate. This appraisal represents the opinion of BK Associates, Inc. and reflects our best judgment based on the information available to us at the time of preparation and the time and budget constraints imposed by the client. It is not given as a recommendation, or as an inducement, for any financial transaction and further, BK Associates, Inc. assumes no responsibility or legal liability for any action taken or not taken by the addressee, or any other party, with regard to the appraised Aircraft. By accepting this appraisal, the addressee agrees that BK Associates, Inc. shall bear no such responsibility or legal liability. This appraisal is prepared for the use of the addressee and shall not be provided to other parties without the express consent of the addressee.

Sincerely yours,

BK ASSOCIATES, INC.

/s/ R. L. BRITTON

R. L. Britton
Vice President
ISTAT Senior Certified Appraiser

RLB/rb
Attachment

SOUTHWEST 2001-1 AIRCRAFT
COLLATERAL POOL

ITEM	ACFT TYPE	SERIAL NUMBER	MFG. DATE	ENGINE	MTOW	HALFTIME BASE VALUE (\$MIL)
----	-----	-----	-----	-----	-----	-----
1	B737-700	27835	12/17/1997	CFM56-7	153,000	33.95
2	B737-700	27836	12/19/1997	CFM56-7	153,000	33.95
3	B737-700	27837	12/31/1997	CFM56-7	153,000	33.95
4	B737-700	27840	5/31/1998	CFM56-7	153,000	34.30
5	B737-700	27846	5/31/1998	CFM56-7	153,000	34.30
6	B737-700	28436	5/13/1998	CFM56-7	153,000	34.30
7	B737-700	27847	6/8/1998	CFM56-7	153,000	34.35
8	B737-700	27848	6/19/1998	CFM56-7	153,000	34.35
9	B737-700	27849	6/30/1998	CFM56-7	153,000	34.35
10	B737-700	27850	6/30/1998	CFM56-7	153,000	34.35
11	B737-700	27853	8/5/1998	CFM56-7	153,000	34.50
12	B737-700	27854	9/30/1998	CFM56-7	153,000	34.55
13	B737-700	27841	10/30/1998	CFM56-7	153,000	34.60
14	B737-700	29278	12/28/1998	CFM56-7	153,000	34.75
15	B737-700	27858	2/25/1999	CFM56-7	153,000	34.90
16	B737-700	29491	3/31/1999	CFM56-7	153,000	34.95
17	B737-700	27859	5/20/1999	CFM56-7	153,000	35.10
18	B737-700	27860	5/19/1999	CFM56-7	153,000	35.10
19	B737-700	27861	5/24/1999	CFM56-7	153,000	35.10
20	B737-700	30589	6/28/2000	CFM56-7	153,000	35.95
21	B737-700	27880	7/6/2000	CFM56-7	153,000	36.00
22	B737-700	29808	9/29/2000	CFM56-7	153,000	36.15
23	B737-700	29816	11/19/2000	CFM56-7	153,000	36.30
24	B737-700	27886	12/26/2000	CFM56-7	153,000	36.35
25	B737-700	27891	3/28/2001	CFM56-7	153,000	36.50
26	B737-700	27890	3/23/2001	CFM56-7	153,000	36.50
27	B737-700	29815	4/16/2001	CFM56-7	153,000	36.60
28	B737-700	27893	6/28/2001	CFM56-7	153,000	36.75
29	B737-700	27894	6/28/2001	CFM56-7	153,000	36.75

TOTALS 1019.55
</Table>

Appendix F: Operating lease rates versus aircraft values (1993, 1996 and 1999)

March 1993

	B747-400 (new)	B747-400 (old)	B757-200 (new)	B757-200 (old)	B737-400 (new)	B737-400 (old)
Market value US\$m		115.8		23.5		23.5
Lease rate / month (US\$000)						
Formula		686.1		175.0		143.6
Market (Avmark)		1,076.0		259.0		245.0
Ratio of formula to market		0.64		0.68		0.59
Interest rate / month		0.34%		0.34%		0.34%
Lease formula		$(1+i)^n$		$(1+i)^n$		$(1+i)^n$
No. of months to run		252		180		240
Lease factor		0.4234		0.5412		0.4410
No. years to retirement		21		15		20
Year built		1989		1983		1988
Avmark % lease to value		0.93		1.10		1.04
Avmark market value US\$m		115.8		23.5		23.5
Annual market lease x 7 US\$m		90.4		21.8		20.6

March 1996

	B747-400 (new)	B747-400 (old)	B757-200 (new)	B757-200 (old)	B737-400 (new)	B737-400 (old)
Market value US\$m	140.6	102.6	45.2	22.1	32.4	21.4
Lease rate / month (US\$000)						
Formula	923.3	729.3	296.5	188.5	212.8	156.0
Market (Avmark)	900.0	780.0	420.0	225.0	350.0	270.0
Ratio of formula to market	1.03	0.93	0.71	0.84	0.61	0.58
Interest rate / month	0.52%	0.52%	0.52%	0.52%	0.52%	0.52%
Lease formula	$(1+i)^n$	$(1+i)^n$	$(1+i)^n$	$(1+i)^n$	$(1+i)^n$	$(1+i)^n$
No. of months to run	300	252	300	180	300	240
Lease factor	0.2131	0.2729	0.2131	0.3955	0.2131	0.2903
No. years to retirement	25	21	25	15	25	20
Year built		1989		1983		1988
Avmark % lease to value	0.64	0.76	0.93	1.02	1.08	1.26
Avmark market value US\$m	140.6	102.6	45.2	22.1	32.4	21.4
Annual market lease x 7 US\$m	75.6	65.5	35.3	18.9	29.4	22.7

March 1999

	B747-400 (new)	B747-400 (old)	B757-200 (new)	B757-200 (old)	B737-400 (new)	B737-400 (old)
Market value US\$m		81.0		28.8		20.4
Lease rate / month (US\$000)						
Formula		585.2		249.5		151.2
Market (Avmark)		729.0		294.0		235.0
Ratio of formula to market		0.80		0.85		0.64
Interest rate / month		0.53%		0.53%		0.53%
Lease formula		$(1+i)^n$		$(1+i)^n$		$(1+i)^n$
No. of months to run		252		180		240
Lease factor		0.2617		0.3839		0.2790
No. years to retirement		21		15		20
Year built		1989		1983		1988
Avmark % lease to value		0.90		1.02		1.15
Avmark market value US\$m		81.0		28.8		20.4
Annual market lease x 7 US\$m		61.2		24.7		19.7

Appendix G: Major events since flotation of British Airways

List includes most major events of relevance to this thesis.

Date	Event
Feb-87	Sale of UK government's shares in BA and flotation
Apr-88	Acquired British Caledonian Airways
Oct-89	Acquired 15% of UAL Corp.
Dec-89	Planned to invest with SN/KL in new Brussels-based airline (EC objections)
Mar-92	Deutsche BA formed
Nov-92	Acquired 100% of Dan-Air
Jan-93	Acquired 49.9% of TAT
	US Air alliance announced (65 city code share approved)
Mar-93	Completed 25% stake in Qantas
Apr-93	Acquires 24.6% of US Air (preferred stock)
May-93	Acquired remaining shares in Brymon
Dec-94	Sale of Caledonian to Inspirations (incl. 5 L1011s)
Apr-95	First B777 delivered
	ATKs/RTKs based on 80kg per pax (up from 75kg)
	TAT/DBA consolidated in group accounts
Jul-95	Qantas shares traded
Jun-96	Strategic alliance with AA announced
Aug-96	EC approve purchase of remaining 50.1% in TAT
Dec-96	Announces intention to sell US Air shares (sold May 97 for \$625m)
Mar-97	Sells ground fleet services to Ryder
Sep-97	Sells landing gear business to Hawker Pacific
	Sells wheels and brakes business to Allied Signal
Nov-97	Announces Go start-up for early 98
Dec-97	Sells Heathrow catering business to Gate Gourmet
Jul-98	EC publishes conditions for AA alliance approval
Sep-98	oneworld alliance born
Feb-99	Announces 9% stake in IB (concluded Dec 99)
	Sells 30% of Equant for £49m (further tranche in Dec 99)
Apr-99	Delivery of last B747-400
	Issues €300m fixed interest (6.75%) preferred securities
Jun-99	Sells catering facility at LGW to Alpha
Jul-99	US DOT rejects application for AA/BA JV immunity
Sep-99	Sells 34 B757 for freighter conversion (for DHL)
	First A319 arrives
Apr-00	Transfers booking, departure control & related activities to Amadeus
May-00	Sells remaining shares in Air Liberte
	Sells 14% in Hogg Robinson to management
Nov-00	Announces intention to sell Go (completed June 2001)
Mar-01	Offer for British Regional subject to regulatory approval (completed May 01)
Sep-01	Terrorist attacks in US
May-02	easyJet granted option to buy DBA by 31 March 2003

Appendix H: Data for British Airways output measures (1982/83 to 2001/02)

	Pax RTKs m	Cargo RTKs m	Incidental Revs (£m)	Deflated Incidental Revs (£m)	Equivalent Incidental RTKs m	Total RTKs m	Total RTKs incl.incident m	Index Total RTKs incl.incident m
1982/83	3,321	986	229	229	500	4,307	4,807	100
1983/84	3,122	1,122	246	235	480	4,244	4,724	98
1984/85	3,518	1,292	268	244	524	4,810	5,334	111
1985/86	3,799	1,356	316	271	622	5,155	5,777	120
1986/87	3,823	1,444	436	362	852	5,267	6,119	127
1987/88	4,552	1,793	446	356	915	6,345	7,260	151
1988/89	5,387	2,249	358	272	735	7,636	8,371	174
1989/90	5,890	2,400	407	287	792	8,290	9,082	189
1990/91	6,178	2,463	399	257	789	8,641	9,430	196
1991/92	6,268	2,510	436	265	830	8,778	9,608	200
1992/93	7,039	2,691	484	284	982	9,730	10,712	223
1993/94	7,801	2,991	589	340	1,123	10,792	11,915	248
1994/95	8,318	3,349	645	363	1,223	11,667	12,890	268
1995/96	9,608	3,476	677	369	1,272	13,084	14,356	299
1996/97	10,214	3,790	751	399	1,415	14,004	15,419	321
1997/98	10,637	4,181	761	392	1,487	14,818	16,305	339
1998/99	11,798	4,277	806	402	1,678	16,075	17,753	369
1999/00	11,720	4,536	848	413	1,804	16,256	18,060	376
2000/01	11,678	4,731	846	404	1,704	16,409	18,113	377
2001/02	10,361	4,032	769	359	1,486	14,393	15,879	330

	Passenger revenues (total) £ million	Passenger share	Passenger revenues (sched) £ million	Charter revenues £ million	Cargo revenues £ million	Cargo share	Incidental £ million	Incidental share	Total revenue £ million
1982/83	1,857	0.82	1,771	86	187	0.08	229	0.10	2,273
1983/84	2,018	0.82	1,906	112	208	0.08	246	0.10	2,472
1984/85	2,385	0.82	2,254	131	253	0.09	268	0.09	2,906
1985/86	2,527	0.81	2,376	151	268	0.09	316	0.10	3,111
1986/87	2,566	0.79	2,425	141	261	0.08	436	0.13	3,263
1987/88	2,990	0.80	2,825	165	287	0.08	446	0.12	3,723
1988/89	3,556	0.84	3,445	111	343	0.08	358	0.08	4,257
1989/90	4,026	0.83	3,925	101	389	0.08	407	0.08	4,822
1990/91	4,147	0.84	4,042	105	376	0.08	399	0.08	4,922
1991/92	4,392	0.84	4,281	111	396	0.08	436	0.08	5,224
1992/93	4,686	0.84	4,533	153	396	0.07	484	0.09	5,566
1993/94	5,552	0.84	5,388	164	461	0.07	589	0.09	6,602
1994/95	6,014	0.84	5,838	176	518	0.07	645	0.09	7,177
1995/96	6,517	0.84	6,473	44	566	0.07	677	0.09	7,760
1996/97	7,043	0.84	6,986	57	565	0.07	751	0.09	8,359
1997/98	7,286	0.84	7,233	53	595	0.07	761	0.09	8,642
1998/99	7,547	0.85	7,485	62	562	0.06	806	0.09	8,915
1999/00	7,536	0.84	7,465	71	556	0.06	848	0.09	8,940
2000/01	7,853	0.85	7,803	50	579	0.06	846	0.09	9,278
2001/02	7,088	0.85	7,036	52	483	0.06	769	0.09	8,340

Appendix I: British Airways data for conversion of passengers to passenger tonne-kms (1984/85 to 2001/02)

		<i>Freight/mail</i>				<i>RTKs adjusted</i>
	<i>Total RTKs m</i>	<i>RTKs m</i>	<i>Pax RTKs m</i>	<i>Pax-kms m</i>	<i>Kg/pax</i>	<i>to 95kg</i>
1984/85	4,810	1,292	3,518	38,386	91.6	4,939
1985/86	5,155	1,356	3,799	41,334	91.9	5,283
1986/87	5,267	1,444	3,823	41,356	92.4	5,373
1987/88	6,345	1,793	4,552	49,123	92.7	6,460
1988/89	7,636	2,249	5,387	57,795	93.2	7,740
1989/90	8,290	2,400	5,890	61,915	95.1	8,282
1990/91	8,641	2,463	6,178	64,734	95.4	8,613
1991/92	8,778	2,510	6,268	65,896	95.1	8,770
1992/93	9,730	2,691	7,039	73,996	95.1	9,721
1993/94	10,792	2,991	7,801	81,907	95.2	10,772
1994/95	11,667	3,349	8,318	87,395	95.2	11,652
1995/96	13,084	3,476	9,608	96,163	99.9	12,611
1996/97	14,004	3,790	10,214	102,304	99.8	13,509
1997/98	14,818	4,181	10,637	106,739	99.7	14,321
1998/99	16,075	4,277	11,798	118,310	99.7	15,516
1999/00	16,256	4,536	11,720	117,463	99.8	15,695
2000/01	16,409	4,731	11,678	116,674	100.1	15,815
2001/02	14,393	4,032	10,360	103,614	100.0	13,876

Source: BA Annual Reports

Appendix J: British Airways Financial and Operating Data (1983/84 to 2001/02)

	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
Fixed assets: cost or valuation (£m)														
Fleet		2,000	2,110	2,203	2,605	3,203	3,426	3,773	4,302	4,940	5,681	6,720	7,875	8,722
Property		255	260	271	313	377	442	517	572	624	673	784	921	1,042
Equipment		197	224	249	297	367	430	493	539	584	624	655	707	764
Total		2,452	2,594	2,722	3,214	3,947	4,298	4,782	5,413	6,147	6,977	8,158	9,503	10,528
Investments (£m)						2,316	2,466	2,799	3,303	3,851	5,021	5,987	6,495	7,207
Fixed assets as % net l-t assets						76	110	108	101	320	561	523	501	608
Fixed assets: cost or valuation (\$m)						97	96	96	97	92	90	92	93	92
Fleet		2,675	2,854	3,372	4,533	5,717	5,721	6,395	7,485	8,349	8,522	10,415	12,364	13,868
Property		342	352	414	544	672	737	875	994	1,054	1,009	1,214	1,446	1,656
Equipment		263	303	381	516	655	718	835	938	986	935	1,015	1,110	1,215
Total		3,280	3,509	4,167	5,592	7,045	7,177	8,105	9,418	10,388	10,466	12,645	14,920	16,739
Average £/US\$ exchange rate	1.34	1.35	1.53	1.53	1.74	1.79	1.67	1.70	1.74	1.69	1.50	1.55	1.57	1.59
Rental payments (£m)														
Aircraft	12	61	86	86	113	124	179	284	236	224	194	132	113	119
Other	24	28	34	34	38	44	54	59	69	78	84	93	104	104
Hire/charter	10	13	14	14	20	18	17	20	23	23	47	129	181	135
Total	46	102	134	134	171	186	250	363	328	325	325	354	398	358
Deprec./amort. for year (£m)	119	146	162	185	214	305	288	264	295	312	374	458	461	506
Depreciation rate (%)		6.0	6.2	6.8	6.7	7.7	6.7	5.5	5.5	5.1	5.4	5.6	4.9	4.8
Operating profit (£ m)	268	292	198	173	236	336	384	167	344	310	496	618	728	546
Value added (£ m)	387	1,035	1,018	1,097	1,318	1,676	1,798	1,636	1,927	1,937	2,339	2,674	2,934	2,949
Value added at 84/85 prices (£ m)		1,035	1,026	1,089	1,384	1,676	1,772	1,550	1,961	1,860	2,198	2,658	2,909	2,957
Index of VA at 84/85 prices		100	99	105	134	162	171	150	190	180	212	257	281	286
Annual lease equivalent (£m)														
Owned fleet	352	264	264	313	359	507	705	1,057	769	564	460	575	672	582
Owned property	45	32	32	38	43	60	91	145	102	71	54	67	79	69
Owned equipment	35	28	35	35	39	42	63	103	65	50	40	43	40	35
Total owned assets	431	324	324	386	440	609	859	1,305	936	685	554	685	791	686
Total lease equivalent (£m)														
Fleet	364	325	399	472	472	631	884	1,341	1,005	788	654	707	785	701
Property/equipment	104	88	108	120	146	146	207	307	236	199	178	203	222	209
Hire/charter	10	13	14	14	20	18	17	20	23	23	47	129	181	135
Total	477	426	520	611	611	795	1,109	1,668	1,264	1,010	879	1,039	1,189	1,044
Total (Indexed)	100	89	109	128	128	167	232	350	265	212	184	218	249	219
Total lease £m per aircraft	2.4	2.0	2.5	2.5	2.8	3.1	4.2	5.9	4.4	3.3	2.4	2.5	2.7	2.3
Total lease pence/ATK	4.6	3.8	4.6	4.7	4.7	5.3	7.1	10.0	7.3	5.1	3.8	3.9	4.1	3.4
Fleet % in total	78.3	79.3	79.3	80.4	80.4	81.7	81.3	81.6	81.3	80.3	79.7	80.5	81.3	80.0
Labour as % Labour + Capital	55.6	60.7	58.7	58.7	58.7	56.5	50.4	41.9	50.5	56.6	62.6	60.6	59.5	64.5
Capital per employee (£)	12,946	10,940	13,174	14,315	18,087	22,085	32,049	23,221	19,875	16,427	18,908	20,940	17,631	
Finance lease costs (£m)	14	13	17	23	46	30	32	54	77	99				

	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
Annual staff cost (£m)		597	658	739	868	1,035	1,126	1,205	1,288	1,315	1,469	1,598	1,745	1,897
UK index of earnings		100	111.5	120.3	130.1	140.9	153.8	168.3	181.8	192.9	199.6	207.5	214.4	222.7
Staff costs at 1984 prices (£m)		597	590	614	667	735	732	716	708	682	736	770	814	852
Index of staff costs at 84 prices		100	99	103	112	123	123	120	119	114	123	129	136	143
Staff costs per ATK (p)		7.6	7.7	8.4	8.6	8.7	9.0	9.0	9.3	8.5	8.5	8.8	9.2	9.2
Depreciation/lease cost per ATK (p)		2.0	2.6	3.1	3.2	3.6	3.8	4.1	3.8	3.5	3.3	3.2	3.0	3.0
Group ATKs (m)		7,837	8,601	8,751	10,083	11,868	12,445	13,351	13,818	15,424	17,233	18,224	18,982	20,542
No. of aircraft		153	159	161	171	203	213	227	230	236	268	289	288	301
Average ATKs per a/c (m)		51	54	54	59	58	58	59	60	65	64	63	66	68
Block hours per year		2,653	2,720	2,801	2,891	2,886	2,787	2,663	2,708	2,927	2,935	2,993	3,022	3,088
Aircraft kms (m)		252	272	282	312	364	375	389	390	431	522	556	567	579
Average tonnes per a/c		31	32	31	32	33	33	34	35	36	33	33	33	35
Total traffic revenue/RTK (p)						48	49	51	51	49	52	53	53	53
Total traffic revenue/RTK (p)						49.6	50.3	53.1	52.2	54.4	57.8	58.2	58.7	58.5
Total traffic revenue/RTK (p)		52.1	51.7	52.1	49.6	49.6	50.3	53.1	52.2	54.4	57.8	58.2	58.7	58.5
Yield index on 84/85 = 100		100.0	99.2	100.8	95.2	100.0	101.5	105.5	98.2	104.2	106.4	100.6	100.9	99.7
Aircraft price index		100.0	102.2	104.3	106.2	108.7	113.0	116.8	120.4	122.6	124.8	127.5	130.0	131.5
Average age of fleet (years)						9.8	9.9	9.8	10.1	8.0	8.1	8.3	9.3	10.3
Av. employees		36,861	38,939	39,498	42,709	43,969	50,204	52,054	54,427	50,803	53,491	54,958	56,760	59,218
Average fuel price (cents/gal)		63.40	62.80	58.36	63.78	60.22	69.72	89.72	70.94	69.32	63.64	59.79	63.16	75.90
Fuel/oil costs (£ mn)		608	570	371	394	417	544	598	521	560	666	622	655	842
Fuel cost per ATK (p)				4.2	3.9	3.5	4.4	4.5	3.8	3.6	3.9	3.4	3.5	4.1
Gallons consumed (m)		1,285	1,224	973	1,075	1,236	1,303	1,130	1,278	1,365	1,570	1,612	1,628	1,764
ATKs per gallon		9.0	9.0	9.0	9.4	9.6	9.6	11.8	10.8	11.3	11.0	11.3	11.7	11.6
Lease Formula:														
Advance periods		1	1	1	1	1	1	1	1	1	1	1	1	1
n (no. years) for fleet		25.0	25.0	25.0	25.0	15.2	15.1	15.2	14.9	17.0	16.9	16.7	15.7	14.7
Premium		0.50%	0.50%	0.50%	0.50%	0.86%	0.86%	3.12%	4.24%	3.71%	1.90%	-0.37%	-0.86%	-1.71%
US\$ LIBOR + 0.5%		11.00%	8.60%	6.90%	7.80%	9.10%	9.40%	8.43%	5.89%	4.21%	4.07%	6.35%	6.29%	6.20%
BA Bond yield (av.)		11.00%	8.60%	6.90%	7.80%	9.46%	9.76%	11.05%	9.63%	7.42%	5.47%	5.48%	4.93%	3.99%
UK CPI % change			3.8%	4.2%	4.4%	5.2%	7.8%	9.5%	5.9%	3.7%	1.6%	2.5%	3.4%	2.4%
BA real cost of capital		4.00%	4.8%	2.7%	3.4%	6.2%	4.3%	3.4%	5.3%	6.4%	6.9%	6.3%	5.6%	6.4%
n (no. years) for property		25	25	25	27.2	29.0	26.1	22.8	31.1	32.8	29.3	30.3	38.4	32.6
n (no. years) for equipment		10	10	10	8.0	7.1	7.8	9.0	9.4	9.5	9.3	10.5	11.9	10.8

Appendix K: British Airways number of aircraft by type and revenue hours flown (1984/85 to 2001/02)

1. Number of aircraft																	
end of FY:	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	
Concorde	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	
B747-100	16	16	16	16	16	16	15	15	15	15	15	15	15	15	9	0	
B747-200	12	14	16	24	24	23	16	16	16	16	16	16	16	16	16	15	
B747-400	0	0	0	0	0	8	19	22	25	28	31	32	36	44	53	57	
B777	0	0	0	0	0	0	0	0	0	0	0	3	8	18	22	33	
L1011-1/100	9	9	9	9	9	9	6	6	5	5	0	0	0	0	0	0	
L1011-200	8	8	8	8	8	8	7	0	0	0	0	0	0	0	0	0	
L1011-500	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	
DC10-30	0	0	0	8	8	8	8	8	7	7	7	7	10	8	3	0	
B767-200	0	0	0	0	0	0	0	0	0	3	3	1	0	0	0	0	
B767-300	0	0	0	0	0	4	9	16	20	23	23	23	25	25	28	27	
B757-200	16	24	26	30	35	36	37	37	42	43	41	44	44	50	51	53	
A320	0	0	0	0	4	8	10	10	10	10	10	10	10	10	10	10	
A319	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	
Trident 2/3	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
B737-200	45	46	44	44	45	43	43	41	39	37	32	34	36	30	21	13	
B737-300	0	0	0	0	0	0	0	0	3	0	7	9	12	22	25	38	
B737-400	0	0	0	0	4	4	5	13	32	36	35	33	35	34	34	34	
B737-500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
MD83	0	0	0	0	0	0	0	0	0	0	0	0	7	9	10	11	
BAC 1-11-500	21	21	21	35	34	34	31	24	6	0	0	0	0	0	0	0	
BAC 1-11-400	5	5	6	5	0	0	0	0	0	0	0	0	0	0	0	0	
Fokker 100/28	0	0	0	0	0	0	0	0	0	0	16	18	18	15	15	15	
Avro RJ100/146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	
Embraer RJ145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
Turbo-props	6	6	9	11	15	16	17	15	14	23	40	41	29	27	23	34	
Total	158	158	164	197	209	224	230	230	241	253	283	293	308	330	327	363	
Changes		0	6	33	12	15	6	0	11	12	30	10	15	22	-3	36	
Pluses		14	8	36	18	17	21	18	34	23	43	14	28	36	21	58	
Minuses		-14	-2	-3	-6	-2	-15	-18	-23	-11	-13	-4	-13	-14	-24	-22	
Extendable leases	16	25	30	35	39	61	61	66	65	59	45	32	30	28	13	39	
S-t op. leases	8	12	13	11	11	11	10	3	16	24	32	48	59	67	88	98	
Total leased	24	37	43	46	50	72	71	69	81	83	77	80	89	95	101	137	
Leases % new		92.9	75.0	8.3	22.2	129.4	0.0	0.0	35.3	8.7	0.0	21.4	32.1	16.7	28.6	62.1	

2. Revenue hours flown		1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00
end of FY:	1984/85	7,319	7,756	7,873	8,122	7,994	7,911	7,043	6,724	6,583	6,635	5,972	5,850	5,958	5,914	5,889	5,963
Concorde		69,205	78,251	68,670	72,897	74,080	69,598	60,592	51,096	54,864	59,955	62,068	62,053	62,064	57,858	50,047	16,788
B747-100		55,606	56,557	69,506	89,237	110,708	111,035	82,939	68,596	68,789	69,103	59,724	67,518	63,329	62,169	71,770	66,084
B747-200		0	0	0	0	0	13,766	65,064	96,771	117,790	132,320	142,266	154,790	178,552	194,506	238,380	264,439
B777		0	0	0	0	0	0	0	0	0	0	0	3,169	16,265	56,771	78,522	121,914
L1011-1/100		22,639	21,977	26,019	24,099	25,627	23,565	20,313	8,971	13,114	9,747	8,143	0	0	0	0	0
L1011-200		32,844	31,556	29,180	27,685	32,812	31,164	26,838	6,441	0	0	0	0	0	0	0	0
L1011-500		0	8,822	7,713	7,761	0	0	0	0	0	0	0	0	0	0	0	0
DC10-30		0	0	0	9,235	36,329	35,625	33,015	38,158	29,403	27,186	29,105	28,128	35,328	40,554	26,776	13,666
B767-200		0	0	0	0	0	0	0	0	0	8,711	17,340	15,413	0	0	0	0
B767-300		0	0	0	0	0	681	17,386	34,786	59,978	83,686	90,370	81,819	90,737	81,548	86,671	87,528
B757-200		30,164	47,268	60,820	65,928	81,354	89,331	88,424	95,561	110,097	107,102	113,650	112,699	118,973	124,282	132,420	137,031
A320		0	0	0	0	6,371	14,347	20,161	23,045	24,820	23,928	23,793	21,749	23,413	24,149	24,242	23,705
A319		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,209
Trident 2/3		29,747	12,139	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B737-200		100,248	119,140	121,021	118,168	118,691	110,016	99,763	96,522	82,554	86,712	81,545	79,189	85,218	85,062	53,680	36,027
B737-300		0	0	0	0	0	0	0	8,969	2,632	790	18,208	20,842	31,405	41,477	88,243	96,833
B737-400		0	0	0	0	2,990	7,785	12,358	8,169	47,960	92,509	97,148	96,887	99,462	91,650	93,252	98,577
B737-500		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MD83		0	0	0	0	0	0	0	0	0	0	0	0	4,143	19,351	23,941	28,893
BAC 1-11-500		39,797	29,595	32,568	43,212	64,923	50,463	51,856	48,575	33,870	1,285	0	0	0	0	0	0
BAC 1-11-400		8,803	9,294	10,586	11,416	0	0	0	0	0	0	0	0	0	0	0	0
Fokker 100/28		0	0	0	0	0	0	0	0	0	0	41,549	39,445	42,500	38,601	38,325	39,697
Avro RJ100/146		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,231
Embraer RJ145		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98
Turbo-props		8,365	10,774	15,673	17,780	23,463	27,699	28,885	26,712	22,491	37,077	91,188	87,419	59,039	66,189	70,329	64,062
Total		404,737	433,129	449,629	495,540	585,342	592,986	614,637	619,096	674,945	746,746	882,069	876,970	916,386	990,081	1,082,487	1,111,745
3/4 engine aircraft		53.7	50.1	46.5	48.2	49.1	49.4	48.1	44.7	43.0	40.8	34.8	36.3	37.7	36.5	36.3	33.0
B737-200																	
Av. hours/aircraft			2,618	2,689	2,686	2,667	2,500	2,320	2,298	2,064	2,282	2,364	2,400	2,435	2,578	2,105	2,119
Av. age/aircraft			4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
B757-200																	
Av. hours/aircraft			2,363	2,433	2,355	2,503	2,516	2,423	2,583	2,787	2,520	2,706	2,652	2,704	2,644	2,622	2,635
Av. age/aircraft			2														
B737-400																	
Av. hours/aircraft						1,495	1,946	2,746	2,368	2,132	2,721	2,737	2,850	2,925	2,657	2,743	2,899

Source: BA Annual Reports

Appendix L: Calculation of BA's Weighted Average Cost of Capital (WACC)

LIBOR 6 MONTH £	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02
April	8.6	13.2	15.5	11.7	10.7	6.1	5.4	7.1	6.1	6.7	7.5	5.3	6.5	5.3
May	8.5	13.2	15.3	11.3	10.1	6.1	5.4	7.1	6.2	6.7	7.5	5.3	6.5	5.2
June	9.3	14.3	15.0	11.0	10.0	6.0	5.5	6.9	6.0	6.8	7.8	5.2	6.4	5.3
July	10.7	13.9	14.9	10.9	10.2	5.9	5.6	7.0	5.8	7.2	7.9	5.3	6.3	5.3
Aug	11.5	13.8	14.9	10.8	10.5	5.7	6.0	7.0	5.9	7.4	7.7	5.6	6.3	5.0
Sept	12.3	14.1	14.9	10.2	10.0	5.9	6.3	6.8	5.9	7.4	7.4	5.9	6.3	4.7
Oct	12.0	15.0	13.8	10.3	8.0	5.7	6.5	6.8	6.1	7.4	7.0	6.1	6.2	4.4
Nov	12.3	15.0	13.2	10.4	6.9	5.5	6.6	6.7	6.6	7.7	6.7	6.0	6.1	4.0
Dec	13.2	15.0	13.2	10.8	7.0	5.3	7.0	6.4	6.6	7.8	6.2	6.2	5.9	4.1
Jan	13.0	15.2	13.6	10.6	6.8	5.4	7.1	6.4	6.6	7.6	5.7	6.4	5.7	4.1
Feb	13.0	15.2	12.8	10.3	5.9	5.3	7.2	6.2	6.4	7.5	5.4	6.4	5.7	4.0
Mar	13.1	15.5	12.0	10.7	5.9	5.3	7.1	6.1	6.5	7.6	5.3	6.4	5.2	4.3
Average	11.4	14.4	14.1	10.8	8.5	5.7	6.3	6.7	6.2	7.3	6.8	5.9	6.1	4.6
Plus 0.5%	11.9	14.9	14.6	11.3	9.0	6.2	6.8	7.2	6.7	7.8	7.3	6.4	7.1	6.1
Tax rate	35	35	34	33	33	33	33	33	33	31	31	30	30	30
After tax	7.8	9.7	9.6	7.5	6.0	4.1	4.6	4.8	4.5	5.4	5.1	4.5	5.0	4.3
Risk-free	9.4	9.6	11.1	9.9	9.1	7.9	8.1	8.3	8.1	7.1	5.5	4.7	4.7	4.8
Beta	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Equity risk premium	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Cost of equity	14.4	14.6	16.1	14.9	14.1	12.9	13.1	13.3	13.1	12.1	10.5	9.7	9.7	9.8
Cost of capital	11.1	12.1	12.9	11.2	10.1	8.5	8.8	9.0	8.8	8.7	7.8	7.1	7.3	7.0
Real cost of capital	6.2	4.3	3.4	5.3	6.4	6.9	6.3	5.6	6.4	5.6	4.4	4.8	5.2	4.8
Sensitivity														
After tax	8.1	10.0	10.0	7.9	6.4	4.5	4.9	5.2	4.8	5.7	5.4	4.8	5.3	4.7
Beta	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Equity risk premium	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Cost of equity	18.4	18.6	20.1	18.9	18.1	16.9	17.1	17.3	17.1	16.1	14.5	13.7	13.7	13.8
Cost of capital	13.2	14.3	15.0	13.4	12.2	10.7	11.0	11.2	11.0	10.9	9.9	9.3	9.5	9.2
Real cost of capital	8.3	6.5	5.5	7.5	8.5	9.1	8.5	7.8	8.6	7.8	6.5	7.0	7.4	7.0

Source: British Bankers Association web site, and author

Appendix M: Sensitivity tests on BA's constant price capital inputs

Constant 1988/89 £s									
BASE CASE	Lease equiv fleet (£m)	Rentals + charter fleet (£m)	Total fleet (£m)		Lease equiv property (£m)	Lease equiv Equip. (£m)	Rentals prop. (£m)	Total prop. (£m)	GRAND TOTAL
1988/89	347	129	476		31	71	44	75	622
1989/90	340	164	504	5.9	32	71	50	82	657
1990/91	359	252	611	21.3	35	67	51	87	765
1991/92	478	211	689	12.8	39	74	57	96	859
1992/93	525	189	714	3.6	47	84	62	109	907
1993/94	600	149	749	4.9	55	90	65	120	959
1994/95	614	124	738	-1.5	54	84	72	125	946
1995/96	650	118	768	4.1	50	80	78	128	976
1996/97	801	112	913	18.9	66	94	77	142	1,149
1997/98	843	125	968	6.0	66	76	83	149	1,193
1998/99	830	155	985	1.8	65	75	90	155	1,215
1999/00	870	163	1,033	4.9	79	93	89	168	1,294
2000/01	897	163	1,060	2.6	87	118	88	175	1,353
2001/02	866	138	1,004	-5.3	92	101	98	191	1,295
Constant 1988/89 £s									
SENSITIVITY 1 30 years	Lease equiv fleet (£m)	Rentals + charter fleet (£m)	Total fleet (£m)		Lease equiv property (£m)	Lease equiv Equip. (£m)	Rentals prop. (£m)	Total prop. (£m)	GRAND TOTAL
1988/89	295	129	424		31	71	44	75	571
1989/90	281	164	444	4.7	32	71	50	82	597
1990/91	291	252	543	22.3	35	67	51	87	697
1991/92	400	211	611	12.5	39	74	57	96	781
1992/93	459	189	649	6.2	47	84	62	109	841
1993/94	528	149	677	4.4	55	90	65	120	887
1994/95	535	124	658	-2.8	54	84	72	125	867
1995/96	553	118	671	1.9	50	80	78	128	879
1996/97	679	112	791	18.0	66	94	77	142	1,027
1997/98	713	125	838	5.9	66	76	83	149	1,063
1998/99	693	155	848	1.2	65	75	90	155	1,078
1999/00	741	163	904	6.6	79	93	89	168	1,164
2000/01	775	163	939	3.9	87	118	88	175	1,231
2001/02	748	138	885	-5.7	92	101	98	191	1,177
Constant 1988/89 £s									
SENSITIVITY 2 High cost capital	Lease equiv fleet (£m)	Rentals + charter fleet (£m)	Total fleet (£m)		Lease equiv property (£m)	Lease equiv Equip. (£m)	Rentals prop. (£m)	Total prop. (£m)	GRAND TOTAL
1988/89	397	129	527		39	77	44	83	686
1989/90	393	164	557	5.7	40	77	50	90	724
1990/91	418	252	670	20.2	43	74	51	95	839
1991/92	549	211	760	13.6	49	82	57	106	948
1992/93	609	189	798	4.9	58	92	62	121	1,011
1993/94	693	149	842	5.6	67	99	65	133	1,073
1994/95	710	124	834	-0.9	66	93	72	138	1,065
1995/96	750	118	868	4.1	64	90	78	143	1,100
1996/97	915	112	1,027	18.3	82	104	77	159	1,289
1997/98	970	125	1,095	6.7	85	85	83	168	1,349
1998/99	966	155	1,121	2.4	85	84	90	175	1,380
1999/00	1,017	163	1,180	5.3	102	103	89	190	1,473
2000/01	1,050	163	1,214	2.8	111	128	88	199	1,540
2001/02	1,019	138	1,157	-4.7	114	112	98	213	1,482
Constant 1988/89 £s									
SENSITIVITY 3 20 years	Lease equiv fleet (£m)	Rentals + charter fleet (£m)	Total fleet (£m)		Lease equiv property (£m)	Lease equiv Equip. (£m)	Rentals prop. (£m)	Total prop. (£m)	GRAND TOTAL
1988/89	453	129	582		31	71	44	75	729
1989/90	462	164	625	7.4	32	71	50	82	779
1990/91	496	252	748	19.5	35	67	51	87	902
1991/92	641	211	852	13.9	39	74	57	96	1,022
1992/93	652	189	841	-1.2	47	84	62	109	1,034
1993/94	741	149	889	5.7	55	90	65	120	1,100
1994/95	769	124	892	0.3	54	84	72	125	1,101
1995/96	845	118	963	7.9	50	80	78	128	1,172
1996/97	1,060	112	1,172	21.7	66	94	77	142	1,408
1997/98	1,109	125	1,234	5.3	66	76	83	149	1,459
1998/99	1,100	155	1,255	1.7	65	75	90	155	1,484
1999/00	1,117	163	1,280	2.0	79	93	89	168	1,540
2000/01	1,123	163	1,287	0.5	87	118	88	175	1,579
2001/02	1,083	138	1,221	-5.1	92	101	98	191	1,512

Appendix N: Majority owned subsidiary companies of airlines

Position at end of FY1999/2000 (airlines shown in italics)

<i>Airline Group</i>	<i>Subsidiary Company</i>		
Air France	<i>CityJet (100%)</i> <i>Regional (97%)</i> <i>Flandre Air (100%)</i> <i>Nouvelle Air Ivoire (51%)</i> <i>Servair (80%)</i> <i>SNC Amadeus France (60%)</i>	Japan Airlines	<i>J-Air (100%)</i> <i>JAL Express (100%)</i> <i>JALC (100%)</i> <i>JALways (100%)</i> <i>Japan Asia Airways (91%)</i> <i>Japan TransOcean Air (51%)</i> <i>Axess International (75%)</i> <i>Jalpak Company (75%)</i>
British Airways	<i>Deutsche BA (100%)</i> <i>British Airways Regional (100%)</i> <i>CityFlyer Express (100%)</i> <i>Go Fly (100%)</i> <i>British Asia Airways (100%)</i> <i>The Plimsoll Line/Brymon (100%)</i> <i>Participations Aeronautiques (86%)</i> <i>British Airways Holidays (100%)</i> <i>Air Miles Travel Promotions (100%)</i> <i>Bedford Associated (100%)</i> <i>Travel Automation Services (100%)</i> <i>Other non-airline companies</i>	Singapore Airlines	<i>Silk Air (100%)</i> <i>Singapore Airlines Cargo (100%)</i> <i>Singapore Airport Terminal (100%)</i>
		Thai Airways	<i>Thai Amadeus (100%)</i> <i>Thai Information Solutions (100%)</i>
		American	None reported
		Delta Airlines	<i>Comair (100%)</i> <i>(from Nov.99)</i> <i>Atlantic Southeast (91%)</i> <i>(from Nov.99)</i>
KLM	<i>KLM cityhopper (100%)</i> <i>KLM uk (100%)</i> <i>Transavia (80%)</i> <i>Cargo Service Center (100%)</i> <i>KLM Catering (100%)</i> <i>KLM Ground Services (100%)</i> <i>Flying School & other companies (100%)</i>	Northwest	<i>Pinnacle Airlines (100%)</i>
		United Airlines	<i>Shuttle & commuter airlines</i> <i>set up as divisions</i>
Lufthansa	<i>Lufthansa Cargo (100%)</i> <i>Lufthansa CityLine (100%)</i> <i>Lufthansa Technik (100%)</i> <i>Lufthansa Airmotive (100%)</i> <i>LSG Services (100%)</i> <i>GlobeGround (100%)</i> <i>Lufthansa Systems (100%)</i> <i>C&N Touristic (50%)</i>	Sources: ATI, Airline Business, airline reports	
Cathay Pacific	<i>Air Hong Kong (100%)</i> <i>Cathay Pacific Catering (100%)</i>		

Appendix O: Data for fleet market values and seat comfort

British Airways

	On B-S Average no. aircraft 99-00	Aircraft value \$m Oldest 1/00	Aircraft value \$m New 1/00	Total value \$m Oldest 1/00	Total value \$m New 1/00	Rev. Hrs 1999-00	Actual Seats	Max. Seats	Actual Seat hrs (000)	Max. Seat hrs (000)
<i>Mainline:</i>										
Concorde	7.0	0.0	0.0	0	0	5,963	100	108	596	644
B747-100	4.0	3.0	6.0	12	24	16,788	356	490	5,977	8,226
B747-200	12.5	7.8	43.0	98	538	66,084	356	490	23,526	32,381
B747-400	55.0	80.0	148.0	4,400	8,140	264,439	405	660	107,098	174,530
B777-200A	27.5	95.5	123.0	2,626	3,383	121,914	227	440	27,674	53,642
B767-300	27.5	35.2	76.0	968	2,090	87,528	252	350	22,057	30,635
B757-200	47.0	28.0	53.0	1,316	2,491	137,031	180	231	24,666	31,654
A320-100	10.0	16.4	19.5	164	195	23,705	149	180	3,532	4,267
B737-200	4.5	3.2	7.5	14	34	36,027	110	124	3,963	4,467
B737-400	22.0	20.3	37.6	447	827	98,577	145	168	14,294	16,561
A319	0.0	28.7	36.0	0	0	4,209	126	145	530	610
Dash 8	17.5	6.0	12.2	105	214	39,070				
Dash 7	2.0	1.3	2.1	3	4					
EMB 145	1.0	12.0	14.0	12	14	901,335			233,913	357,618
Total BA				10,164	17,953			Max vs actual %		52.9

American Airlines Inc.

						Rev. Hrs 1999	Actual Seats			
A300-600R	10.0	34.5	71.5	345	715	113,698	242	361	27,477	41,045
B727-200	69.0	1.9	4.8	131	331	217,686	150	189	32,653	41,143
B757-200	68.0	22.0	52.7	1,496	3,584	383,469	188	231	72,092	88,581
B767-200	8.0	21.0	40.2	168	322	120,450	172	255	20,717	30,715
B767-200ER	22.0	27.3	73.0	601	1,606	0	165	255	0	0
B767-300ER	37.0	35.2	76.0	1,302	2,812	236,082	207	350	48,869	82,629
F100	71.0	9.5	21.0	675	1,491	235,425	97	109	22,836	25,661
DC10-10	8.0	3.8	7.5	30	60	15,148	275	380	4,161	5,756
DC10-30	4.0	13.0	25.0	52	100	17,155	277	380	4,743	6,519
MD-11	11.0	63.0	100.0	693	1,100	44,567	247	410	10,986	18,272
MD-82	147.0	12.3	26.0	1,808	3,822	1,010,101	139	172	140,404	173,737
B777	5.5	95.5	123.0	525	677	51,392	237	440	12,180	22,612
MD 87	0.0	13.9	19.9	0	0	17,520	133	139	2,330	2,435
MD 90	5.0	30.0	36.0	150	180	15,513	148	172	2,296	2,668
B737-800	12.0	39.5	42.5	474	510	79,753	146	189	11,644	15,073
Total AA				8,450	17,309	2,557,959			413,388	556,848
								Max vs actual %		34.7

Air France

						Rev. Hrs 1999	Actual Seats	Max. Seats	Actual Seat hrs (000)	Max. Seat hrs (000)
A310-200	6.0	14.7	20.0	88	120	22,155	164	279	3,633	6,181
A310-300	4.0	22.2	68.5	89	274	16,571	167	279	2,767	4,623
A320	47.5	16.4	19.5	779	926	172,888	159	180	27,489	31,120
A319	11.5	28.7	36.0	330	414	45,455	135	145	6,136	6,591
A321	7.5	37.4	46.5	281	349	36,938	189	220	6,981	8,126
A340-300	15.0	89.0	118.0	1,335	1,770	84,291	252	380	21,241	32,031
Concorde	5.0	0.0	0.0	0	0	3,315	100	108	332	358
B747-100	0.0	3.0	6.0	0	0	4,684	373	490	1,747	2,295
B747-200	5.0	7.8	43.0	39	215	47,085	342	490	16,103	23,072
B747-300M	2.0	41.0	53.0	82	106	17,082	508	490	8,678	8,370
B747-400 & C	13.0	80.0	148.0	1,040	1,924	71,650	391	660	28,015	47,289
B747-400F	0.0	97.0	149.0	0	0	51,593				0
B767-300ER	0.0	35.2	76.0	0	0	25,854	225	350	5,817	9,049
B737-200	12.5	3.2	7.5	40	94	39,347	114	124	4,486	4,879
B737-300	9.0	15.5	32.3	140	291	27,813	130	149	3,616	4,144
B777-200	8.0	95.5	123.0	764	984	42,836	270	440	11,566	18,848
B737-500	18.0	18.3	30.5	329	549	67,586	112	124	7,570	8,381
Total AF				5,335	8,015	754,988			156,177	215,357
								Max vs actual %		37.9

Lufthansa

A300B4-600	11.0	23.0	35.0	253	385	43,733	233	361	10,190	15,788
A310-300	7.0	22.2	68.5	155	480	12,593	183	280	2,298	3,526
A319-100	20.0	28.7	36.0	574	720	61,198	126	145	7,711	8,874
A320-200	36.0	41.5	48.0	1,494	1,728	101,981	147	180	14,991	18,357
A321-100	20.5	37.4	46.5	767	953	67,324	182	220	12,253	14,811
A340-200	6.0	74.0	103.0	444	618	29,937	212	300	6,347	8,981
A340-300	14.5	89.0	118.0	1,291	1,711	87,405	247	440	21,589	38,458

United Airlines

B747-400	18.5	80.0	148.0	1,480	2,738	192,787	363	660	69,982	127,239
B747-200	1.0	7.8	43.0	8	43	22,152	369	490	8,174	10,854
B777-200	33.0	95.5	123.0	3,152	4,059	196,370	292	440	57,340	86,403
DC10-30	0.0	13.0	25.0	0	0	11,005	298	380	3,279	4,182
DC10-10	11.5	3.8	7.5	44	86	22,058	287	380	6,331	8,382
B767-300	12.5	35.2	76.0	440	950	149,309	218	350	32,549	52,258
B767-200	19.0	21.0	40.2	399	764	76,516	168	255	12,855	19,512
B757-200	47.0	22.0	52.7	1,034	2,477	400,624	182	231	72,914	92,544
B727-200	75.0	1.9	4.8	143	360	224,931	147	189	33,065	42,512
A319	24.0	28.7	36.0	689	864	120,937	126	145	15,238	17,536
A320-200	21.5	41.5	48.0	892	1,032	237,445	144	180	34,192	42,740
B737-300	10.0	15.5	32.3	155	323	393,350	129	149	50,742	58,609
B737-500	42.0	18.3	30.5	769	1,281	205,970	112	124	23,069	25,540
B737-200	24.0	3.2	7.5	77	180	67,452	109	124	7,352	8,364
DC10-30F	4.0	20.0	37.0	80	148	14,795				

UA Total				9,360	15,305	2,335,701			427,082	596,676
									Max vs actual %	39.7

Cathay Pacific

A330-300	12.0	82.0	110.0	984	1,320	39,420	314	440	12,378	17,345
A340-300	11.0	89.0	118.0	979	1,298	76,139	250	440	19,035	33,501
B777-200	4.0	95.5	123.0	382	492	35,734	336	440	12,007	15,723
B777-300	5.5	105.5	133.0	580	732		367			
B747-200/300	12.5	7.8	43.0	98	538	33,726	415	490	13,996	16,526
B747-400	16.0	80.0	148.0	1,280	2,368	99,864	387	660	38,647	65,910
B747-200F	7.0	23.0	67.0	161	469	36,026				
B747-400F	2.0	97.0	149.0	194	298	11,534				

Total CX	70			4,658	7,514	332,443			96,063	149,005
									Max vs actual %	55.1

Japan Air Lines

DC10-40	12.5	7.0	12.5	88	156	40,095	275	380	11,026	15,236
B747-100	4.5	3.0	6.0	14	27					
B747-200	9.5	7.8	43.0	74	409					
B747-300	13.0	38.0	56.0	494	728	108,283	393	490	42,555	53,059
B747-400	29.5	80.0	148.0	2,360	4,366	164,177	384	660	63,044	108,357
B767-200	3.0	21.0	40.2	106	228	61,965	270	350	16,731	21,688
B767-300	7.5	35.2	76.0	473	750					
MD-11	2.0	63.0	100.0	126	200	39,055	239	410	9,334	16,013
B737-400	1.5	20.3	37.6	30	56	11,437	150	168	1,716	1,921
B777-200	1.0	95.5	123.0	96	123	29,322	387	440	11,348	12,902
B777-300	2.0	3.2	7.5	6	15					
B747-200F	5.0	23.0	67.0	115	335	15,585				

JL Total	91			3,981	7,393	469,919			155,753	229,175
									Max vs actual %	47.1

Singapore Airlines

B747-400	35.0	80.0	148.0	2,800	5,180	157,771	386	660	60,900	104,129
B777-200	12.5	95.5	123.0	1,194	1,538	51,325	288	440	14,782	22,583
B777-300	4.5	105.5	133.0	475	599	17,733	332	550	5,887	9,753
A340-300	14.5	89.0	118.0	1,291	1,711	74,004	365	440	27,011	32,562
A310-300	15.0	22.2	68.5	333	1,028	45,716	183	280	8,366	12,800
A310-200	0.5	14.7	20.0	7	10	1,101	180	280	198	308
B747-300/300M	2.0	40.0	54.0	80	108					
B747F	7.5	97.0	149.0	728	1,118	43,849				

SQ Total	92			6,907	11,290	391,499			117,144	182,136
									Max vs actual %	55.5

KLM

MD-11	10.0	63.0	100.0	630	1,000	50,431	297	410	14,978	20,677
Fokker 70	0.0	15.5	17.0	0	0	35,186	80	80	2,815	2,815
RJ100	0.0	11.0	13.5	0	0					
Fokker 50	0.0	4.9	9.8	0	0	34,322	50	58	1,716	1,991
B747-400	4.5	80.0	148.0	360	666	25,915	424	660	10,988	17,104
B747-400 Combi	14.5	75.0	147.5	1,088	2,139	86,505	424	660	36,678	57,093
B747-300	2.0	38.0	56.0	76	112	33,982	424	660	14,408	22,428
B747-300 Combi	7.5	41.0	53.0	308	398	18,323	424	660	7,769	12,093
B767-300	0.0	35.2	76.0	0	0	56,879	224	350	12,741	19,908
B757-200	0.0	35.2	76.0	0	0					

Delta Air Lines										
MD-90	16.0	30.0	36.0	480	576	60,327	150	172	9,049	10,376
B727-200	110.0	1.9	4.8	209	528	387,630	149	189	57,757	73,262
L-1011-100/200	19.0	4.2	7.1	79	135	6,704	300	400	2,011	2,682
L-1011-500	11.0	7.2	11.8	79	130	36,135	218	330	7,877	11,925
B777-200	2.0	95.5	123.0	191	246					
B767-200	15.0	21.0	40.2	315	603	60,225	183	255	11,021	15,357
B737-200	45.0	3.2	7.5	144	338	199,071	115	124	22,893	24,685
B737-800	7.0	39.5	42.5	277	298					
B757-200	59.0	22.0	52.7	1,298	3,109	421,575	183	231	77,148	97,384
B767-300	4.0	35.2	76.0	141	304	141,206	252	350	35,584	49,422
B767-300ER	43.0	49.5	82.5	2,129	3,548	234,549	195	350	45,737	82,092
MD-88	63.0	17.2	25.0	1,084	1,575		142	172	0	0
B737-300	3.0	15.5	32.3	47	97	83,828	128	149	10,730	12,490
MD-11	8.0	63.0	100.0	504	800	76,194	265	410	20,191	31,240
DL Total	405			6,975	12,285	1,707,444			299,999	410,915
									Max vs actual %	37.0
Northwest										
A320	66.5	41.5	48.0	2,760	3,192	275,088	150	180	41,263	49,516
DC9-10	8.0	0.6	0.8	5	6	24,759	78	100	1,931	2,476
DC9-40	12.0	1.8	2.7	22	32	34,310	100	115	3,431	3,946
DC9-50	35.0	3.6	5.2	126	182	102,200	112	125	11,446	12,775
DC9-30	115.5	1.7	3.9	196	450	337,199	122	139	41,138	46,871
MD-80	8.0	9.0	9.3	72	74					
A319	5.0	28.7	36.0	144	180	31,098	124	145	3,856	4,509
B727-200	29.0	1.9	4.8	55	139	81,930	149	189	12,208	15,485
B747-200	21.0	7.8	43.0	164	903	77,988	371	490	28,934	38,214
B747F	9.0	97.0	149.0	873	1,341	37,175			0	0
B747-400	12.0	80.0	148.0	960	1,776	65,153	418	660	27,234	43,001
B757	48.0	22.0	52.7	1,056	2,530	204,458	190	231	38,847	47,230
DC10-40	17.0	7.0	12.5	119	213	84,315	285	380	24,030	32,040
DC10-30	15.0	13.0	25.0	195	375	71,157	280	380	19,924	27,040
NW Total	401			6,746	11,394	1,426,830			254,242	323,101
									Max vs actual %	27.1
Thai										
B747-400	13.0	80.0	148.0	1,040	1,924	70,007	405	660	28,353	46,205
B747-300	2.0	38.0	56.0	76	112	6,461	405	660	2,617	4,264
B777-300	2.0	105.5	133.0	211	266	17,106	340	550	5,816	9,408
B777-200	7.0	95.5	123.0	669	861	26,621	358	440	9,530	11,713
B737-400	11.0	20.3	37.6	223	414	24,358	150	168	3,654	4,092
A300-600	0.0	23.0	35.0	0	0	55,827	247	361	13,789	20,154
A310-200	1.0	14.7	20.0	15	20					
A330-300	10.5	82.0	110.0	861	1,155	33,445	315	440	10,535	14,716
MD-11	4.0	63.0	100.0	252	400	16,255	285	410	4,633	6,665
B747F	0.0	97.0	149.0	0	0					
TG Total				3,347	5,152	250,080			78,927	117,216
									Max vs actual %	48.5

Appendix P: Avmark jet values by aircraft type (US\$ million)

Passenger/combi:	Year first built	Jan-00		Jan-99	
		Older	New	Oldest	New
B747SR	n/a	3.9	12.0	4.0	8.3
B747-100	1969	3.0	6.0	3.1	6.3
B747-200B	1971	7.8	43.0	8.5	46.0
B747-300	1983	38.0	56.0	36.0	54.0
B747-300 Combi	n/a	41.0	53.0	45.0	57.0
B747-400	1989	80.0	148.0	83.0	147.5
B747-400 Combi	1989	75.0	147.5	77.0	147.5
MD-11	1990	63.0	100.0	64.3	103.0
A340-200	1993	74.0	103.0	77.8	107.0
A340-300	1994	82.0	110.0	86.0	110.0
A330-200	n/a	94.6	100.0	99.0	102.0
A330-300	1994	82.0	110.0	86.0	110.0
L-1011-100	1974	3.3	6.5	3.8	7.0
L-1011-200	1975	5.0	7.7	5.4	6.2
L-1011-500	1979	7.2	11.8	7.8	12.5
B777-200A	1995	95.5	123.0	97.0	128.0
B777-200ER	n/a	119.0	131.0	122.0	134.0
B777-300	n/a	105.5	133.0	n/a	n/a
DC-10-40	1972	7.0	12.5	5.5	9.3
DC-10-30	1972	13.0	25.0	12.0	25.7
DC-10-10	1971	3.8	7.5	4.5	7.6
A300-600R	1988	34.5	71.5	37.0	68.0
A300B4-200	1975	6.2	11.5	6.2	12.0
A310-200	1985	14.7	20.0	15.5	22.0
A310-300	1982	22.2	68.5	23.5	68.0
B767-200	1982	21.0	40.2	22.0	41.0
B767-200ER	1984	27.3	73.0	29.0	74.0
B767-300	1986	35.2	76.0	36.5	78.0
B767-300ER	1988	49.5	82.5	51.0	82.5
B757-200PW	1983	22.0	52.7	23.3	53.5
B757-200ER	n/a	28.5	53.0	29.5	51.0
A321-100	1994	37.4	46.5	39.1	47.5
A320-100	1987	16.4	19.5	16.5	19.7
A320-200	1989	41.5	48.0	23.8	40.5
A319-100	1996	28.7	36.0	30.0	35.5
B727-200Adv	1972	1.9	4.8	2.0	5.0
B737-200Adv	1972	3.2	7.5	3.3	7.5
B737-300	1984	15.5	32.3	16.2	32.5
B737-400	1988	20.3	37.6	21.2	38.0
B737-500	1990	18.3	30.5	18.6	31.0
MD-83	1985	14.7	31.0	15.3	29.0
MD-82	1981	12.3	26.0	12.8	27.0
MD-90	1995	30.0	36.0	31.3	37.0
MD-88	1988	17.2	25.0	17.8	25.0
Fokker 100	1988	9.5	21.0	10.5	22.2
EMB 145	n/a	12.3	14.5	n/a	14.5
DHC-8-300	1988	6.0	12.2	n/a	n/a
DHC-7	1977	1.3	2.1	n/a	n/a
Cargo:					
B737-300F		17.0	33.5	17.0	33.5
B747-200F/S		23.0	67.0	25.0	70.0
DC8-73F		14.8	19.0	15.0	20.0
B747-400F		97.0	149.0	99.8	149.0

Source: Avmark Aviation Economist, July/August 2000

Appendix Q: Output data for sample airlines (1999/2000)

	FY ended	KL 31/03/2000	BA 31/03/2000	LH 31/12/1999	AF 31/03/2000	AA 31/12/1999	UA 31/12/1999	DL 31/12/1999	NW 31/12/1999	SQ 31/03/2000
Passenger-kms (mn)		59,231.2	125,211.7	84,414.2	85,422.4	177,299.0	203,381.5	169,512.0	119,410.9	65,718.0
RTKs (mn)										
passengers		5,940.9	11,269.1	8,458.3	7,688.0	16,081.4	18,304.3	15,286.0	10,825.0	6,277.9
freight		4,056.5	4,133.8	6,925.5	4,830.0	2,511.4	3,580.9	1,985.0	3,011.7	5,638.8
mail		152.8	147.9	145.2	188.6	525.9	893.7	568.7	392.7	109.2
charter		0.0	43.0	13.0	4.5	9.8	11.4	11.8	13.9	3.6
total		10,150.3	17,150.0	15,542.0	12,711.1	19,128.6	22,790.3	17,851.5	14,243.3	12,029.5
Passengers as % total RTKs		58.5	65.5	54.4	60.5	84.1	80.3	85.6	76.0	52.2
Equiv. incidental RTKs (mn)		1,452.5	1,634.1	1,338.7	683.3	1,210.0	2,188.9	1,397.0	1,397.0	760.5
Equiv. RTKs adjusted by kg per passenger		11,288.9	19,438.9	16,386.9	13,727.6	19,935.7	24,706.6	18,803.6	14,857.7	12,374.3
Equiv. RTKs adjusted by seat density & kg		11,585.7	21,189.2	16,386.9	12,301.9	16,064.0	22,212.9	15,869.2	10,455.0	13,651.1
Equiv. RTKs adjusted by seat density & kg (UA=100)		52.2	95.4	73.8	55.4	72.3	100.0	71.4	47.1	61.5
Total unadjusted output (Equiv. RTK basis)		11,602.8	18,849.1	16,880.7	13,394.4	20,338.6	24,979.2	19,248.5	15,003.8	12,390.6
Freight RTKs as % of adjusted total RTKs		35.0	19.5	42.3	39.3	15.6	16.1	12.5	28.8	41.3
Average kg per passenger		100.3	90.0	100.2	90.0	90.7	90.0	90.0	90.7	95.2
Percent domestic passengers in total RTKs		0.0	2.9	6.5	11.0	85.7	63.4	76.2	55.7	0.0
Adjusted kg per passenger		95.0	94.7	94.4	93.9	88.4	88.7	87.4	89.4	95.0
Comfort factor (Indexed on LH seat pitch)		105.3	114.8	100.0	92.2	75.3	86.2	80.2	58.8	120.4
Adjusted passenger RTKs (seats & kg)		7,376.3	16,864.6	9,303.2	7,278.8	13,016.9	17,726.9	13,303.7	7,036.7	7,899.4
Translog output index (UA=100) adjusted		45.1	94.6	60.7	44.3	71.9	100.0	72.9	41.5	46.7
Translog output index (UA=100) unadjusted		37.1	66.3	54.8	45.1	83.8	100.0	79.9	57.9	38.0
Operating revenues (local currency in million)										
Sched. pax + bags		9,958	7,465	15,166	49,377	14,486	15,467	13,234	8,607	5,992
freight		2,082	556	3,785	6,389	493	677	402	613	1,909
mail				248	378	139	230	155	111	41
charter		98	71	620	0	10	19	29	37	22
incidental total		1,737	848	1,707	3,018	957	1,574	1,082	500	239
TOTAL		13,875	8,940	21,526	59,161	16,085	17,967	14,901	9,868	8,202
Incidental - air transport (gross)										176
Incidental - other (net)										63
Revenue per RTK (local currency)		1.20	0.52	1.28	4.42	0.79	0.72	0.77	0.66	0.66
Revenue per RTK (PPPs)		0.58	0.78	0.64	0.86	0.79	0.72	0.77	0.66	0.36
Pax revenue per RTK (PPPs)		0.66	0.67	0.82	1.02	1.11	0.87	0.99	1.22	0.41
Cargo revenue per RTK (PPPs)		0.25	0.20	0.27	0.20	0.20	0.19	0.20	0.20	0.18
Operating costs (local currency in million)		11,923	8,856	25,136	54,883	15,083	16,609	13,640	9,099	7,411
Interest paid (local mn)		133	408	429	1,028	0	297	223	347	0
Depreciation + rentals (local mn)		608	648	1,356	3,833	852	968	1,478	399	1,094
Aircraft rentals (local mn)		1,139	190	209	3,208	539	879	584	363	245
Accounting operating ratio (%)		115	97	99	106	107	108	107	104	111
Economic operating ratio (%)		112	96	93	104	102	105	111	103	97
Exchange rate		2.16	0.62	1.85	6.41	1.00	1.00	1.00	1.00	1.70
GDP PPP exchange rate		2.06	0.664	2.00	6.65	1	1	1	1	1.84
Operating revenues (PPP US\$ mn)										
Sched. pax + bags		4,834	11,242	7,583	7,425	14,486	15,467	13,234	8,607	3,262
freight		1,011	837	1,892	961	493	677	402	613	1,039
mail		0	0	124	57	139	230	155	111	22
charter		47	107	310	0	10	19	29	37	12
incidental total		843	1,277	854	454	957	1,574	1,082	500	130
TOTAL		6,735	13,464	10,763	8,886	16,085	17,967	14,901	9,868	4,466

Sources: ICAO Financial Data Series F-No.50, 1999 and Annual Reports

Appendix R: Input data for sample airlines (1999/2000)

FY ended	KL	BA	LH	AF	AA	UA	DL	NW	SQ
Wages, salaries & benefits (local)	2,852	1,472	4,297	17,455	6,034	6,822	4,988	3,547	1,684
Wages, salaries & benefits (US\$)	1,324	2,381	2,326	2,723	6,034	6,822	4,988	3,547	981
Wages, salaries & benefits (PPPUS\$)	1,385	2,217	2,148	2,625	6,034	6,822	4,988	3,547	906
Lease equiv. market value fleet US\$	482	1,406	1,362	781	1,456	1,406	1,050	831	1,170
Lease equiv. market value fleet PPPUS\$	482	1,406	1,362	781	1,456	1,406	1,050	831	1,170
Lease equiv. market val. other assets PPPUS\$	80	278	57	62	130	143	165	46	11
Aircraft lease costs (local)	1,139	190	209	3,208	539	879	584	383	229
Total equiv. lease costs (local)	2,372	1,231	2,830	8,616	2,125	2,428	1,798	1,240	2,234
Lease equiv. market val. other assets local	165	184	114	416	130	143	165	46	21
Total equiv. lease costs (PPP US\$)	1,101	1,992	1,532	1,344	2,125	2,428	1,799	1,240	1,316
Operating lease rentals as % total capital input	50	14	7	36	25	36	32	29	9
Depreciation (total) local	608	619	n/a	3,833	968	852	1,057	399	1,118
Depreciation (fleet) local	429	508	1,098	n/a	741	610	1,057	299	1,035
Flight equip. before deprec. Local: end	10,577	11,251	24,489	62,548	18,041	16,803	14,950	7,507	15,887
Flight equip. before deprec. Local: begin	10,503	10,756	22,906	62,548	15,249	14,951	12,181	7,282	15,323
Flight equip. before deprec. Local: average	10,540	11,003	23,697	62,548	16,645	15,877	13,566	7,395	15,595
Flight equip. after deprec. Local: end	6,213	7,850	12,887	38,818	11,700	12,686	10,091	4,748	8,996
Flight equip. after deprec. Local: begin	5,934	7,402	12,418	37,729	9,540	10,781	8,083	4,560	9,142
Flight equip. after deprec. Local: average	6,074	7,626	12,652	31,274	10,620	11,734	9,087	4,654	9,069
Aircraft market value (US\$m) - low	2,954	17,953	8,672	5,335	8,450	9,360	6,975	6,746	6,907
Aircraft market value (US\$m) - high	5,189	10,164	14,047	8,015	17,309	15,305	12,285	11,384	11,290
Aircraft market value (US\$m) - estimate	4,367	12,953	12,542	7,061	13,411	12,951	9,673	7,657	10,384
Aircraft market value (Local m) - estimate	9,410	8,009	23,188	45,263	13,411	12,951	9,673	7,657	17,618
Market over net book ratio	1.55	1.05	1.83	1.45	1.26	1.10	1.06	1.65	1.94
Other assets before deprec. Local: end	2,778	2,115	1,500	10,951	2,927	2,991	3,492	1,315	622
Other assets after deprec. Local: end	1,606	1,657	1,041	3,821	1,215	1,361	1,822	419	195
Other assets after deprec. Local: begin	1,482	1,507	901	3,621	1,178	1,275	1,213	423	146
Other assets after deprec. Local: average	1,534	1,582	971	3,621	1,196	1,318	1,518	421	171
Other assets after deprec. Local: adjusted	2,377	1,662	1,778	5,240	1,510	1,455	1,615	693	332
Total gross assets (local)	13,318	13,118	25,197	73,499	19,573	18,687	17,058	8,709	16,217
Effective rate of fleet depreciation (%)	4.1	4.6	4.6		4.5	3.8		4.0	6.6
Effective rate of fixed asset depreciation (%)				5.2		12.4	6.2		
Total years for non-fleet depreciation	15.6	19.1			12.9			13.2	7.5
Estimate for aircraft spares (%)	10.0	6.0	6.0	8.0	6.0	6.0	6.0	6.0	10.0
Employees year end				52,721					
Employees year begin				49,082					
Average or mid-year staff numbers	27,302	56,350	45,001	50,907	93,335	98,295	77,648	51,887	18,679
Adjusted staff numbers	27,276	60,536	43,979	48,032	81,593	91,319	69,924	41,807	19,997
Average aircraft utilisation (block hours)	11.1	10.3	9.8	11.6	10.0	10.7	10.5	9.5	11.7
Average age of fleet (years)	9.2	9.0	7.0	8.9	11.0	9.9	12.3	20.1	5.2
Overall average load factor (%)	77.3	67.3	71.1	61.7	53.5	57.5	58.2	61.7	71.1
Fleet size: average period (total)	116	285	299	212	675	566	580	409	92
Fleet size: average period (owned)	63	238	243	164	478	343	405	401	92
RTKs per aircraft (mn)	100.0	66.1	56.5	63.2	30.1	42.6	33.2	36.7	134.7
Operating lease percentage of total	46	17	19	23	29	41	30	2	1
Lease Formula:									
Advance periods	1	1	1	1	1	1	1	1	1
n (no. years) for fleet	15.8	16.1	18.0	16.1	14.0	15.1	12.7	4.9	19.8
Aircraft economic life	25	25	25	25	25	25	25	25	25
Interest rate (LIBOR + 0.5%)	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%

Appendix S: Productivity ratios for sample airlines (1999/2000)

	KL	BA	LH	AF	AA	UA	DL	NW	SQ
Labour input index (UA=100)	30	66	48	53	89	100	77	46	22
Capital input index (UA=100)	45	82	63	55	88	100	74	51	54
Adjusted RTK translog/capital input (UA=100)	99.5	115.3	96.2	80.0	82.1	100.0	98.4	81.3	86.0
Unadjusted RTK translog/capital input (UA=100)	81.9	80.9	86.8	81.4	95.8	100.0	107.8	113.4	70.1
Adjusted RTK translog per employee (UA=100)	151.0	142.7	126.1	84.2	80.4	100.0	95.2	90.7	213.1
Adjusted RTK/capital input (UA=100)	115.0	116.3	116.9	100.0	82.6	100.0	96.4	92.1	113.3
Adjusted RTK/employee (UA=100)	174.6	143.9	153.2	105.3	80.9	100.0	93.3	102.8	280.6
Adjusted RTK equiv. per wage \$	8.37	9.56	7.63	4.69	2.66	3.26	3.18	2.95	15.07
Adj. RTK equiv. (inc incident) per capital \$	10.52	10.64	10.70	9.15	7.56	9.15	8.82	8.43	10.37
Adj. RTK equiv. (pre incident) per capital \$	9.93	11.41	10.20	9.06	7.44	8.76	8.86	8.12	10.18
Partially adjusted RTK equiv. per capital \$	10.26	9.76	10.70	10.21	9.38	10.18	10.45	11.98	9.40
Unadjusted RTK equiv. per capital \$	10.54	9.46	11.02	9.96	9.57	10.29	10.70	12.10	9.41
Capital share of value added (%)	44.3	47.3	41.6	33.9	26.0	26.2	26.5	25.9	59.2
RTK equiv. per capital and labour (TFP)	9.26	10.06	8.78	5.88	3.49	4.27	4.17	3.87	12.08
TFP index (translog UA = 100)	126	129	113	83	81	100	96	88	125
TFP index (UA = 100)	145	130	137	103	81	100	94	100	164
Adjusted RTKs per aircraft	183.90	89.22	67.57	75.01	33.64	64.76	39.18	26.07	149.19
Average PPP US\$ wage rate	50,718	39,341	47,741	51,561	64,649	69,403	64,240	68,386	48,505
Average Market US\$ wage rate	48,482	42,247	51,689	53,491	64,649	69,403	64,240	68,386	52,505
Lease equiv. (PPP \$) per employee	40,358	32,900	34,837	27,986	26,046	26,589	25,725	29,668	65,834
Adjusted RTKs per employee	424,756	350,029	372,610	256,119	196,880	243,246	226,950	250,077	682,661
Adjusted RTKs per employee (UA=100)	175	144	153	105	81	100	93	103	281
Lease equiv. (PPP \$) per aircraft (m)	8.8	6.0	4.9	6.0	3.0	3.9	2.8	2.9	14.2
Average sector length (km)	2,027	1,839	1,200	1,404	1,906	1,785	1,367	1,456	3,969
Average tonnes per aircraft	36	40	34	32	23	27	23	27	53

Appendix T: Sensitivity tests for airline cross-section analysis

Economic Life: 20 years

	FY ended	KL	BA	LH	AF	AA	UA	DL	NW	SQ	CX	JL
		31/03/2000	31/03/2000	31/12/1999	31/03/2000	31/12/1999	31/12/1999	31/12/1999	31/12/1999	31/03/2000	31/12/1999	31/03/2000
Lease equiv. market value fleet US\$		630	1,800	1,743	1,000	1,863	1,799	1,344	1,064	1,497	1,044	831
Lease equiv. market value fleet PPPUS\$		630	1,800	1,743	1,000	1,863	1,799	1,344	1,064	1,497	1,044	831
Lease equiv. market val. other assets PPPUS\$		103	356	73	80	166	183	211	58	15	109	230
Aircraft lease costs (local)		1,139	190	209	3,208	539	879	584	363	229	231	99,975
Total equiv. lease costs (local)		2,717	1,523	3,563	10,128	2,568	2,861	2,139	1,485	2,794	9,179	217,317
Lease equiv. market val. other assets local		211	236	146	532	166	183	211	58	27	923	37,070
Total equiv. lease costs (PPP US\$)		1,261	2,462	1,929	1,580	2,568	2,861	2,139	1,485	1,647	1,183	1,965
Depreciation (total) local		608	619	n/a	3,833	968	852	1,057	399	1,118	2,727	63,722
Depreciation (fleet) local		429	508	1,098	n/a	741	610	741	299	1,035	2,409	42,730
Flight equip. before deprec.Local: end		10,577	11,251	24,489	62,548	18,041	16,803	14,950	7,507	15,867	55,822	1,327,166
Flight equip. before deprec.Local: begin		10,503	10,756	22,906	62,548	15,249	14,951	12,181	7,282	15,323	54,599	1,343,465
Flight equip. before deprec.Local: average		10,540	11,003	23,697	62,548	16,645	15,877	13,566	7,395	15,595	55,211	1,335,316
Flight equip. after deprec. Local: end		6,213	7,850	12,887	38,818	11,700	12,686	10,091	4,748	8,996	40,018	630,785
Flight equip. after deprec. Local: begin		5,934	7,402	12,418	23,729	9,540	10,781	8,083	4,560	9,142	40,562	631,084
Flight equip. after deprec. Local: average		6,074	7,626	12,652	31,274	10,620	11,734	9,087	4,654	9,069	40,290	630,935
Aircraft market value (US\$m) - low		2,954	17,953	8,672	5,335	8,450	9,360	6,975	6,746	6,907	5,031	3,729
Aircraft market value (US\$m) - high		5,189	10,164	14,047	8,015	17,309	15,305	12,285	11,394	11,290	8,135	7,106
Aircraft market value (US\$m) - estimate		4,367	12,953	12,542	7,061	13,411	12,951	9,673	7,657	10,384	7,241	5,762
Aircraft market value (Local m) - estimate		9,410	8,009	23,168	45,263	13,411	12,951	9,673	7,657	17,618	56,185	637,246
Market over net book ratio		1.55	1.05	1.83	1.45	1.26	1.10	1.06	1.65	1.94	1.39	1.01
Other assets before deprec.Local: end		2,778	2,115	1,500	10,951	2,927	2,991	3,492	1,315	622	8,080	410,402
Other assets after deprec. Local: end		1,606	1,657	1,041	3,621	1,215	1,361	1,822	419	195	6,126	170,830
Other assets after deprec. Local: begin		1,462	1,507	901	3,621	1,176	1,275	1,213	423	146	5,632	182,405
Other assets after deprec. Local: average		1,534	1,582	971	3,621	1,196	1,318	1,518	421	171	5,879	176,618
Other assets after deprec. Local, adjusted		2,377	1,662	1,778	5,240	1,510	1,455	1,615	693	332	8,198	178,384
Total gross assets (local)		13,318	13,118	25,197	73,499	19,573	18,867	17,058	8,709	16,217	63,290	1,745,717
Average aircraft utilisation (block hours)		20.4	9.8	9.8	15.0	14.1	18.3	15.0	9.7	11.7	12.4	15.7
Average age of fleet (years)		9.2	9.0	7.0	8.9	11.0	9.9	12.3	20.1	5.2	7.2	10.0
Overall average load factor (%)		77.3	67.3	71.1	61.7	53.5	57.5	58.2	61.7	71.1	72.0	67.7
Fleet size: average period (total)		116	285	299	212	675	586	580	409	91	75	138
Fleet size: average period (owned)		63	238	243	164	478	343	405	401	92	75	91
RTKs per aircraft (mn)		184.2	79.4	69.6	81.7	42.6	72.8	47.5	37.4	135.4	107.9	143.2
Lease Formula:												
Advance periods		1	1	1	1	1	1	1	1	1	1	1
n (no. years) for fleet		10.8	11.1	13.0	11.1	9.0	10.1	7.7	-0.1	14.8	12.8	10.1
Aircraft economic life		20	20	20	20	20	20	20	20	20	20	20
Interest rate (LIBOR + 0.5%)		6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%

Economic Life: 30 years

	FY ended	31/03/2000	KL	BA	LH	AF	AA	UA	DL	NW	SQ	CX	JL
		31/03/2000	31/12/1999	31/03/2000	31/12/1999	31/03/2000	31/12/1999	31/12/1999	31/12/1999	31/12/1999	31/03/2000	31/12/1999	31/03/2000
Lease equiv. market value fleet US\$		424	1,212	1,174	673	1,255	1,212	1,212	905	717	1,009	703	560
Lease equiv. market value fleet PPPUS\$		424	1,212	1,174	673	1,255	1,212	1,212	905	717	1,009	703	560
Lease equiv. market val. other assets PPPUS\$		69	239	49	54	112	123	123	142	39	10	74	155
Aircraft lease costs (local)		1,139	190	209	3,208	539	879	879	584	363	229	231	99,975
Total equiv. lease costs (local)		2,202	1,088	2,468	7,870	1,906	2,215	2,215	1,631	1,119	1,957	6,259	179,023
Lease equiv. market val. other assets local		142	159	98	358	112	123	123	142	39	18	622	24,973
Total equiv. lease costs (PPP US\$)		1,022	1,759	1,336	1,228	1,906	2,215	2,215	1,631	1,119	1,153	807	1,619
Depreciation (total) local		608	619	n/a	3,833	968	852	852	1,057	399	1,118	2,727	63,722
Depreciation (fleet) local		429	508	1,098	n/a	741	610	610	1,057	299	1,035	2,409	42,730
Flight equip. before deprec. Local: end		10,577	11,251	24,489	62,548	18,041	16,803	16,803	14,950	7,507	15,867	55,822	1,327,166
Flight equip. before deprec. Local: begin		10,503	10,756	22,906	62,548	15,249	14,951	14,951	12,181	7,282	15,323	54,599	1,343,465
Flight equip. before deprec. Local: average		10,540	11,003	23,697	62,548	16,645	15,877	15,877	13,566	7,395	15,595	55,211	1,335,316
Flight equip. after deprec. Local: end		6,213	7,850	12,887	38,818	11,700	12,686	12,686	10,091	4,748	8,996	40,018	630,785
Flight equip. after deprec. Local: begin		5,934	7,402	12,418	23,729	9,540	10,781	10,781	8,083	4,560	9,142	40,562	631,084
Flight equip. after deprec. Local: average		6,074	7,626	12,652	31,274	10,620	11,734	11,734	9,087	4,654	9,069	40,290	630,935
Aircraft market value (US\$m) - low		2,954	17,953	8,672	5,335	8,450	9,360	9,360	6,975	6,746	6,907	5,031	3,729
Aircraft market value (US\$m) - high		5,189	10,164	14,047	8,015	17,309	15,305	15,305	12,285	11,394	11,290	8,135	7,106
Aircraft market value (US\$m) - estimate		4,367	12,953	12,542	7,061	13,411	12,951	12,951	9,673	7,657	10,384	7,241	5,762
Aircraft market value (Local m) - estimate		9,410	8,009	23,168	45,263	13,411	12,951	12,951	9,673	7,657	17,618	56,185	637,246
Market over net book ratio		1.55	1.05	1.83	1.45	1.26	1.10	1.10	1.06	1.65	1.94	1.39	1.01
Other assets before deprec. Local: end		2,778	2,115	1,500	10,951	2,927	2,991	2,991	3,492	1,315	622	8,080	410,402
Other assets after deprec. Local: end		1,606	1,657	1,041	3,621	1,215	1,361	1,361	1,822	419	195	6,126	170,830
Other assets after deprec. Local: begin		1,462	1,507	901	3,621	1,176	1,275	1,275	1,213	423	146	5,632	182,405
Other assets after deprec. Local: average		1,534	1,582	971	3,621	1,196	1,318	1,318	1,518	421	171	5,879	176,618
Other assets after deprec. Local, adjusted		2,377	1,662	1,778	5,240	1,510	1,455	1,455	1,615	693	332	8,198	178,384
Total gross assets (local)		13,318	13,118	25,197	73,499	19,573	18,867	18,867	17,058	8,709	16,217	63,290	1,745,717
Average aircraft utilisation (block hours)		20.4	9.8	9.8	15.0	14.1	18.3	18.3	15.0	9.7	11.7	12.4	15.7
Average age of fleet (years)		9.2	9.0	7.0	8.9	11.0	9.9	9.9	12.3	20.1	5.2	7.2	10.0
Overall average load factor (%)		77.3	67.3	71.1	61.7	53.5	57.5	57.5	58.2	61.7	71.1	72.0	67.7
Fleet size: average period (total)		116	285	299	212	675	586	586	580	409	91	75	138
Fleet size: average period (owned)		63	238	243	164	478	343	343	405	401	92	75	91
RTKs per aircraft (mn)		184.2	79.4	69.6	81.7	42.6	72.8	72.8	47.5	37.4	135.4	107.9	143.2
Lease Formula:													
Advance periods		1	1	1	1	1	1	1	1	1	1	1	1
n (no. years) for fleet		20.8	21.1	23.0	21.1	19.0	20.1	20.1	17.7	9.9	24.8	22.8	20.1
Aircraft economic life		30	30	30	30	30	30	30	30	30	30	30	30
Interest rate (LIBOR + 0.5%)		6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%

Cost of Capital: 8.4%

FY ended	KL	BA	LH	AF	AA	UA	DL	NW	SQ	CX	JL
31/03/2000	31/03/2000	31/03/2000	31/12/1999	31/03/2000	31/12/1999	31/12/1999	31/12/1999	31/12/1999	31/03/2000	31/12/1999	31/03/2000
Lease equiv. market value fleet US\$	560	1,601	1,550	889	1,658	1,601	1,196	946	1,332	929	739
Lease equiv. market value fleet PPPUS\$	560	1,601	1,550	889	1,658	1,601	1,196	946	1,332	929	739
Lease equiv. market val. other assets PPPUS\$	91	316	65	71	148	163	188	52	13	97	205
Aircraft lease costs (local)	1,139	190	209	3,208	539	879	584	363	229	231	99,975
Total equiv. lease costs (local)	2,543	1,375	3,193	9,364	2,344	2,643	1,967	1,361	2,511	8,191	204,363
Lease equiv. market val. other assets local	188	210	130	473	148	163	188	52	24	821	32,978
Total equiv. lease costs (PPP US\$)	1,180	2,224	1,728	1,461	2,344	2,643	1,967	1,361	1,480	1,056	1,848
Depreciation (total) local	608	619	n/a	3,833	968	852	1,057	399	1,118	2,727	63,722
Depreciation (fleet) local	429	508	1,098	n/a	741	610	1,057	299	1,035	2,409	42,730
Flight equip. before deprec. Local: end	10,577	11,251	24,489	62,548	18,041	16,803	14,950	7,507	15,867	55,822	1,327,166
Flight equip. before deprec. Local: begin	10,503	10,756	22,906	62,548	15,249	14,951	12,181	7,282	15,323	54,599	1,343,465
Flight equip. before deprec. Local: average	10,540	11,003	23,697	62,548	16,645	15,877	13,566	7,395	15,595	55,211	1,335,316
<i>Flight equip. after deprec. Local: end</i>	<i>6,213</i>	<i>7,850</i>	<i>12,887</i>	<i>38,818</i>	<i>11,700</i>	<i>12,686</i>	<i>10,091</i>	<i>4,748</i>	<i>8,996</i>	<i>40,018</i>	<i>630,785</i>
<i>Flight equip. after deprec. Local: begin</i>	<i>5,934</i>	<i>7,402</i>	<i>12,418</i>	<i>23,729</i>	<i>9,540</i>	<i>10,781</i>	<i>8,083</i>	<i>4,560</i>	<i>9,142</i>	<i>40,562</i>	<i>631,084</i>
<i>Flight equip. after deprec. Local: average</i>	<i>6,074</i>	<i>7,626</i>	<i>12,652</i>	<i>31,274</i>	<i>10,620</i>	<i>11,734</i>	<i>9,087</i>	<i>4,654</i>	<i>9,069</i>	<i>40,290</i>	<i>630,935</i>
Aircraft market value (US\$m) - low	2,954	17,953	8,672	5,335	8,450	9,360	6,975	6,746	6,907	5,031	3,729
Aircraft market value (US\$m) - high	5,189	10,164	14,047	8,015	17,309	15,305	12,285	11,394	11,290	8,135	7,106
Aircraft market value (US\$m) - estimate	4,367	12,953	12,542	7,061	13,411	12,951	9,673	7,657	10,384	7,241	5,762
Aircraft market value (Local m) - estimate	9,410	8,009	23,168	45,263	13,411	12,951	9,673	7,657	17,618	56,185	637,246
Market over net book ratio	1.55	1.05	1.83	1.45	1.26	1.10	1.06	1.65	1.94	1.39	1.01
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Other assets after deprec. Local: end	1,606	1,657	1,041	3,621	1,215	1,361	1,822	419	195	6,128	170,830
Other assets after deprec. Local: begin	1,462	1,507	901	3,621	1,176	1,275	1,213	423	146	5,632	182,405
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Other assets after deprec. Local: adjusted	2,377	1,662	1,778	5,240	1,510	1,455	1,615	693	332	8,198	178,384
Total gross assets (local)	13,318	13,118	25,197	73,499	19,573	18,867	17,058	8,709	16,217	63,290	1,745,717
Average aircraft utilisation (block hours)	20.4	9.8	9.8	15.0	14.1	18.3	15.0	9.7	11.7	12.4	15.7
Average age of fleet (years)	9.2	9.0	7.0	8.9	11.0	9.9	12.3	20.1	5.2	7.2	10.0
Overall average load factor (%)	77.3	67.3	71.1	61.7	53.5	57.5	58.2	61.7	71.1	72.0	67.7
Fleet size: average period (total)	116	285	299	212	675	586	580	409	91	75	138
Fleet size: average period (owned)	63	238	243	164	478	343	405	401	92	75	91
RTTs per aircraft (mn)	184.2	79.4	69.6	81.7	42.6	72.8	47.5	37.4	135.4	107.9	143.2
Lease Formula:											
Advance periods	1	1	1	1	1	1	1	1	1	1	1
n (no. years) for fleet	15.8	16.1	18.0	16.1	14.0	15.1	12.7	4.9	19.8	17.8	15.1
Aircraft economic life	25	25	25	25	25	25	25	25	25	25	25
Interest rate (LIBOR + 0.5%)	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%