The Airline Industry

Challenges in the 21st Century

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...a Cristina, Ester, Marco e Luca, l' essenza della mia vita...

Preface

The debate on the future of the aviation sector and the viability of its traditional business practices is the core of this book. The liberalization of the EU market in the 1990s has radically modified the competitive environment and the nature of airline competition. Furthermore, the new millennium began with terrorist attacks, epidemics, trade globalization, and the rise of oil prices, all of which combined to push the industry into a "perfect storm".

Airline industry profitability has been an elusive goal for several decades and the recent events has only accentuated existing weaknesses. The main concern of industry observers is whether the airline business model, successful during the 1980s and 1990s, is now sustainable in a market crowded by low-cost carriers. The airlines that will respond rapidly and determinedly to increase pressure to restructure, consolidate and segment the industry will achieve competitive advantages. In this context, the present study aims to model the new conduct of the 'legacy' carriers in a new liberalized European market in terms of network and pricing competition with low-cost carriers and competitive reaction to the global economic crises.

The current evolution of the aviation sector in Europe can be described in terms of the combination of two main factors: (1) the liberalization process which began in the EU during the 1990s and the succeeding boom of the low-cost carriers. This has changed the nature of competition, as new entrants or potential entrants have different business models, especially concerning the network organization; and (2) the set of specific exogenous factors such as terrorism, epidemics, trade globalization, and the rise of oil price.

The traditional model that was successful during the 1980s and 1990s is evolving in a market where there is fierce competition from the low-cost carriers. The low-cost carriers have had a serious impact on the airline industry, but the extent and nature of this effect have been largely regionalized. The concept of 'low-cost carrier' originated in the United States with Southwest Airlines at the beginning of the 1970s. In Europe, the Southwest model was copied in 1991, when the Irish company Ryanair, previously a traditional carrier, transformed itself into a low-cost carrier and it was followed by other low-cost carriers in the UK (e.g. easyJet in 1995). In the literature, there are several similar definitions of a low-cost carrier, also known as a ‘low fare’ or ‘no-frills’ airline, which is described by core characteristics that seem to be common to the majority of the low-cost models. These are high aircraft utilization; Internet booking; use of secondary airports; minimum cabin crew; lower wage scales; lower rates of unionization among employees; one class of seating; short ground turn-around times; no cargo carried; very simple fare structures and price strategies; adoption of strict yield management techniques; e-ticketing; often no seat allocation (for faster boarding); no frills, i.e. the passengers having to pay for food and beverages; no connections; point-to-point services. It should be noted that this increased competition in the aviation sector led the traditional airlines to adopt some of the characteristics of the low-cost airlines in an attempt to better survive in this new deregulated environment.

This book represents a revised version of my PhD thesis. The original decision to start researching the observed phenomena in airline economics was based on two motivations: my passion for aviation and the great positive influence of a few outstanding persons whom I have met during the course of my life. My passion for aircraft and flying began as a childhood dream, and today in writing this book I am still living the dream. First, I would like to thank Prof. Aura Reggiani. She introduced me to the international academic arena by offering me the opportunity to work at the University of Italian Switzerland in Lugano. With her intellectual stimulation and pragmatic and tenacious attitude, she convinced me to publish my thesis as a book.

Aura also introduced me to Prof. Peter Nijkamp and Prof. Piet Rietveld. They agreed to promote my thesis despite my busy agenda with KLM Royal Dutch Airlines, and I could not have had better supervisors. I would like to thank Peter and Piet for the style, quality and efficacy of their supervision. At every meeting or work session and in emails, they never forgot to add inspiring and encouraging words to their indescribable professionalism and scientific knowledge. Even their tacit criticism was motivating and aimed at getting the best out of me. I was impressed by Peter because, in just two lines of comments, he identifies and solves issues, and by Piet because he is always right when commenting on mathematical or econometric models.

Dr. Marco Alderighi of Milan Bocconi University and Valle D’Aosta University was a great help. He closely followed all my work and contributed actively. His intuitions, innovative ideas and collaboration have made my thesis a better work. I consider Marco one of the most intelligent young researchers I have ever met in my life. Above all, I have found a friend whom I will never forget.

KLM Royal Dutch Airlines has been my employer for the last eight years and has provided me with the facilities to finalize the book successfully. In particular, I would like to thank Anton van Dasler, Domingo De Cola, Hester Bruijninckx, Peter Bootsma, Paul Gregorowitsch, Just Kerckhoff, Toon Balm, Harm Kreulen, all the staff at the Revenue Management Department in Amstelveen, and my colleagues in the KLM Italian office, from whom I have learned the best business practices of the airline industry and some of the “secrets of KLM success”. A ‘thank you’ to Patricia Ellman, who took care of the English correction with incredible speed and quality. Thanks also to Dr. Eric Pels and Dr. Oliviero Baccelli who offered me the opportunities to organize a few workshops with the students of the Free University of Amsterdam and Milan Bocconi University.

Finally, Cristina, my love, and our children Marco, Ester and Luca. Words are not enough to describe the strength you were able to give me. There were uncountable nights and week-ends when I could hear Cristina singing a lullaby to our little ones while I was busy writing a new section. A special thank you for your patience and your faith in me, that helped this flight arrive at its final destination.

Milan, Italy *Alessandro Cento*
12 May 2008

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Introduction

"If the facts don't fit the theory, change the facts."

Albert Einstein

1.1 The 'Old Industry'

From the mid-1990s to the beginning of the new millennium, the aviation industry faced one of the biggest booms in its history. Worldwide increases in GDP, riding on the wave of the new economy, and a greater demand for travel resulting from globalization stimulated the airlines to healthy growth of around 4–6 percent per year. However, this tendency was not continued in subsequent years. At the beginning of 2000, the economic slowdown brought an end to the growth phase, and the terrorist attacks of 11 September 2001 and the SARS virus in 2003 exacerbated the situation. In 2004, the airline industry probably faced the most difficult period of its existence.

The uncertainty about the future was clearly expressed in the official press releases of KLM President and CEO Leo van Wijk after the 11 September terrorist attack (Wijk 2001):

> ...many passengers are cancelling their reservations and we can expect diminishing load factors as a result. Demand is diminishing on various intercontinental routes and I do not expect this to change in the near future... (www.klm.com).

Similarly, on 19 September 2001, Lufthansa CEO Jurgen Weber officially announced (Weber 2001):

> ...there is uncertainty about the length and effect of the crisis and the future developments in the aviation industry (www.lufthansa.com).

There has always been a fundamentally precarious balance within the industry between profit generation and loss. One of the biggest exceptions to this rule occurred during the 1990s, when the global economic upturn boosted travel demand.

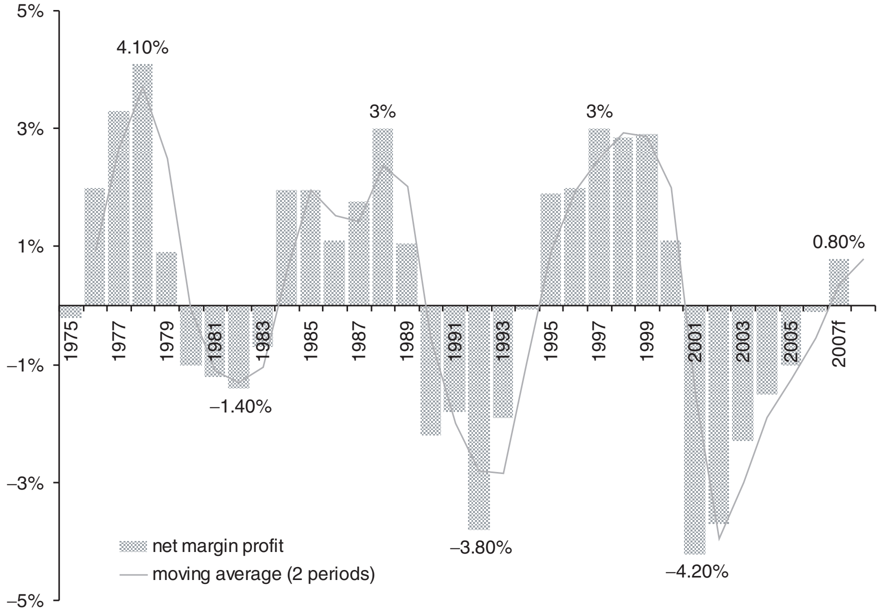

Fig. 1.1 Net margin profits of the world-wide airline industry (Source: ICAO and IATA forecasts 2006–2007)

Furthermore, the major airlines gained from the new economy in terms of computer technology progress, which enables new business processes such as 'network management' or 'yield management', e-commerce and e-services to be supported.[1] Quantitative analyses permitted the improvement of demand forecasting and the optimization of seats supplied in the network (Fig. 1.1).

Nevertheless, during these years, a group of airlines, known as low-cost carriers, were able to generate profits and positive growth by generating a cost advantage, no frills, and a point-to-point network business model, in contrast to the traditional hub-and-spoke national flag carriers. Nowadays, the low-cost business model is quite popular and is advocated as an alternative, or sometimes as a complement, for the traditional airline business model, which, on the contrary, aims to cover all market segments and city-pairs, and these airlines are therefore now named 'full-service carriers'.

The market deregulation in the United States in 1978 mainly affected the network strategy of carriers. In the period that followed, a number of 'trunkline' carriers rapidly reorganized their network structures from a point-to-point (PP) system into a hub-and-spoke (HS) system.[2] The second effect of the deregulation on the network

[1] Some examples of e-services are e-ticketing and Internet check-in.

[2] According to Reynolds-Feighan (2001), this reorganization took place between 1978 and 1985. Many authors (see, e.g., Borenstein, 1989; Berry, 1994; Button et al., 2000; Oum et al., 1995; Burghouwt, 2003) put much effort into explaining the reasons for the change and the advantages

strategy was the use of the PP system by low-cost airlines such as Southwest Airlines. About 10 years later, the EU deregulation process produced similar results, although its effect on the market was not so radical. The European carriers had already concentrated intercontinental flights into an HS structure, while they developed a mixed HS and PP network for shorter distances (national and international flights).

The objective of the HS network design is the maximization of the number of city-pairs to cover all traffic segments (business and leisure). An HS network design focuses on the connectivity within hubs which is typically implemented by concentrating the flights’ landing and take-off time at the hubs (hub waves). The wave design determines the connectivity of the outbound and inbound flights. The disadvantages of the HS strategy are: the lower quality service to the passenger (who would normally prefer direct flights); and an increase in operational costs for the airline. Indeed, these waves create peak times in the hubs and, consequently, congestion with possible delays, including missed connections.

The business innovations that boomed in the second half of the 1990s were the alliances and commercial partnerships, which developed into three main global alliances (Sky Team, One World, Star Alliance). A certain value for the passengers (interlining[3]) as well as some scale effects for the airlines, made these alliances quite successful.

1.2 The ‘New Industry’

In the last quarter of 2000, the fundamentally precarious balance between revenue and cost (per available seat-kilometre) turned negative. The crisis initially started as demand slowdown followed by the cost impact of overcapacity from the supply side. Different from the situation for airlines during the Iraq war in 1991, five additional factors turned the crisis into a “perfect storm” for global aviation (Franke 2004):

1. The crisis of 2000 started at the time of a positive peak just before an economic downturn (in 1991–92 the crisis occurred at an inverse peak just before an upturn in the global economy).
2. The terrorist attacks of September 11 generated fear of air travel and constituted an exogenous demand shock.
3. The 2003 Iraq war, together with the SARS epidemic, caused a second exogenous demand shock.
4. The full-service carriers were making few business innovations compared with the network and yield management practices developed in the 1990s.

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of carriers. Above all, it was emphasized that both trunk and regional carriers adopted the HS structure to exploit the dominant position of the hub and the cost advantages of a centralized network, such as economies of density and scale.

[3] ‘Interlining’ means the use of more than one airline for a journey.

5. The Third Package of EU deregulation was applicable from 1997. One of its consequences was the boost to the low-cost carrier development as an attractive alternative for price-sensitive clients during the period of economic downturn and fears about intercontinental journeys.

The low-cost business model was developed in the early 1970s in the US (from Southwest Airlines) but it was only after more than 20 years that the analysts and airline practitioners started considering it as a serious threat to the full-service model. Nevertheless, it was initially perceived only as a regional phenomenon, limited to the US or the United Kingdom and to a successful separate niche market, characterized by passengers with low willingness-to-pay and connecting secondary city-pairs. But nowadays, the scenario has changed. The low-cost carriers experienced fast growth after 1999 (see Fig. 1.2[4]) and often compete with the full-service carriers on the same routes and for coincident segments.

However the low-cost airline models have evolved differently per continent while the traditional airlines have responded to the low-cost competition by reducing costs despite continuing to lag far behind the low-cost model.

Francis (2006) highlighted some of the factors that have acted as catalysts for the development of low-cost carriers. These factors are the following:

- Deregulated markets
- Entrepreneurs

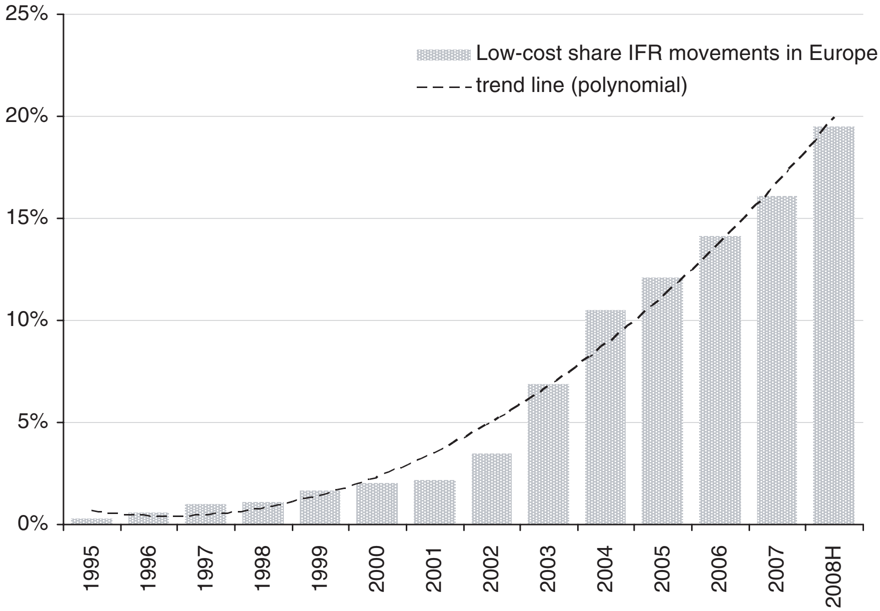

Fig. 1.2 Growth of low-cost carriers in Europe (Source: EUROCONTROL 2007)

[4] EUROCONTROL is the European Organization for the Safety of Air Navigation.

- Population and relative wealth
- Airport availability/capacity sold cheap and free of congestion to allow intensive operations
- Internet diffusion in order to ease sales, simple tariff price transparency, circumnavigation of travel agent control of distribution channel

Francis identified a strong relation between the intensity of these factors and the development of local societies. This is a determinant for the position of the different countries and continents in the market development life cycle of low-cost airlines. Table 1.1 compares the life cycles of these services across the world as presented in a study of the European Parliament’s Committee on Transport and Tourism.

Market liberalization has been an indispensable condition for the introduction of low-cost airlines in all geographical contexts but by itself this is far from being sufficient to encourage their evolution over the life cycle indicated in Table 1.1. On the other hand it is doubtful whether without sufficient levels of the catalytic factors, the authorities would have introduced the market deregulation present nowadays in Europe and US.

The competitive pressure associated with the evolution of low-cost models affected the traditional airlines models. Their reaction was to tend to adopt cost-cutting strategies as they were driven to adopt some of the characteristics of the low-cost airlines in an attempt to survive in this new deregulated environment.

Before the liberalization, the limited scope of the alliances developed in the 1990s, together with the high coordination costs and the unwillingness to merge further, meant that major cost reduction potential was not fully realized. It is questionable whether the commercial alliances helped to prepare the full-service carriers for the economic crises and the low-cost challenge. Nevertheless, the new century began with a phase of EU airline consolidation through mergers and acquisitions. KLM Royal Dutch Airlines acquisition by Air France in 2004 showed its competitors what can be achieved with greater scale in the highly fragmented industry.

Table 1.1 Market developments of low-cost airlines (Source: European Parliament Study 2007)

Life cycle stage			Europe				
	USA	CANADA	UK	Mainland	East Europe	ASIA	Rest of the world
1. Innovation	▲	▲	▲	▲	▲	▲	▲
2. Proliferation	▲	▲	▲	▲			▲
3. Consolidation	▲	▲	▲	▲			
4. 2nd phase of entrants	▲						
5. Consolidation	▲						
6. Market maturity	▲						

1.3 The Objective of this Study

In the aviation industry various actors such as authorities, airports, airlines and passengers combine to determine the endogenous dynamics. These dynamics, together with the exogenous forces, affect the airline strategy and business organization. The current evolution of the aviation sector in Europe can be described in terms of the combination of two main factors: (1) The liberalization process which started in the EU during the 1990s and the succeeding boom of the low-cost carriers. This process has radically modified the competitive environment where traditional airlines operate. The market contestability has increased, as demonstrated by the increased number of competitors or potential competitors on the different routes. The nature of competition has changed, as new entrants or potential entrants have different business models, especially concerning the network organization (i.e. the low-cost carriers); (2) Specific exogenous factors such as terrorism, epidemics, and globalization have pushed the aviation industry into a 'perfect storm'. There is need for a debate on the future of the aviation sector and the survivability of the evolution of the business models. The main concern is how the traditional model, successful during the 1980s and 1990s, is evolving in a market crowded by low-cost carriers.

> The objective of this study is to analyse the new strategic conduct of the full-service carriers (or legacy carriers) in a more liberalized European market in terms of how they have coped with global economic crises and increased competition with low-cost carriers.

To accomplish this objective, three important research questions are addressed:

- How can *full-service carriers* react in the short-term to survive the global crises and still maintain a long-term network strategy? Specifically, how did the European carriers cope with the recent global crises?
- How do the *full-service carriers* compete in pricing, and how did they react to the low-cost carrier' entry?
- Is the *hub-and-spoke* configuration still a possible network strategy when competing with point-to-point network operations? Can we empirically detect the network design of European carriers?

The study opted for a systemic analysis to the air transport sector and develops along two parts as presented in Fig. 1.3. Part I (Chaps. 1 and 2) provides a brief analysis of the main characteristics and changes in the aviation sector, mainly from the supply side, which have followed the market deregulation. The deregulation effects on the industry have been broadly analysed by several authors looking specifically at the effect on one aspect or another of the industry, such as network development, pricing behaviour, airlines-airports relations, and alliances. We briefly present all these elements in the new perspective, that of the airlines strategy and business model. Indeed, after the deregulation we can identify three main categories of airline business models (despite the model variants within each category are several): full-service carriers, low-cost carriers and charter carriers. Thus, in Chap. 1 we attempt to provide a concise but complete panorama of the key elements of each category of business model emerging after the EU deregulation. This chapter represents the

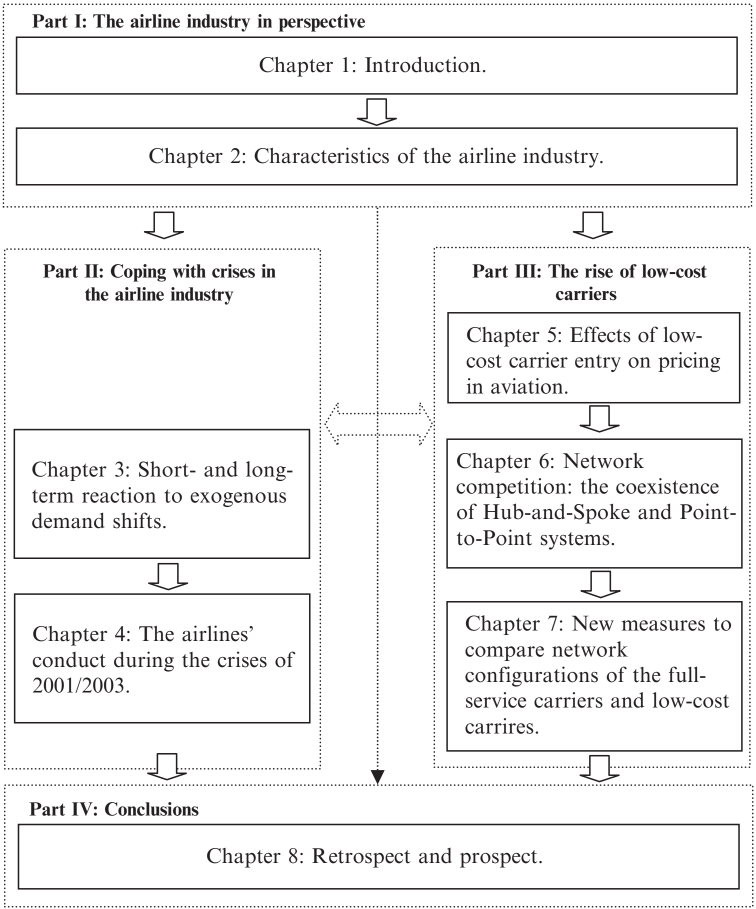

Fig. 1.3 Outline of the book

background of the research. Part II is dedicated to the first research questions from both an empirical and a theoretical perspective. Two terrible events have characterized the world economy: the September 11 terrorist attack on the Twin Towers in New York and on the Pentagon in Washington in 2001, and the SARS epidemic in East Asia which began in February 2003. These events have produced two dramatic crises. By analysing these two important demand shifts, we are able to detect some determinants of the full-service carriers' conduct. The idea behind our approach is simple and innovative. It is simple because we think that the carriers should have the same conduct during the crisis as during the no-crisis period, i.e. profit maximization. It is innovative—we believe—for at least two reasons.

The first reason is that the survivability maybe addressed at first glance as a short-term problem and therefore can be solved by maximizing the short-term profit. However, we think that the carrier conduct should be modelled in terms of both the short- and the long-term profit maximization problem. This approach is supported by the assumption of the presence of *adjustment costs*: that is, carriers encounter costs in changing the network configuration, so that their choice to close a route and re-open it after the crises is both a short- and a long-term decision. The adjustment costs also induce carriers to behave strategically, a carrier that increases (or decreases) its capacity during the crisis period, forces its competitor to reduce its capacity offer in the post-crisis period. This phenomenon is known in the literature as *pre-emption*. The combination of adjustment costs and pre-emption provides an indication of the network flexibility of the carrier to adapt to the new market situations (of both crisis and no-crisis).

The second reason why our approach is innovative is that the maximization problem is presented in a dynamic game-theoretical framework organized into three stages, which are a time-continuous sequence of periods (pre-crisis, crisis, post crisis). From an empirical point of view (Chap. 4), we test the outcomes of our game theory model by measuring the variation in the carrier's capacity supply and explaining it by an econometric model based on two variables: the passenger reduction due to the shock, and the carrier's expected profitability of the market.

Part III is dedicated to answering the third and fourth research questions, i.e. the reaction of the full-service carriers to the entry of the low-cost carriers. Specifically, in Chap. 5 we investigate how the full-service carriers price-compete and respond to the low-cost carrier entry. We develop a theoretical model of airline competition, which accommodates various market structures, some of which include low-cost players. The framework is based on the recent literature on product differentiation in oligopolistic markets. We can identify two approaches to this problem in the literature: the traditional one, which models the firm's demand as a function of prices and assumes no interdependencies among markets, i.e. business travellers do not demand the leisure products and vice-versa; and the approach of Wilson (1993), Rochet and Stole (2002) and Dessein (2003) who all develop a model with market interdependencies and where the firm's demand is expressed in terms of utility levels provided to consumers by the firms.

Our model differs from the previous ones as it sets the problem in the traditional form (i.e. in terms of prices), but it takes into account the market interdependencies. This simplification is possible because we assume that qualities are exogenously determined as in traditional oligopolistic models. Hence, we arrive at our intermediate position between the traditional modelling approach and the one proposed by Wilson and others.

Moreover, we introduce the assumption that the customers are horizontally and vertically heterogeneous, i.e. in real terms different passengers live at different distances from the airports and they are sensitive to product qualities such as business and economy service. The outcomes of this model are the price equilibria for different market structures and segments (business or leisure). These results are tested by an econometric analysis based on a sample of monthly data on city-pairs routes from Italy to three European countries (Germany, the UK, and the Netherlands) including airfares for four different carriers (Alitalia, Lufthansa, British Airways and KLM). Differently from what is done in other research studies, where price dispersion or average prices has been analysed,[5] we perform our econometric estimation on the basis of eight market segments (six in economy class and two in business class) and four market structures (monopoly; symmetric duopoly; asymmetric duopoly; and asymmetric oligopoly[6]).

Chapters 6 and 7 deal with the fourth research question. We compare the full-service carrier with the low-cost carrier business model in terms of their network configuration. In Chap. 6, we approach the problem from the theoretical perspective of a carrier that has to decide its best network strategy. In the literature this problem is often presented as a single carrier that maximizes its profit (or it minimizes its costs). We propose to examine the problem with a game-theory approach where different carriers play their strategy depending on the possible strategy of the competitors. We assume that the carriers play three different network strategies: point-to-point (PP), hub-and-spoke (HS), or multi-hub (MH), and we identify the conditions under which Nash asymmetric equilibriums may exist, i.e PP with HS or PP with MH. We further discuss how the outcomes of the model can be used to describe the observed coexistence of different network configurations.

Finally, the airline network configurations are empirically assessed in Chap. 7 with the aim of effectively representing the complexity of modern carriers' network design and, if possible, accounting for differences between low-cost carrier and full-service carrier networks in Europe. This is a relatively new research attempt in terms of empirical methodology, with only a few notable previous exceptions. We explain why it is a new contribution. Reynolds-Feighan (2001) identified the HS configuration of a carrier when there is a high concentration level of air traffic in both space (geographical dimension) and time (temporal dimension) by coordination of the timetables. However, while a substantial number of research studies on airline network configurations have focused on the spatial dimension, only a relatively small number of empirical studies have attempted to measure the temporal dimension of airline networks, see, e.g., Rietveld and Brons (2001); Veldhuis and Kroes (2002).[7]

Traditional analyses of airline networks have measured the network configuration by means of concentration indices of traffic or flight frequency (Caves et al. 1984; Toh and Higgins 1985; McShan 1986; Reynolds-Feighan 1994, 1998, 2001; Bowen 2002). These methodologies have mainly addressed the issue of describing and classifying networks in terms of measures of geographical concentration. These measures, such as the Gini concentration or Theil index, provide a measure of frequency or traffic concentration of the main airports. When a network structure is complex (as in reality), including multi-hubs or a mixed PP and HS strategy, the concentration indices record high values for all types of structure but fail to discriminate clearly between different network shapes.

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[5] See Borenstein (1985); Berry (1994); Borenstein and Rose (1994); McManus (2001); Macskási (2003).

[6] For an explanation of these types of market, we refer to Sect. 5.2.2.

[7] Burghouwt and de Wit (2003) present a remarkable literature review and classification of previous studies based on the network configuration definitions and methodologies presented by the various authors.

The temporal dimension has been analysed by, for example, Veldhuis (1997), Bootsma (1997) and Burghouwt and de Wit (2003), who calculated connectivity indexes (wave structure quality) at the hubs airport, e.g. the weighted in connection index.

Our study follows the Reynolds-Feighan definition of network configuration and therefore empirically assesses both the spatial and the temporal and combines them in one complete description of the network configuration.

Moreover, we apply two alternative empirical methods originating from social network analysis and which, to date, have never been used in the transport economics literature. These methods are in the Freeman index and what is named the Bonacich approach, which both seem to produce more meaningful results than the Gini concentration index concerning their capability to detect the geographical shapes.

Part V provides the conclusion of the study. The answers to the research questions are discussed and the results of our studies are proposed as stepping stones to point the way to new research directions.

Chapter 2
Characteristics of the Airline Industry

The real difficulty in changing any enterprise lies not in developing new ideas, but in escaping from the old ones.

John Maynard Keynes

2.1 Introduction

In recent years, the European airline industry has exhibited impressively dynamics. The sector has gone through a drastic change on both the supply and the demand side. Unlikely in other industries, the driving forces governing the recent changes do not depend mainly on technological factors, but on developments in the legal, institutional, and cultural domains. Legal and institutional aspects have clearly affected the structure of the market, while cultural forces have influenced spatial mobility and its *characteristics*.

On the supply side, we observe that only a few industries have faced changes as dramatic as those that have occurred in the European airline industry in the past 20 years. Over this time period, the industry has evolved from a system of long-established state-owned carriers operating in a regulated market to a dynamic, free-market industry. Before the deregulation, only one or two flag carriers operated the European routes, with airfares being regulated by state bilateral agreements.

The process of deregulation and the subsequent process of privatization have induced important changes in the structure of the airline market.

This chapter presents a concise analysis of the main *characteristics* and *changes* in the aviation sector, mainly from the supply side, which has followed the deregulation.[1] The aim is to draw a new profile of the airline industry in terms of new airline business models and compare their characteristics in a way which has rarely been presented in the literature to date. Section 2.2 describes the deregulation of

[1] This chapter mainly attempts to describe the European market but draws parallels with other markets. Thus, some elements of the description can easily be generalizable to other markets.

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the EU aviation market and part of the relevant literature. The discussion mainly concerns its effects on the airlines' strategies and how they have consequently reorganized their models. In Sect. 2.3 these new models are described, with particular emphasis on network, pricing, and alliances. These three elements are discussed more in-depth in Sects. 2.4, 2.5 and 2.6, respectively. Section 2.7 concludes this analysis and introduces Parts II and III of this study.

2.2 Market Deregulation

At the Chicago Convention in 1944, 52 state members[2] discussed some forms of agreements in order to regulate: (1) capacity and frequency; (2) airfares; (3) freight levels; and (4) the application of the traffic rights or 'air traffic freedoms'.[3]

The Convention also established the International Aviation Organization (ICAO), i.e. an inter-governmental agency responsible for the coordination of worldwide technical and operational standards. The four regulatory elements together were able to effectively reduce the entry of new carriers, the pricing freedom, and the production levels, and therefore they limited any form of price or network competition. International carriers such as KLM or Lufthansa defined their international strategy depending on a set of bilateral service agreements (known as 'bilaterals') between the government of their country of aircraft registration and the destination country. The bilateral agreements specified the traffic rights for each operating carrier, the number of airports in which they operate, the number of carriers, and the frequencies of flights between the fixed airports. Those airlines were, in practice, the national flag carriers of each country (state-owned). Since 1947 the International Air Transport Association (IATA) has had the authority to set the ticket prices charged by international airlines at the worldwide international IATA conference.[4] The national carriers, national governments, and the national airports dominated international air-transport until 1978.

In 1978, the United Stated domestic market started to become liberalized. In the 1980s and 1990s many international bilateral agreements were changed (see Doganis 2001). Almost 25 years after the US market deregulation, Anderson et al. (2005) identified the major changes produced in the US market. Those changes include the entry of the low-cost carriers, waves of mergers among the major carriers, rapid growth in the number of air travellers, general decline of airfares, increased variability in fares across the market, and the emergence of the HS system. Anderson provides evidence on the nature of the competition in the

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[2] The national government involvement in the development of the airline industry was decided in the Paris Convention in 1919, where the allied countries after the First World War decided that nation states would have sovereignty on their own airspace.

[3] See Appendix I for the complete list of 'Freedoms of the Air'.

[4] The International Air Transport Association was founded in Havana in 1945. Its main purpose was to represent the interests of airlines and counterweight the ICAO. Tariffs come to be regulated by the IATA.

post-deregulation US market. The study presents a historical review of the US market since deregulation, and then develops an econometric model of domestic air fares in order to investigate how the level of competition, the low-cost carrier entry, or the HS systems affect the airfares of a particular route or airport. The paper concludes that airfares decreased in US as a result of higher competition and the low-cost carrier entry. However there was also found to be a ‘hub effect’, i.e. the carrier applies a price premium on the traffic originating from its main hubs.

Following the lead of the US, the European deregulation began about 10 years later. Three policy ‘packages’ were agreed in 1988, 1990 and 1993, and full deregulation came into force in 1997. The Third Package[5] was the most important one as, by then, pricing capacity and access were fully deregulated. Within the EU, airlines could now operate between two other Member States via their home country (the ‘Sixth Freedom’ defined by the Chicago Convention) and even operate domestic flights within other European Member States (the ‘Seventh Freedom’ or cabotage right). The carriers can compete freely on routes, frequencies, prices, and service levels. In addition, previous limitations on cross-border mergers within the EU were removed. Thus, the old state-owned carriers, which belong to single countries, can be replaced by a broader private ownership structure, despite the national borders. However, much of the extra-EU network is still regulated by bilateral agreements and this still has a significant impact on the network structure of the carriers.

The deregulation effects on the industry have been broadly analysed by several authors in terms of network development, pricing behaviour, airlines-airports relations, and alliances. Some examples are Borenstein (1989, 1992); Dresner and Windle (1995); Button et al. (2000); Oum et al. (2000); Pels (2000); Schipper (1999) and Barrett (2004).

In the US, the deregulation has resulted in two main effects on network strategy. First, a large number of ‘trunkline’ carriers have reorganized their network structures from a point-to-point (PP) system into a hub-and-spoke (HS) system. Second, (see Gillen and Morrison, 2003) there has been an increase in the adoption of PP systems by low-cost, no-frills airlines such as Southwest Airlines.

In the EU, the deregulation produced a slow and rather small effect on routes and fares (see Brueckner and Pels, 2003) in the initial stage, but during the late 1990s the changes gradually became bigger. The first change was the rise of the international airlines’ alliances. The reasons behind the emergence of alliances are demand-related (i.e. the economic globalization has created demand for intercontinental flights) and supply-related (i.e. long intercontinental flights need one or more stop and require an interline journey provided by different airlines). A brief analysis of the economic factors behind the alliances’ development is presented in Sect. 2.6. The second effect was the further development of the HS strategy by the former flag carriers. The HS configuration was already the predominant structure in Europe before the deregulation. However, Brueckner and Pels (2003) questioned whether these networks were functioning in the HS manner. Their answer was that, despite their radial configuration, they mainly functioned as PP networks but without the

[5] See, e.g., Starkie (2002); Chang and Williams (2002).

relevant volume of connecting traffic. The main reason for this was that, given the geographical size of the European countries and the fact that the flag carriers were connecting all major cities with price and capacity regulated by bilateral agreements, the potential for connecting traffic within Europe was limited.

At an earlier stage of the EU deregulation, Berechman and de Wit (1996) addressed a potential deregulation effect which still seems to be still latent in the market. Their research question was: '…in a profit maximizing environment if airlines are free to enter and exit the market, design their networks and set fares and level of services, which West European airports will they favour as their main hub?…'. The study was carried out in 1996 when the EU liberalization was not yet finalized but one of its conclusions was that the airlines would intensify the use of the HS system and would select a specific hub so as to maximize their profits.

Berechman and de Wit concluded that, in the immediate future, national carriers in the EU will continue to operate in their national home base for a substantial part of their products, but they will probably take the opportunity of a liberalized market by developing a secondary Euro-hub complementary to their national hub. Finally a concentration in the internal market will take place thus creating room for enhanced HS operations. While the concentration and development of the HS system is widely documented as the main effect of deregulation, the selection of a specific hub by airlines is not evident. Most of the carriers still have their hubs in their original country. However, this aspect raises the questions whether the EU deregulation has effectively created sufficient market liberalization, as simulated by the Berechman and de Wit model or whether it was able to diminish the role of hubs as entry market barriers.

The third effect was the growth of low-cost carriers such as Ryanair and easyJet. They experienced fast growth after 1999 and often compete with full-service carriers on the same routes and for coincident segments, and they did not suffer as much from the crisis in the air transport industry after September 11, this is because the low fare levels still attract many passengers, and the air travelling public's fearing of flying to sensitive regions (North America and Asia) diverted passengers to fly intra-Europe.

The deregulation and the increased competition have reduced the air fares. Thus some effects on the charter operations are possible given that the gaps between the charter fares and the scheduled low-cost carrier fares are being reduced.

2.3 The Open-Skies Agreement between the EU and the US

On 30 March 2008, the most ambitious air service deal ever negotiated, took effect. European airlines can now fly without restrictions from any point in the EU to any point in the US. The new EU–US agreement is expected to increase competition and reduce the airfares in the biggest international air transport market.

The Open-Skies agreement contains numerous positive elements but *three key elements* seem decisive in the future of the worldwide air traffic.

1. *Recognition of all European airlines as 'community air carriers'*: All European companies are classified identically without discrimination based on their country of origin (if in the EU).
2. *Flights now possible between any point in the EU to any point in the US*: the airlines will be able to fly from any European airport to any US destination.
3. *Flights now possible beyond the US towards third countries*: European companies will also be allowed to go beyond the US and provide destinations using the US as a stopover. With respect to the operation of cargo flights between the US and third countries: freight will follow the same above-mentioned rules as passenger traffic.

This will allow flights from any European airport to any US airport with any European or US company. This major improvement will equalize the rights of all EU Member States which previously did not have a bilateral agreement with the US and thus enhance the destination possibilities for many Europeans.

Some other key factors of the agreement provide for cooperation in fields such as security, safety and environment.

1. *Security*: The EU and the US will work towards compatible standards and practices for entering territories in order to facilitate air regulation.
2. *Safety*: A consultation procedure will be set up to consider safety concerns on either side, and there will be recognition of the development of safety responsibilities at EU level.
3. *Environment*: The US airlines may be subject to taxation of aviation fuel on routes between Member States.

This agreement represents only a first step in the process of metallization of the European and US sky. Both the EU and US agreed to engage a second phase of negotiations after May 2008 aimed at tackling the following issues: facilitating foreign investments; fostering the development of liberalization. Indeed the deal leaves in place *some key limitations*:

1. *Ownership and the control of the airlines*. Foreign entities remain limited to owning no more than 25 percent of the voting shares in a US carrier—49 percent in an EU carrier—and foreigners can not exercise actual control on US carriers.
2. *The US domestic market remains entirely closed* to foreign airlines, and cabotage in the US remains prohibited under the 'Fly America' policy.

Most important of all, the US carriers will finally enter London Heathrow, the key getaway airport in Europe for the US to full compete with the EU carriers.

2.4 Airline Business Models

The emerging forms of business models in the airline industry are presented in terms of how the carrier generates revenue, its product offering, value-added services, revenue sources, and target customers.

The deregulation and new competitive interactions between firms always result in some adjustment of the player's own business model to that of the competitor.

Three main sets of airline business models that will be described in the next sections are:

1. Full-service carrier or FSC
2. Low-cost carrier or LCC
3. Charter carrier or CC

2.4.1 Full-Service Carriers

A full-service carrier (FSC) is defined in this study as an airline company developed from the former state-owned flag carrier, through the market deregulation process, into an airline company with the following elements describing its business model:

- *Core business*: Passenger, Cargo, Maintenance.
- *Hub-and-spoke network*: This has as its major objective the full coverage of as many demand categories as possible (in terms of city-pairs[6]) through the optimization of connectivity in the hub. This item will be presented in-depth, in Sect. 2.4.
- *Global player*: Domestic, international and intercontinental markets are covered with short-, medium- and long-haul flights from the hubs to almost every continent.
- *Alliances development*: No individual airline has developed a truly global network. Thus the network is virtually enlarged by interlining with partner carriers and become part of multi-HS systems.
- *Vertical product differentiation*: This is affected through in-flight and ground service, electronic services (Internet check-in) and travel rules to cover all possible market segments.
- *Customer relationship management (CRM)*: Every FSC has a loyalty program to retain the most frequent flyers. The frequent flyers programs (FFP) have became part of a broader strategy called CRM. The general purpose of CRM[7] is to enable carriers to better manage their customers through the introduction of reliable processes and procedures for interacting with those customers. The final aim of the CRM is to enhance the passenger's buying and travelling experience in order

[6] Airlines' demand can be divided into: *primary need*, or the need for a passenger to travel from A (origin) to B (destination) and back at a certain time on a certain day. The use of the 'city-pair market' or 'O&D market' derives from this reason; and s*econdary need* or the preference for a certain airline, compared in terms of product quality, brand, and pre-and post-sales customer services, etc.

[7] The term CRM is used to describe either the software or the whole business strategy oriented to customer needs. The main misconception of CRM is that it is only software, but actually it is the whole business strategy. Major areas of CRM focus on automated service processes, personal information gathering and processing, and self-service. It attempts to integrate and automate the various customer-serving processes within a company.

to personalize the carriers' services. In this perspective, the CRM is an extra tool to differentiate the airline product.

- *Yield management and pricing*: To support product differentiation, pricing and yield management is sophisticated, with the aim of maximizing the network revenues. This item will be presented in-depth in Sect. 2.6.1.
- *Multi-channel sales*: Sales channels are divided into indirect off-line (intermediate travel agencies) or indirect on-line (web intermediate electronic-agents); direct on-line: the passenger buys the tickets directly via the airline's Internet site[8]; direct off-line: the passenger buys the tickets directly via the airline's call centre, the airlines city office (CTO), or the airline's airport office (ATO). The FSC cover all of these channels.
- *Distribution system*: The complexity of the distribution system described above is technologically supported by external companies called Global Distribution Systems (GDSs). Among the most diffused GDSs are: Galileo, Amadeus, WorldSpan, Sabre.

2.4.2 Low-Cost Carriers

The concept of 'low-cost carriers' or LCC originated in the United States with Southwest Airlines at the beginning of the 1970s. In Europe, the Southwest model was copied in 1991, when the Irish company Ryanair, previously a traditional carrier, transformed itself into an LCC and was followed by other LCCs in the UK (e.g. easyJet in 1995). In the literature, there are several similar definitions of an LCC, also known as a low fare or no-frills airline (see Appendix II for a complete list of LCC existing in Europe). In this study an LCC is defined as an airline company designed to have a competitive advantage in terms of costs over an FSC.[9] In order to achieve this advantage, an LCC relies on a simplified business model (compared with the FSC), a model which is characterized by some or all of the following key elements:

- *Core business*: This is passenger air-service despite the ancillary offers are increasing and becoming part of the LCC core business.
- *Point-to-point network*: The network is developed from one or a few airports, called 'bases', from which the carrier starts operating routes to the main destinations. Destinations are only continental within the EU or the US. No connections are provided at the airport bases, which function as aircraft logistics and maintenance bases.
- *Secondary airports*: City-pairs are connected mainly from the secondary or even tertiary airports—such as London Luton—that are less expensive in terms of landing tax and handling fee and experience less congestion than the larger ones,

[8] Some authors have analyzed the e-commerce market in the airline industry (see Roy and Filiatrault, 1998; Nyshadham, 2000; Jarach, 2002).

[9] Riley (2003) defines the LCC as an airline that '. . . aims to keep operating costs significantly lower than the traditional flag-carrying airlines. . . ' [p. 16].

such as London Heathrow. Small airports will strive to gain the LCC' operation and the usual way is to reduce airport charges. Similarly, air transport activity generates welfare that is a multiple of the airports' activities, inducing regional economic and social development. Local authorities recognize that the LCC operation is a potential driver for social and economic developments, and are willing to provide financial help (for example: tax exemption, marketing support while LCCs start a new connection). The reduced airport fees can be understood as an incentive, as most of these secondary airports are public. These incentives can be quite relevant and can be deemed to contravene the EU's competition rules.

- *Single aircraft fleet*: In general, the LCC operates with one type of aircraft such as the Boeing 737 series with a configuration of 149 seats. The fleet composition also depends on the fact that they operate on only short- or medium-haul routes.
- *Aircraft utilization*: The aircraft is in the air, on average, more hours a day compared with FSCs that have to respect the connectivity schedule.
- *No frills service*: The product is not differentiated as they do not offer lounge services at airports, choice of seats, and in-flight service, and they do not have a frequent flyer program. Fare restrictions are removed so that the tickets are not refundable and there is no possibility to rebook with other airlines. This item will be presented in-depth in Sect. 2.5.2.
- *Minimized sales/reservation costs*: All tickets are electronic and the distribution system is implemented via the Internet or telephone sales centre (only direct channels). Passengers receive an e-mail containing their travel details and confirmation number, when they purchase. The LCC does not intermediate the sale with travel agents and nor does it outsource the distribution to GDS companies.
- *Ancillary services*: LCC increasingly have revenue sources other than ticket sales. Typical examples are commissions from hotels and car rental companies, credit card fees, (excess) luggage charges, in-flight food and beverages, advertising space. The potential growth of this revenue comes from telephone operations and gambling on board. Mintel (2006) reported that Ryanair's revenue from sources other than ticket sales contributed €259 million to its 2005–06 net profit of €302 million. Those revenues already represent 16 percent of the carrier's total revenue. For easy Jet, that kind of income originally represented only 6.5 percent of the airline's total revenue, but it increased by 41.3 percent from 2004.

Not every low-cost airline implements all of the points mentioned above. For example, in 2005 Air Berlin started the UK domestic services as feeders to its German services out of Stansted, exploring the hub-and-spoke operations.

The differences between the FSC and LCC business models are multifaceted (see, e.g., Alderighi et al., 2004). The significant structural cost gap between the two models results from these fundamental differences. Table 2.1 breaks down the cost gap between the FSC and the LCC business models. Overall, the LCC model can operate at 49 percent of FSC costs. In particular, 37 percent out of a total 51 percent of costs difference can be attributed to explicit network and airport choices (or business place and process complexity); another 9 percent of the LCC cost advantage comes from the distribution system and commercial agreements (costs which are narrowing with the elimination of commissions and GDS). A remarkably

Table 2.1 The LCC has 51% cost advantages in relation to the FSC (Source: Doganis, 2001)

	Cost reduction	Cost per seat
Full-service carrier		100%
Low-cost carrier		
Operating advantages		
Higher seating density	−16	84
Higher aircraft utilization	−2	82
Lower flight and cabin crew costs	−3	79
Use cheaper secondary airports	−4	75
Outsourcing maintenance/single aircraft type	−2	73
Product/service features		
Minimal station costs and outsourced handling	−7	66
No free in-flight catering, fewer passenger services	−5	61
Differences in distribution		
No agents or GDS commissions	−6	55
Reduced sales/reservation costs	−3	52
Other advantages		
Smaller administration and fewer staff/offices	−3	49
Low-cost carrier compared with a full-service carrier		49%

small proportion (13 percent) of the cost differential is product/in-flight service-related. The relative simplicity or complexity of their business models distinguishes the LCCs from the FSCs.

LCCs have successfully designed a focused, simple operating model around non-stop air travel to and from high-density markets. On the other hand, the FSC model is cost-penalized by the synchronized hub operations (e.g. long aircraft turns, slack built into schedules to increase connectivity) that implicitly accept the extra-time needed for passengers and baggage to make connections. In addition, the FSC business model relies upon highly sophisticated information systems and infrastructure to optimize its hubs. Franke (2004) stated that the most relevant success factors of LCCs are their network configuration and their streamlined production processes in relation to FSCs. This issue will be addressed in more depth in Chaps. 6 and 7.

2.4.3 Charter Carriers

A charter carrier (CC) is defined, in this study,[10] as ‘an airline company that operates flights outside normal schedules, by a hiring arrangement with a particular customer’.[11] Charter flights have acquired the more specific meaning of a flight whose only function is to transport holidaymakers to tourist destinations. However,

[10] Studying the charter business model does not come within the scope of the study. However for the sake of completeness, we have decided to include a concise description of this model here.

[11] The CCs are defined in contrast to scheduled flights even though they also operate to regular schedules (not always published).

tickets are not sold directly by the charter airline, but by tour operator companies who have chartered the flight.

Although charter airlines typically carry passengers who have booked, individually or as small groups to beach resorts, historic towns, or cities where a cruise ship is waiting for them, sometimes an aircraft is chartered by a single group, such as members of a company, a sports team, or the military. In general, charter flights are sold as part of a package holiday in which the price paid includes flights, accommodation and other services. In the past, this was a regulatory requirement. With the EU deregulation the 'flight-only packages' can now be sold only to those who want to travel to the destination.

Most European charter airlines now form part of vertically-integrated organizations, incorporating a tour operator, travel agency chain, airline and, more often hotels and ground transportation companies. Some examples of vertically-integrated charters are Britannia Gmbh, Condor, Air Jet, and Virgin Sun. Some FSCs have set up charter divisions: for example, KLM owns Martin Air or Lufthansa owns Condor. For a detailed description of the charter market, we refer to Doganis (1991).

Furthermore, CCs frequently operate from airports, or dedicated terminals, where there is no scheduled service. Much of the traffic through small- and medium-sized airports in the United Kingdom consists of charter flights, and the survival of these airports often depends on the airline landing fees they get from the charter companies. The economy of density pursued by CCs requires that the flights should operate on the basis of near 100 percent seat occupancy, and the standard of seating and service may be lower than on scheduled airlines. (But this is by no means always the case).

Mason et al. (2000) reveal that in 1997 the two largest LCCs in Europe, easyJet and Ryanair, had unit costs more than double those of the largest UK charter airlines. CCs were divided into the ones that form part of vertically-integrated tour operating groups and those that remain independent. The sources of cost advantage that the two types of charter airline have over the LCCs were analysed and identified as the following:

- Larger aircraft and longer-haul destinations;
- Higher load factor, aircraft utilization and labour productivity; and
- Lower distribution costs, landing fees, aircraft leasing costs, and admin & finance costs.

Williams (2001) provides a brief overview of the charter carrier business model and its vertical integration in the EU. He addresses the question whether Europe's charter carriers will be replaced by LCCs and his answer is negative.

2.5 Competition between Business Models

Competitive interactions between firms always result in adapting the player's own business model to that of the competitors, and this is also occurring in the airline industry. The LCC sector continues to grow strongly, and as it does so the business

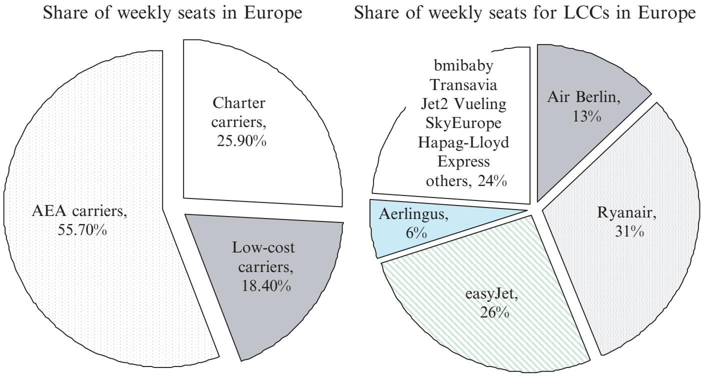

Fig. 2.1 Weekly seats supplied in Europe in summer 2006 (Source: European Parliament Study, 2007)

model is refined and adapted. Figure 2.1 gives the weekly percentage share of seats, and refers to the supply of seats in Europe. The 'other' group corresponds essentially to the CC. Three companies (Ryanair, easyJet and Air Berlin) account for 75 percent of the LCC's seats. Some LCCs have tried to avoid mutual competition. Ryanair, for instance, focuses on smaller markets and regional airports, while easyJet is targeting bigger markets and primary airports.

The European LCC market continues to grow strongly: for example, Ryanair (+23 percent) and easyJet (+16 percent) in 2006. The flag carriers are slightly losing market share to the LCCs. The main question is whether the same growth rhythm and market share evolution will continue and whether those companies can keep their current cost structure. Indeed some inputs, such as fuel, labour cost and aircraft leasing, could become much more expensive, resulting in a slowdown in this growth. But also an explosive growth can become a threat to the low-cost philosophy, and generates higher wages and a more complex management structure. As an example, Air Berlin with the acquisition of dba in 2006 and the charter company LTU in 2007 is growing with economies of scope, as LTU has rights over a considerable number of valuable slots at congested airports (e.g. Düsseldorf).

Airbus and Boeing, the main aircraft manufacturers, have a huge list of orders from airlines and this has changed their negotiating positions resulting in higher purchase prices and lease costs for the carriers. The same cost increases for LCC applies to pilots. Ryanair, for instance, is not longer charging pilots for their training. Finally, some airports are becoming congested, resulting in cost increases for the airlines. These developments may reduce the future competitive cost advantages of LCCs compared with FSCs or CCs.

A study by Mintel (2006) has concluded that there are some signs that the market has reached a certain level of maturity. Some of the signals are the potentially increasing competition from conventional carriers on city pairs. This is demonstrated by, amongst other, Brussels Airlines' price reaction to the entry of easyJet on the Brussels-Geneva route. With increased competition there is the

Table 2.2 LCCs consolidation and bankruptcies in Europe (Source: European Parliament Study, 2007)

Year	Airline	Country	Event
1999	AB Airlines	UK	Bankruptcy
	Color Air	Norway	Bankruptcy
	Debonair	UK	Bankruptcy
2002	GO	UK	Merger with Ryanair
2003	Air Lib	France	Bankruptcy
	Buzz	UK	Merger with Ryanair
	Goodjet	Sweden	Bankruptcy
2004	Air Polinia	Poland	Bankruptcy
	Basic Air	Netherlands	Re-branded in Transavia
	Duo Airways	UK	Bankruptcy
	Germaia Express	Germany	Merged with dba
	Flying Finn	Finland	Bankruptcy
	GetJet	Poland	Bankruptcy
	Jetgreen	Ireland	Bankruptcy
	Skynet Airlines	UK	Bankruptcy
	V-Bird	Netherlands	Bankruptcy
	VolareWeb	Italy	Bankruptcy
2005	Air Andalucia	Spain	Bankruptcy
	Eujet	Ireland	Bankruptcy
	Intersky	Austria	Bankruptcy
	Maersk Air	Denmark	Merged with Sterling
2006	Air Tourquoise	France	Bankruptcy
	Air Wales	UK	Bankruptcy
	Budget Air	Ireland	Bankruptcy
	Dba	Germany	Merged with Air Berlin
	Flywest	France	Bankruptcy
	HiFly/Air Luxor	Portugal	Bankruptcy
	MyTravelite	UK	Reintegrated into MyTravel Airways
	Snalskjusten	Sweden	Bankruptcy
2007	LTU	Germany	Merged with Air Berlin

possibility, as in any competitive market, of short-term excess capacity, and then bankruptcies, mergers and takeovers can occur. Table 2.2 shows that for some airlines (e.g. Air Berlin) the strong growth can partly be explained by the acquisition of other airlines.

The CCs as well were confronted with a decreasing market share due to LCC competition. Some of them, such as Thomsonfly in the UK, introduced LCC characteristics into their business model. Both Air Berlin and Sterling Airways are also good examples of traditional CCs that re-branded into LCCs. Other charter companies started to offer air-only tickets, besides their traditional holiday packages.

To compete with the LCCs, the FSCs implemented more strategies, the main ones are the following:

Table 2.3 Examples of LCC subsidies created by FSC

Holding	LCC subsidy
AirFrance-KLM	Transavia
Iberia	Clickair
SAS	Snowflake
Bmi	Bmibaby

- Creation or acquisition of LCC subsidies in order to establish a multi-brand strategy and maintain a strict distinction between the products. Some examples of subsidy creation are listed in Table 2.3.
- Network rationalization by cutting the less profitable routes. For example, Lufthansa abandoned Berlin when Air Berlin became a dominant carrier, the same happened for Swiss in Geneva with easyJet dominance.
- Reinvention of the business model into an LCC. Aer Lingus (2006) and Meridiana (2003) are two examples of network carriers that transformed themselves into LCCs. Aer Lingus is the most significant example as it faced a major challenge to survive in the new environment after September 11, from its main short-haul competitor Ryanair. The reaction of the Board of Aer Lingus to the new environment was the creation of a survival plan for the company which was unveiled in 2001. Its main objectives were to create a more efficient business model, implement a significant cost-reduction programme, reduce staff numbers by one-third, and radically change the way it does business. Aer Lingus had to implement some low-cost principles and redefine itself as a quasi-LCC facing a prominent competitor, Ryanair. Willie Walsh, known as a miracle worker for the Aer Lingus plan, is today the new chief executive of British Airways.

This evolution shows that most of the FSCs are continuously adjusting some important characteristics of their business models. The reaction is basically the same for most of the European traditional carriers. In the markets where the competition from LCCs is strong, traditional carriers are endeavouring to decrease their unit cost in order to offer lower prices.

2.5.1 FSC Aiming for Higher Cost-Efficiency

The differences in operating costs between FSCs and LCCs are quite relevant. IATA (Economics Briefing No. 5, 2006) reported that in Europe these differences were 40 percent versus easyJet and 64 percent versus Ryanair in 2004, while in the USA there was a 36 percent cost gap in terms of operating costs per available seat kilometre (ASK) for the three largest US network airlines versus Southwest. The advantage of the LCCs in Europe reflects the premium service offered by the FSCs, and the use of short-haul traffic to feed into long-haul networks, which enables the FSCs

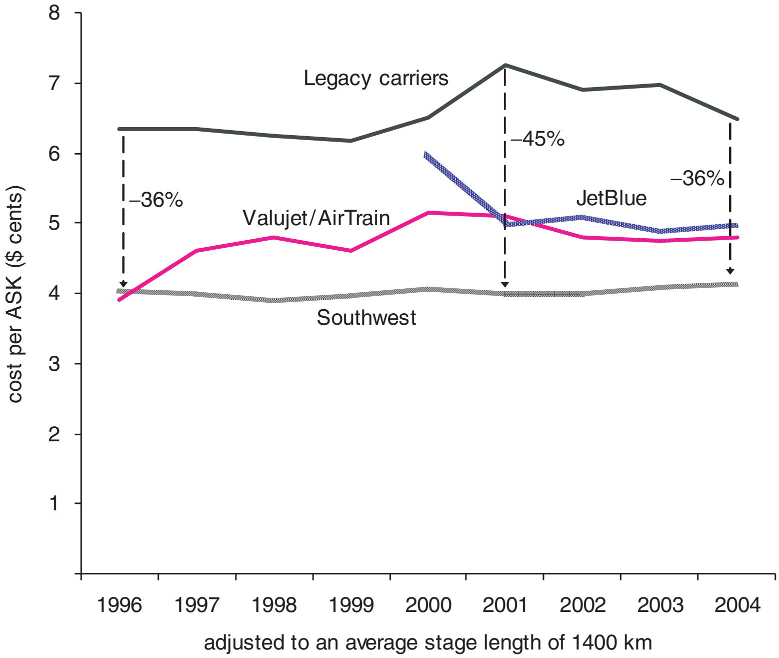

Fig. 2.2 Cost per ASK for US airlines, 1996–2004 (Source: IATA)

to derive higher average yields than the LCCs. Major restructuring among the US FSCs has seen the gap with Southwest Airlines narrow from 45 percent in 2001 to 36 percent in 2004 (see Fig. 2.2).

Southwest Airlines shows a sable cost trend and the difference versus FSCs in 2004 was the same as in 1996. JetBlue and AirTran have also managed to maintain a significant cost difference with the FSCs.

European FSCs have reduced their unit costs since 2001, especially on the sales and distribution side (see Fig. 2.3). However Ryanair, easyJet and Virgin Express have also managed to reduce costs to a similar or even greater magnitude. While the larger LCCs continue to exert strong low-cost competition, it is not such a clear picture for other smaller LCCs. The smaller LCCs (e.g. AirTran in the US, Virgin Express in Europe) have less of a cost gap compared with the FSC and have seen a more volatile movement in costs over time.

Cost restructuring should involve short-term cost reduction in order to conserve cash and supply with constrained demand. The FSCs and CCs have already cut staff, deferred marketing expenses, reduced capacity, retired equipment early and cancelled plane deliveries. Those initial cuts will however, not be sufficient. Surviving companies will need to make longer-term adjustments, including restructuring their fleets, product reconfiguration, and renegotiation of labour agreements, some carriers have even sought bankruptcy protection as a means of resetting their cost structure (Delta and Northwest Airlines benefit from the so 'Chap. 11' legal conditions).

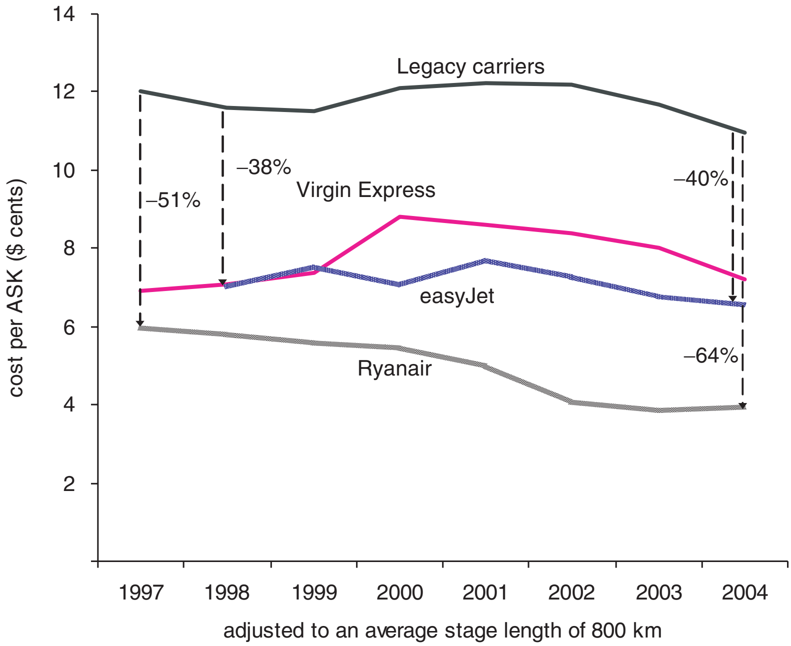

Fig. 2.3 Cost per ASK for European airlines, 1997–2004 (Source: IATA)

2.5.2 The Rise in Fuel Prices

The emergence of LCCs empathize the need for many existing airlines to improve their cost efficiency. The sharp rise in oil and jet fuel prices since 2003 has added greater urgency to the need to cost cutting. The average crude oil price has increased from $31 per barrel in 2003 to $60 per barrel in 2006 and an expected average of $106 per barrel in 2008 (see Fig. 2.4). The FSC has used a combination of stronger revenue growth and higher efficiency gains to offset the large impact of higher fuel costs. However, though the industry has made substantial improvements it still faces a degree of inefficiency to bear the actual oil price increase. Today in May 2008 the crude oil price has reached levels $120, and analysts expect it to reach $ 200 in 2009.

Most airlines hedge their fuel costs. *Fuel hedging* is the practice of making advance purchases of fuel at a fixed price for future delivery to protect against the shock of anticipated rises in price. In this period of rising in oil prices, hedging is a crucial part of business for the most successful airlines as fuel is usually an airline's second highest cost (after labor). All the major airlines have hedged fuel prices since the 1980s, but as the major carriers have run into financial difficulties in recent years, they have no longer had the cash to play the oil-futures market. Last year Delta held positions but was forced to sell them in a short-term cash crunch. Those hedges would have protected about a third of its fuel needs. Continental has no hedges in

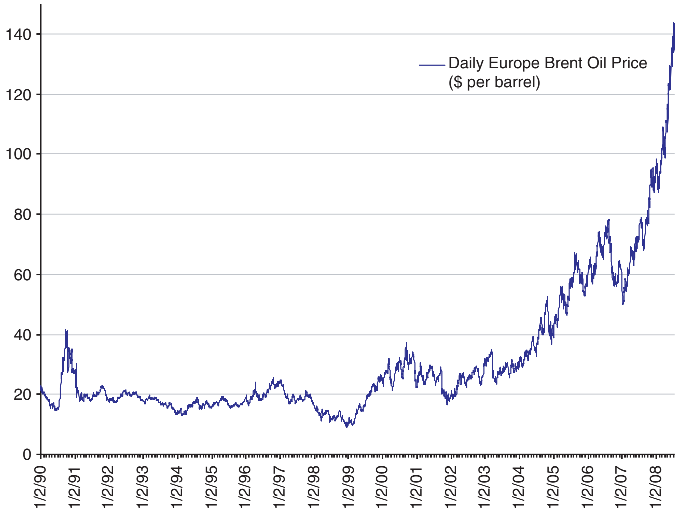

Fig. 2.4 Europe Brent Spot Price FOB - Dollars per Barrel. (Source: US Energy Information Administration)

oil-futures contracts this year. United Airlines, which filed for bankruptcy protection in December 2002, has 30% of its fuel hedged at $45 per barrel.

Even the most successful airlines are likely to run into difficulties on the hedging front soon. With oil prices so high for so long, no investment bank is willing to cover $106 barrels of oil, no matter how much cash the airlines can provide. Thus, the challenge for the coming years is to control energy costs, maintain the low airfares that consumers increasingly favor and not transfer entirely the jet fuel surcharges to the final price.

LCC can be particularly vulnerable to the fuel price increase. They benefit from 37% operational cost advantage on FSC, which comes from higher seat density. This advantage can vanish as the fuel price will impact more on their higher fleet utilization costs than the FSCs.

Small airlines and with small scale cost advantage are entering bankruptcy or stopped operating. Some bankrupted small companies in 2006–07 are: Western, Aloha Airways, Ata Airways, Skybus, Frontier, Eos, Big Sky Airlines, Champion Air, Harmony Airways Nac Air in Usa and Canada: Euromanx, Silverjet, Quick Airways, Air Adriatic, Direct Fly, Coast Air, Fly Air in Europe: Adam Air, Oasis in Asia.

Andy Harrison, chief executive of EasyJet, said:

Oil remains the biggest challenge and uncertainty.

The FSC sector in Europe has gone through a consolidation. We may expect that it is now the turn of the LCCs. In Europe there are some LCCs with good profit margins (esayJet, Ryanair, Air Berlin), and around three or four majors will consolidate the others that can not face this emergency situation.

2.6 Airline Network

The network is a key strategic factor of airlines, as it is the main driver for generating revenue and costs as well as a source of competitive strength or weakness. Gillen (2005) considers the network strategy to be an integral part of the airline strategy, and the network structure to be a function of demand side externalities and uncertainty, as well as supply-side network economics. Network economies have mainly been on the demand side, while in the airline networks they are viewed as being, for the most part, on the supply side. Network configuration is not just a cost issue: a network strategy can confer revenue advantages as well.

The network structure ranges from fully-connected or point-to-point (PP) to hub-and-spoke (HS) to alliance (fully-contracted), or to a mix of these strategies. The forces leading to the choice of each strategy will be described in the following sections and analyzed in Chaps. 6 and 7.

2.6.1 Network Economics

The US deregulation has resulted in the rise of the HS system by the FSCs and the increased adoption of the PP system by the LCCs. In the EU this result has not been widely documented in the literature. Berechman and Shy (1996) have highlighted three elements to explain the rise of the HS structure: firm costs; demand and entry deterrence.

Network costs are driven by economy of scope, economy of density and route length. Economies of scope arise when many travellers of different city-pair markets are combined for at least part of their journey on a single aircraft. These are exploited by bundling traffic over one or more hubs of an HS or multi-HS system. Economies of density are derived from the aircraft size. Unit costs (seat-kilometre costs) decrease with the aircraft size, but they do not necessarily have a linear relationship (production scale). Economies of density are exploited if the network is designed in order to bundle small traffic flows onto routes that would otherwise support smaller aircraft with higher seat-km costs. Caves et al. (1984) and Brueckner et al. (1992) provides empirical evidence of economy of density in airline network. Hendricks et al. (1995) show that economies of density can explain why the HS system is the optimal system. The key to this explanation lies in the level of density economies. However, when they compare the HS with the PP system, they find that an HS network is preferred if the marginal costs are high and demand is low. But given fixed costs and intermediate values of variable costs, a PP system is preferred.[12]

Route length affects the aircraft unit cost, which falls as route length increases. This holds since the fixed costs related to the flights are spread over a larger

[12] Pels et al. (2000) explored the optimality of airlines networks using linear marginal cost functions and symmetric demand functions.

output, and the variable costs do not increase proportionally with distance (see Holloway (2003). There are a few papers that model airline network competition. Among these, it is worth mentioning Oum et al. (1995), who present a network game in which carriers *investing in hubbing* make a firm 'tough' in the multi-product market competition. The use of HS networks turns out to be a device for entry deterrence. Another contribution to the analysis of network competition is given by Adler (2001) who studies a two-stage duopoly competition where carriers first choose their hubs, the connections to spokes and the frequencies, and then they compete both on direct and indirect routes. She finds that there are multiple equilibria as well as no equilibrium, depending on the parameters. Other papers on the topic include Hansen (1990), who studies hub competition in choosing the level of frequencies, and Hong and Harker (1992), who mainly analyse the competition for slot allocation. Bhaumik (2002) investigated the welfare implications of carriers' competition and the role of a regulator. Finally, Hendricks et al. (1997) analyse asymmetric duopoly competition where departure time is used as a crucial competitive variable.

2.6.2 Network Management

Carriers determine network supply through a process called network management. This process can be described in four steps (see Fig. 2.5; for a recent review of network management, see Holloway (2003).

1. *Network strategy*. This is the highest level of network decision with two to three years' horizontal time ahead, including fleet development, financial targets and alliances for passage, cargo and maintenance production lines. The decision is based on the current and forecasted situation in terms of traffic, air-politics, economics, and competitors' development. Chin and Tay (2001), Smith (1997), and Bruning and Hu (1988) focus on the profitability and investment decision to expand the fleet of North American and Asian carriers.

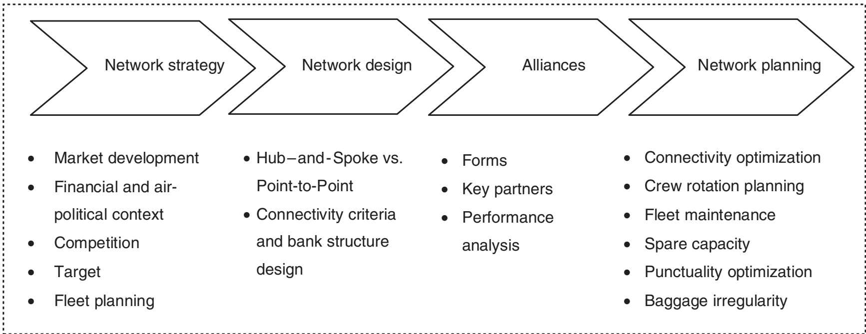

Fig. 2.5 Network Management phases

2. *Network design*. This is the translation of the network strategy into network configuration (HS or PP), connectivity, and hub developments. It includes long- and medium-term fleet planning and supply issues such as frequency, aircraft rotation and hub waves design.
3. *Alliances.* The network can be broadened by incorporating the departures of alliances partners in order to increase the offer to the customers. No airline has—or it is likely to develop—a truly global network. Dennis (2000) considers the scheduling issues that particularly affect alliances including multiple-hub operations, other interfaces between routes, airport slot and terminal allocations, and the through-working of aircraft.
   Chang and Williams (2002) and Janic 1997) investigate the relation between the liberalization, alliance, and performance of the airlines. The reasons behind the developments of alliances will be presented in Sect. 2.6.
4. *Network planning.* This refers to short-term adjustments of schedules and production planning on a day-to-day basis, which takes place every semester. Those include action to optimize connection time at the hub, ad-hoc changes of the aircraft size, crew planning, punctuality and baggage irregularity. This process follows the short-term demand fluctuation and competitor moves. Crises such as September 11 or the SARS epidemic have affected the network planning of the European carriers. Chapters 3 and 4 are dedicated to analyzing how the carrier's network planning has functioned to react to the global crises.

2.6.3 Network Definitions

There is no unique or even widely-used definition of what exactly constitutes an HS or a PP network, instead a number of definitions coexist. From a network design perspective, the HS or PP network can be described by using a simple network of four nodes. Figure 2.6 depicts two ways of connecting the nodes: on the right, the nodes are fully connected through point-to-point relations, while, on the left, there is a hub-and-spoke relation. Airport H is the hub through which the other airports are connected. Note from the Fig. 2.6 that it takes three routes to connect all the nodes in the HS system, whereas this takes six routes in the PP network. Generalizing the example, given n airports, the possible number of city-pair combinations is $n(n-1)/2$. Hence, the pure PP system requires $n(n-1)/2$ routes to cover all combinations, whereas the HS system allows carriers to cover the same airport combinations with only $(n-1)$ routes.

From an air traffic management perspective, Reynolds-Feighan (2001) identified the HS configuration of a carrier when there is a high concentration level of air traffic in both space and time. Burghouwt and de Wit (2003) explain the spatial configuration by the levels of concentration of an airline network around one or a few central hubs. This definition was adopted in many geographical network analyses and measured by the Herfindal index (McShan, 1986), or by Gini index or Theil's entropy index (Reynolds-Feighan, 1998). Temporal configuration is related to the

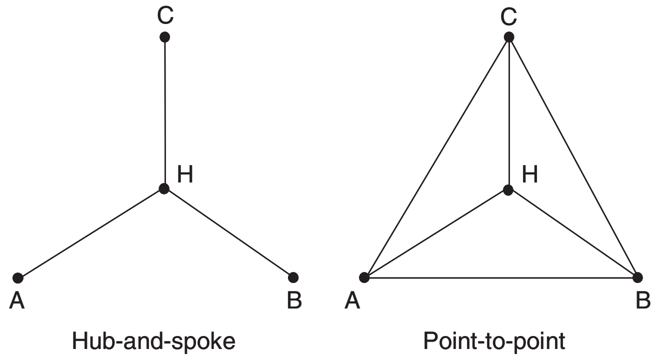

Fig. 2.6 A scheme of point-to-point and hub-and-spoke configurations

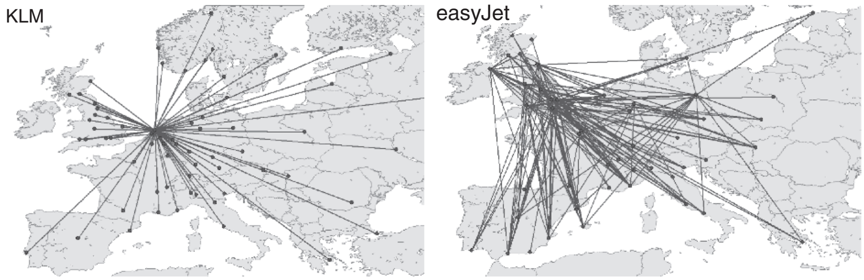

Fig. 2.7 The hub-and-spoke network of KLM in Europe versus the 'almost-fully-connected' (point-to-point) network of easyjet (Source: OAG, November 2004)

airline's flight schedule. Bootsma (1997) defines the temporal configuration as 'the number or quality of indirect connections offered by an airline or alliance by adopting a wave-system structure in the flight schedule. A wave-system structure consists of a number of connection waves, which are a complex of incoming and outgoing flights, structured such that all incoming flights connect to all outgoing flights [. . .]' Bootsma (1997, p. 53).

In contrast, a network is PP-structured when traffic flows are temporally and spatially dispersed. However, the development of a PP network originates from one or few airports, called bases, from which the carrier starts operating routes to the main destinations. The number of routes may increase, but hardly ever reaches the ideal PP configuration where all the airports are connected to each other. The reasons for this strategy are economic and air-political. Not all the city-pairs have enough demand volume to justify the operation of profitable flights, or there may be difficulties for carriers to obtain slots at all airports, and finally, logistic costs of fleet rotation may make it convenient for the airlines to develop operational bases. Figure 2.7 provides an example of real HS versus PP configurations.

2.7 Pricing and 'Yield' Management

Air-travel demand is characterized by factors such as high fluctuations, consumer heterogeneity, and uncertainty about the traveller's departure date or even the ultimate destination of the journey. On the other side, airline supply is limited by aircraft capacity and has a very perishable nature, i.e. the unsold seats cannot be reused after the flight has departed. Thus the process of pricing and inventory control (allocation of aircraft seats) is among one of the most complex ones faced by the modern airlines.

Over the past years, a set of techniques to allocate limited and highly perishable resources among differentiated consumers have been adopted by carriers. These techniques are known as 'yield management',[13] also known as revenue management or revenue enhancement. Lieberman (1991), defines yield management as a 'systematic approach to applying pricing and inventory controls to the sale of a perishable asset'. The goal of yield management is to maximize the operating revenue in such a complex market environment. In this definition there are three keywords: (a) differentiated customers, (b) limited and perishable resources, and (c) revenue maximization. Customers are not homogeneous in travel behaviour and in willingness-to-pay, thus carriers can segment the demand and differentiate their product to fulfil the demand. The second and the third item can be explained jointly. Once the perishable output is produced (availability of seats), costs can be considered sunk costs, and therefore the yield maximization problem coincides with profit maximization.[14]

2.7.1 The FSC Yield Management

We call *FSC yield management* the set of techniques that are usually adopted by the FSC. A recent review of research in yield management as well as a taxonomy of the FSC revenue management is given by Weatherford and Bodily (1992) or Gallego and van Ryzin (1997). Weatherford and Bodily identify 14 descriptors that can be used to set the yield management problems. Our description is organized in terms of seven simple principles:

(a) *Market segmentation*. Travellers do not have homogeneous behaviour and demand can be segmented. The demand for business travel is concentrated on flights at the start and end of working days of the week. Business travellers book later than leisure travellers and need to change travel arrangements at short notice. Some of the segmentation key variables are: the purpose of travel (business or leisure); the purchase timing (early bookings or last-minute bookings); and the purchase location (country of purchase, Internet, travel agent or

[13] For a review of different yield management techniques, we refer to Weatherford and Bodily (1992).

[14] This explains why it is called revenue or yield management and not *profit management*.

airport ticket office). Further segmentation can be created through distribution channels; specialist markets such as marine, missionary, ethnic and students, are sold tickets through dedicated agents.

(b) *Product differentiation.* To respond to the market segmentation, airlines differentiate the supplied quality by adding extra services to the basic transport. Those are typically in-flight services, ground services (food and entertainment, fast check-in, VIP waiting lounges, etc.) and fences (see c below).

(c) *Booking classes and fences*. In order to ensure that any segment of passengers purchases its required levels of quality, the carriers apply fences. Product fences are rules that regulate the ticketing purchase and the conditions imposed on each traveller category. In general, the fences are known to the passenger as the travel rules and conditions included in the tickets. Some examples are: ticket cancellation or travel date change penalties, purchase time limits, or minimum number of days to stay at the travel destination (see Table 2.4). Air products are offered to the market through the aircraft reservation classes.[15] One or more airfares are applicable to each class of reservation.

(d) *Price setting*. The purpose of travel and the passenger's personal characteristics influence their willingness to pay, their price elasticity, and their quality demand. Leisure travellers may be very price-elastic, and businessmen may be more time-sensitive and less price-elastic (see Fig. 2.8). Airfare levels are set according to the different willingness-to-pay and product quality desired by the travellers. The theoretical literature shows that the use of booking classes and

Table 2.4 KLM travel conditions from the Netherlands to Europe in 2005 (Source: www.klm.com)

Product	Booking classes	Conditions (fences)			
		Minimum stay	Changes	Cancellations	Combinations
TAKE OFF Super-deal fare	E, N, T, L, K	3 nights or one Saturday night	No	No	No
OVERNIGHT attractive and flexible fare	B, S	1 night	Yes at €25	Yes at €75	with Same Day Return Fare and/or Select Fare
SAME DAY RETURN Economy class same day return fare	X	None	Yes at €25	Yes at €75	with Overnight Fare and/or Select Fare
SELECT comfort and ease fare	Z, C, J	None	Yes	Yes	with Overnight Fare and Same Day Return Fare

[15] Carriers label classes with capital letters. For example, the booking classes of KLM are: J, C, I, Z for business cabin and X, S, B, M, H, K, L, Q, T, V for economy cabin.

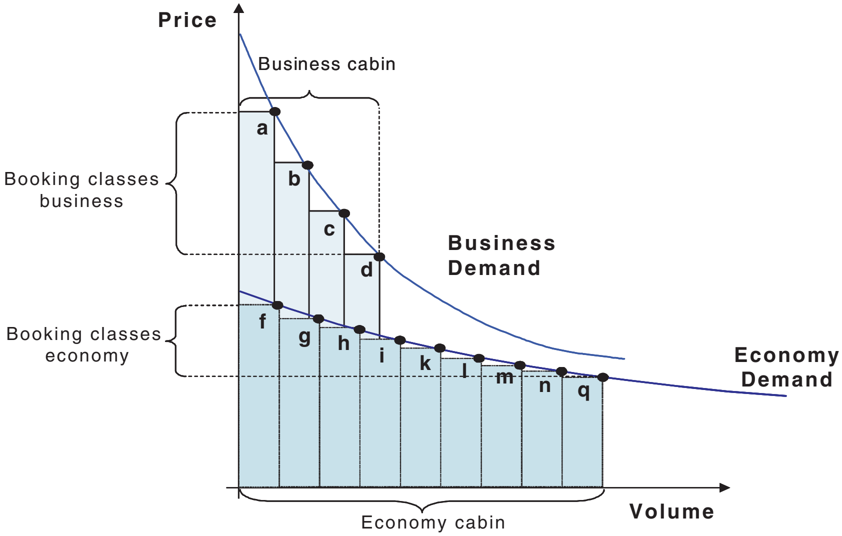

Fig. 2.8 Demand curves for economy and business product and the use of booking classes to price discriminate the passengers

fences allows carriers to price discriminate (see Fig. 2.8). Dana (1998) showed that carriers use those restrictions to screen consumers when their demand is heterogeneous and uncertain. Although even those restrictions have some effect on air carriers’ costs, they constitute major discriminatory tools used by airlines. Two theoretical studies have addressed the connection between price discrimination and market concentration in the airline market: Dana (1998) showed that price discrimination by air carriers could be observed even if market concentration is low and a carrier has no market power; and Gale and Holmes (1993) proved that, under certain conditions, a monopoly airline will offer tickets with restrictions so that they will be selected by the consumer with a high valuation of time. Both studies pointed out that carriers use fences to price discriminate. Empirical studies of the airline market show that, as market concentration increases, so does the average price level (Borenstein, 1992; Morrison and Winston, 1990). Borenstein and Rose (1994), in their seminal paper on price dispersion in the airline market, found a negative effect of market concentration on price dispersion.

(e) *Forecasting and inventory control*. By having discrete fare classes, the yield management system has to face the problem of forecasting the demand and then allocating the right number of seats to each class in order to optimize the revenue. This activity is called *inventory control*, and it is usually implemented for all flights operating between any combinations of city-pairs of the network up to one year into the future. The approach is to forecast and protect enough seats for high yielding demand and then leave other seats progressively available for lower fares. The seat availabilities are set to obtain that particular mix of business in each class which will maximize the expected revenue. In short the yield management problem is to get the best mix from a portfolio of fares with different values and risks attached. The problem is solved by optimization algorithms, which depend on forecasts of demand for each booking class. These forecasts are based on large databases recording the complete booking history of each booking class per flight, per day over several years.

(f) *Overbooking, no-shows and go-shows.* Because of the possibility of no-shows (a passenger who books a seat but does not show-up at the departure time) and go-shows (a passenger who has a valid ticket without a reservation but just shows up at the departure time), most airlines accept reservations in excess of capacity. This may result in flights being overbooked and the possibility of refusing seats to ticketed passengers (*denied boarding*). The overbooking level is set equal to the difference between the forecasted no-shows and go-shows. When demand exceeds capacity, customers are serviced by other airlines or given compensations (nearby hotel, free taxi, etc.). The problem is to determine the pricing and the overbooking policy, that maximize the expected revenue. In the absence of a proper overbooking policy the unpredicted no-shows means that the flight departs with empty seats. For a more detailed analysis of this topic, we refer to Gallego and van Ryzin (1997), who developed a dynamic, stochastic yield management model including the overbooking policy.

(g) *Distribution*. From a yield management perspective, the airline product is the combination of a route connecting point A to point B of the network, rules and travel conditions, and seat allocation, which is all sold for a certain airfare. The distribution system should display the product's characteristics and its actual availability (seat availability) for each origin and destination and booking class. Therefore, inventory control and the distribution system must be linked. The modern GDS (global distribution system) is able to support the different airlines' own inventory control.

The airlines price setting will be extensively analysed in Chap. 5 where a theoretical model of airline price competition with product differentiation and consumer heterogeneity is developed and empirically tested.

2.7.2 The LCC Yield Management

The LCC yield management differs radically from traditional yield management. It is based on the concept that there is a latent large-price sensitive market, which will travel (or travel by plane) only at a low enough price.

(a) *No-explicit market segmentation.* There is no explicit segmentation or, at least, the segmentation is only applied through time of booking and choice of flight. The passenger who wishes to pay lower prices must book early or on the flights for which there is less demand.

(b) *No-product differentiation.* The product is not differentiated and the fences are removed: no Sunday rule, date limits, changes fee, and so on. This means that one-way pricing is possible with the outbound and inbound journey being priced separately but fully combinable. Those factors make the inventory control of LCCs from a technical perspective simpler to manage than FSCs.

(c) *Price versus demand is a continuum function.* The key factor in being able to offer low fares is to have low operating costs. However, the LCC fare setting is counter to the traditional model. LCCs modify the selling price of each flight as a function of the departure date. If a price is too low, the flight will fill up early and higher-yielding late-booking business will be turned away. On the contrary, if the price is too high, the flight is at risk of departing with empty seats.

(d) *Booking classes.* Each flight only has one price available at any point in time and not as many booking classes as the FSC.

(e) *Internet distribution.* The passengers purchase via the Internet and have the transparency to compare prices as a function of date or time of departure. Those who are more price-sensitive can choose the lower demand flights.

The problem is therefore much simpler than that of the FSCs. The idea is that the demand will be such that on busier flights a premium fare can still be applied. Indeed, it is often observable that LCCs are actually more expensive than their FSC competitors. At the same time, on other flights the lower prices ensure a reasonable load factor. Solving this problem requires an understanding of the relationship between the demand and the price. Thus, the traditional approach of booking-class mix has turned into a price optimization problem. Prices are no longer fixed but dynamic and adjusted to reflect demand at one point in time. This can be achieved by plotting the optimal path thought the price/demand graph as in Fig. 2.9. The

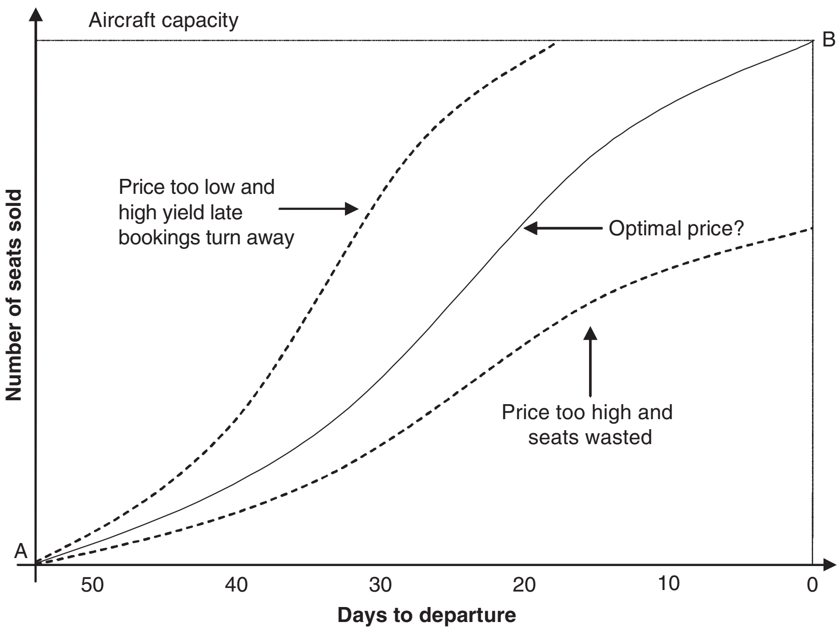

Fig. 2.9 Optimal and sub-optimal booking patterns up to the day of departure (Source: Fletcher (2003))

difficulty with this approach is that the price elasticity can change throughout the period before the flight departure as the mix of travellers can change.

To summarize, the LCC yield management is much simpler than the conventional approach of the FSC. Instead of forecasting the different segments of demand and trying to achieve the best booking-class mix, the alternative is to create demand by low fares and use the pressure of the created extra demand to fill the flight and increase the yield (price optimization).

2.8 Airline Alliances

The emergence of the international alliances occurred after the market deregulation. The alliances affect the major activities of the carriers depending on the type and level of alliance. Networks could be integrated into different forms by incorporating the departures/arrivals of a partner carrier. The major objective is to add as many destinations as possible by accessing the connection system of the partners. The reasons for creating the alliances are *air-political*, i.e. the airline has no traffic rights and is precluded from controlling a foreign carrier that has this right; *economical*, e.g. its costs or fleet are unsuitable for that market; *infrastructural*, e.g. slots are not available; or *financial-related*, e.g. the airline has insufficient resources to develop new markets. Pels (2001) analysed the benefit for both airlines and customers to enter alliances. For an airline, the benefits are the same as adopting a hub-and spoke network: cost factors, demand factors and entry deterrence. By entering into an alliance, a carrier can increase market densities and reduce fixed costs in the markets with, for example, a code-sharing agreement. From the customer's perspective, Pels states that the major sources of the potential increase in consumer surplus are: the network effect; increased densities on different links; and joint pricing of complementary links. Park and Zhang (2000) find that consumer surplus tends to increase if an alliance is a complementary alliance, but it decreases if the alliance is parallel (collusive) in nature. A recent paper of Zhang (2005) examines the competition models for three types of strategic alliances: vertical, horizontal and hybrid alliances. The authors define vertical alliances when two firms link up their complementary products. This form of alliance confers a strategic advantage by allowing the partners to commit credibly to grater outputs, and the strategic effects arising from the elimination of the double-marginalization problem in vertical integration. The horizontal alliances reduce competition not only in the market where prior competition between the partners takes place, but also in the other markets of the alliance network. The hybrid alliance is a mix of vertical and horizontal alliances and it is likely to have both pro- and anti-competitive effects.

From the airline perspective, network complementary amongst partners is clearly one key factor in creating an alliance. This stimulates the creation of multi-hub systems to capture traffic flows from a secondary or tertiary airport behind one hub to a secondary or tertiary airport behind another hub. Dennis (2000) considers the scheduling issues that particularly affect alliances including: multiple-hub

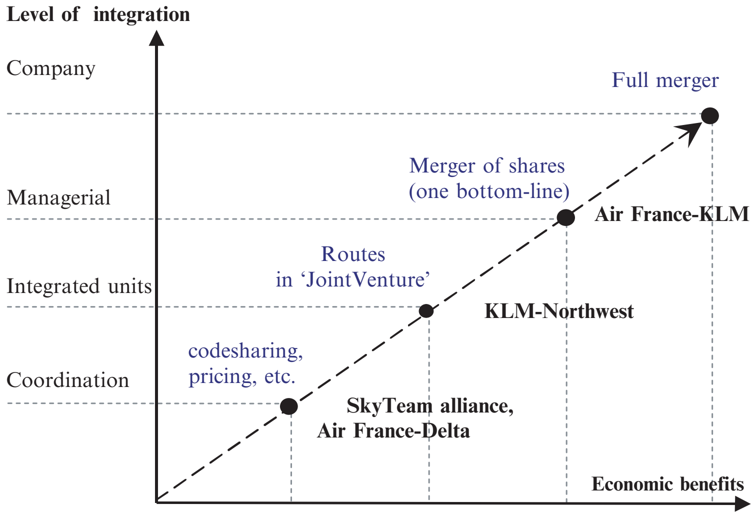

Fig. 2.10 Different forms of alliances (Source: KLM, (2005))

operations; other interfaces between routes; airport slot and terminal allocations; and the through-working of aircraft. The idea behind alliances is the outsourcing of capacity supply when the use of the carrier's aircraft is not possible. The types of outsourcing most adopted are: the code-sharing agreements; the blocked-space agreement; franchising and/or leasing agreements; and joint venture service. For a complete description of these agreements, we refer to Holloway (2003).

Figure 2.10 shows different forms of alliances plotted according to the increased economies of scale and scope levels that can be reached. Coordination alliances are the first levels of cooperation among partners, usually in terms of schedules, code-sharing, pricing and frequent flyer programmes. Examples of coordination alliances are presented in Table 2.5 and the global network created by Star alliance is displayed in Fig. 2.11.

Airlines can integrate part of the network or company unit. An example is the joint venture of KLM and Northwest Airlines for the routes between the US and the Netherlands. A joint service requires that one of the carriers undertakes the revenue management activities for both carriers. Inventory on the joint service is jointly priced and promoted. In this case, the partners are not competing against each other. Joint services generally require either a revenue sharing agreement (based on some level of assumed costs attributed to the operating partner) or a cost-and-revenue sharing agreement. A specific joint revenue management unit has been established in the KLM headquarters in Amsterdam to manage these joint routes for both carriers.

Before the market deregulation, national institutions and regulation were against mergers and takeovers, constituting international barriers that lead to the formation of alliances. Recently, both in the US and the EU, these barriers are being reduced and alliances are evolving in company merging. Brueckner and Spiller (1994), and

Table 2.5 Major airline alliance groups in 2008

oneworld	SKYTEAM	STAR ALLIANCE
Aer Lingus	Aeroflot—Russian Airlines	Air Canada
American Airlines	China Southern Airlines	Air China
British Airways	Aeromexico	Air New Zealand
Cathay Pacific	Air France—KLM	ANA
Finnair	Alitalia	Asiana Airlines
Iberia	CSA Czech Airlines	Austrian
LAN Chile	Continental Airlines	BMI
Qantas	Delta Air Lines	LOT Polish Airlines
Japan Airlines	Korean Air	Lufthansa
Malév Hungarian Airlines	Northwest Airlines	SAS
Royal Jordanian Airlines	Air Europa	Singapore Airlines
	Copa Airlines	Shanghai Airlines
	Kenya Airways	South African Airways
		Spanair
		Swiss
		Thai Airways International
		TAP Portugal
		Turkish Airlines
		United
		US Airways

Fig. 2.11 The global network of Star Alliance in 2006 (Source: OAG)

Keeler and Formby (1994) demonstrated the cost incentives for airline consolidation. On the revenue side, the stronger market presence of the merged networks may translate into higher fares (Morrison, 1996).

In 2004, KLM and Air France created the first-cross border merger in Europe. A new group, called Air France-KLM, controls 100 percent of the two former operational airlines, which so far remain operationally independent. Apart from Air France-KLM, a new consolidation in the EU is taking place between Lufthansa and Swiss or in the US between American West and US Airways. Carlton et al. (1980) developed a methodology for estimating consumer' benefits resulting from a merger in the US. They indicated that airline mergers may confer substantial consumer benefits in the form of superior service (single carriers in place of multiple-carriers).

2.9 Mergers and Acquisitions; Three Mega-Carriers in Europe?

Cost efficiency can also be achieved by mergers or acquisitions (M&A). This consolidation phase has started mainly in Europe between the FSCs but also between LCCs, and it could reshape the national carriers' scope and increase competition between US, EU and Asian carriers. Indeed, consolidation can yield three major benefits to airlines.

First, operational synergies can provide opportunities for cost rationalization, from scale benefits in procurement, sales, maintenance, and airport operations to sharing overheads and information technology systems. Secondly, network synergies can reduce costs and improve asset utilization by eliminating of redundant routes. Increased revenues can be generated through pricing harmonization achievable thanks to the increased market share and improved load factors. Third, consolidation can improve carriers' competitive positions by providing a platform for growth, greater negotiation power with partners, and benefits from improved capital management. Therefore, consolidation would usually provide the greatest scope for value creation.

The acquisition of KLM Royal Dutch Airlines by Air France in 2004, has shown its rivals what can be achieved with greater economy of scale in the highly fragmented industry. After integrating its two networks and hubs, Air France–KLM SA has reached a growing portion of European market share, particularly among high-paying business travellers on long-haul flights. Lufthansa followed in 2005 with the smaller acquisition of Swiss International Air Lines. The success of that deal has made Lufthansa open to the possibility of further acquisition, as its executives have declared. Iberia declared itself to be open to a potential acquisition and received a proposal from British Airways which already owns 10 percent of Iberia. British Airways could face further competitive pressure from Lufthansa. Scandinavian Airlines System planned to sell its 20 percent share in British Midland Airways (bmi). Lufthansa already owns 30 percent shares of bmi and it will most probably become the client of SAS to reach 50 percent ownership of bmi. Lufthansa could gain market

Table 2.6 Largest network airlines in EU by share of ASK and speculation about mergers

% ASK	in 2004	in 2006		Mega-carriers (?)	
British Airways	20.4	Air France—KLM	22.5	Lufthansa Swiss SAS Austrian Virgin Atlantic	31.2
Lufthansa	17.8	Lufthansa—Swiss	20.6	Air France KLM Alitalia	27.4
AirFrance	14.9	British Airways	20.4	British Airways Iberia	27.2
KLM	7.6	Alitalia	4.9	Other	14.2
Iberia	6.8	Virgin Atlantic	4.0		
Alitalia	4.9	SAS	3.8		
Virgin Atlantic	4.0	Austrian	2.8		
SAS	3.8	Other	21.0		
Swiss	2.8				
Austrian	2.8				
Other	14.2				

Source: OAG(2004) and own elaboration.

shares by buying a large stake in Virgin Atlantic Airways Ltd. Singapore Airlines is looking for a buyer of its 49 percent stake in Virgin Atlantic.

Table 2.6 illustrates that British Airways, Lufthansa and Air France are the principal FSCs in the EU market (the data exclude the LCCs). These three carriers are responsible for over half the ASK and over 40 percent of weekly flights operated by the EU network airlines. If KLM's operation is added to that of its owner, Air France, or Swiss's operation is added to that of Lufthansa, then 63.5 percent of ASK are performed by the top three carriers. The rest of the EU's airlines offer much smaller shares of capacity.

In the coming year, a series of deals could result that may even leave the European airlines industry built around the region's three biggest carriers: British Airways PLC, Deutsche Lufthansa AG and Air France-KLM SA.

This could put the European FSC, even more in competition with US carriers that have expanded their international network in recent years to escape from competition from the LCCs in the US domestic market.

2.10 Conclusions

In this chapter we have provided a brief description of the airline industry in terms of new airline business models and a comparison of their main characteristics. The process of deregulation and the subsequent process of privatization have induced important changes in the strategy of the airlines. At least three new business models can be identified: full-service carriers (FSCs), low-cost carriers (LCCs), and charter carriers (CCs).

The FSC model developed from the former state-owned flag carrier model, through the market deregulation process, into a new airline company with a hub-and-spoke network or, through international alliances, multi-hub-and-spokes systems. Sophisticated yield management techniques were adopted in order to control the aircraft availability and to provide an even more differentiated product. The LCC business model has experienced fast growth in Europe after the deregulation. LCCs have successfully designed a focused, simple operating model around a point-to-point, no-frills product. They did not suffer as much as the FSCs from the crisis in the air transport industry after September 11, thanks to the low fare levels which still continue to attract many passengers and the diversion away from sensitive regions (North America and Asia) towards intra-European flights.

Nowadays, FSCs and LCCs often compete on the same routes and for coincident segments, while the LCCs' performance indicators are in general higher than those of FSCs. The conclusions of this chapter are threefold:

1. *LCCs can provide some important cost lessons for FSCs*. There are still large cost differences between FSC and LCCs both in EU end US, though the nature of the gap can differ between the US and the EU. For example, there is less of a difference in infrastructure costs in the US than, in other regions, with less opportunity for LCCs to concentrate on secondary airports. The size and spread of the cost gap highlights that there are several areas, from distribution to aircraft utilization, where the network airlines can move closer to an LCC approach in order to lower costs.
2. *Greater Cost Efficiency is already being achieved by FSCs.* US and European FSCs have managed to make progress in lower their unit costs (and particularly non-fuel unit costs) since 2001. A reduction in distribution and overhead costs has been the main driver. Cost efficiency is also being achieved by merger or acquisitions (M&A). The acquisition of KLM Royal Dutch Airlines by Air France in 2004 has shown its rivals what can be achieved with greater economy of scales in the highly fragmented industry.
3. *The Hub-and-Spoke model can, however, also provide some competitive advantages*. The higher product quality that can be offered by FSCs (e.g. comfort, more convenient airports, personal rewards through loyalty schemes) can be used to attract customers willing-to-pay a premium for the additional service. FSCs do still have advantages within their own business model by for distance using multiple aircraft types to adjust capacity to prevailing demand conditions on different routes. In addition, the airline network itself provides several advantages over LCCs on many routes. For example, over half of all European long-haul traffic originates from short-haul traffic on feeder routes, thus, FSCs can benefit from a higher level of economy of scope.

In the remainder of this study, first, in Part II, we analyse how the FSCs have conducted themselves and reacted to the September 11 and the SARS crises in view of their short-term network planning and long-term network strategy. Then, in Part III, the competition between LCCs and FSCs is addressed in terms of both network and pricing. The price reaction of the FSCs to the entry of the LCCs, is analysed theoretically and tested empirically in relation to the revenue management strategies. Finally, the differences between, and the coexistence of, different FSC and LCC network designs are discussed and measured empirically.

Part II
Coping with Crises in the Airline Industry

Chapter 3
Short- and Long-Term Reaction to Exogenous Demand Shifts[1]

Although this may seem a paradox,
all exact science is dominated by the idea of approximation.

Bertrand Russell

3.1 Introduction

In less than 10 years, the liberalization of the European airline industry has placed flag carriers in a highly competitive and dynamic environment. One of the reasons for the demand dynamic clearly results from the peculiarity of the industry: airline carriers have to produce one of the most perishable goods (passenger transport). This fact has forced carriers to implement and refine practices and strategies in order to react promptly to the ups and downs of the demand. In Chap. 2 we described the common practices employed to face short-term demand fluctuations that usually rely on advanced pricing policies, called ‘yield management’. Long-lasting demand shifts require a reaction in terms of capacity supply described in Sect. 2.4.2 as ‘network planning’.

In this chapter, we focus on this second aspect. Exploring the behaviour of carriers in such a complex context seems to be very difficult unless it is based on particular situations as important demand shifts. Recently, two terrible events have characterized the world economy: the September 11 terrorist attack on the Twin Towers in New York and on the Pentagon in Washington in 2001, and the SARS epidemic in East Asia which began in February 2003. These events have produced two dramatic crises especially in, respectively, the North American and the Asian market. By analysing these two important demand shifts, we are able to detect some determinants in order to analyse the carriers’ conduct. In particular, we have split the carriers’ conduct into short- and long-term determinants to capture information

[1] An earlier version of this chapter together with Chap. 4 appeared as a joint article (Alderighi et al. 2004) in the *Journal of Air Transport Management* 10: 97–107, 2004.

about the carrier's strategies (internal policy, expectations for the evolution of the markets, etc.) and its specific characteristics (structure of the network, adjustment costs, financial situation). To be comprehensive, an analysis based on short- and long-term components needs to be both theoretical and empirical. From a theoretical point of view, we show that, if capacity variations are costly, it is optimal to base a capacity reaction on both short- and long-term profitability where the right mix depends upon the importance and duration of the shock. From an empirical point of view, we can explain the carrier's capacity choices with two variables: the passenger reduction due to the shock, and the expected profitability of the market.

To clarify the first point, suppose that an unexpected shock reduces demand. A carrier can react by decreasing its offer but incurring a cost of adjustment. If the shock is brief, the carrier's choice during the crisis period is mainly based on the expected situation after the crisis. In fact, its reaction aims to limit the costs of reducing and restating the capacity. On the contrary, when there is a long-lasting shock, the carrier focuses on the crisis period, as post-crisis profits are far away and their discounted value is low. Adjustment costs also induce carriers to behave strategically. In fact, a carrier that increases (or decreases less) the capacity during the crisis period forces its competitor to reduce its capacity offer in the post-crisis period. This phenomenon is known in the literature as 'pre-emption'. Pre-emption reduces the reactivity of the carrier to the shock during the crisis.

Theoretical results are based on the assumption that carriers encounter adjustment costs in changing the network configuration, so that their choice depends on short- and long-term variables. Any modification of the flight supply involves costs. For instance, a carrier that decides to enter a new route needs to have new rights at the airport (slot), organize new staff, promote and advertise the new route, launch price actions, and so on. Moreover, in the short term, the aircraft for the new route has to be moved from another route to the new one, and the logistic activity has to be adjusted to the new aircraft rotations. Finally, reducing frequencies or closing a route is a costly decision seeing that a carrier needs to change the aircraft rotations or definitely ground a plane. It is worth noting that adjustment costs are first of all set-up costs and hence are higher when carriers want to enter or expand a route than when they want to exit from or reduce it.

We assume that adjustment costs are usually high for large carriers (carriers with higher market shares), since they employ local ground staff, but are low for small carriers that usually outsource ground activities. In addition, closing and opening an intercontinental route implies a re-optimization of the network, which is more complex and costly for larger carriers. Other factors such as specific network characteristics and the flexibility of the fleet, i.e. the number of aircraft that can operate both on short- and long-haul routes, can have an impact on the importance of the adjustment costs. The existence of adjustment costs motivates the decision to change the capacity supply only few times a year and in the meantime to compete in prices.

In Chap. 2 we presented the network management as the process to develop and control the network. This process is usually organized in terms of four levels: (1) *network strategy*, (2) *network design*, (3) *alliances*, (4) *network planning*. Crises such as September 11 or the SARS epidemic have affected the network planning of the European carriers. This chapter and the next one are dedicated to analysing how the network strategy and planning have functioned to react to the global crises.

Specifically, we present a dynamic game-theoretical framework organized in three stages, which are a time-continuous sequence of periods. In each period, carriers take operational actions (i.e. they choose a price); in each stage, they choose their tactics (corresponding to a capacity offer); and, in the entire game, they follow a strategic plan (i.e. the choice of a strategy to solve the overall game). The empirical model presented in Chap. 4 does not consider operational decisions but focuses on tactical and strategic plans that are driven by short- and long-term indicators, respectively.

Recently, the literature has reported new research in the field of the airline crisis. In particular, Hätty and Hollmeier (2003), Alderighi and Cento (2005) present a view of the airline crisis after the September 11 and SARS epidemic. Their first contributions are strongly related to this chapter, being divided into two parts, one dealing with the theoretical framework and the other with the results of the North American crisis. Their second contribution originates from the internal debate in the crisis management unit at Lufthansa Airlines. In that study, it is shown that the reduction of air traffic demand is matched by industry capacity reduction. When demand declines, capacity can not be adjusted immediately because of the insufficient flexibility. These authors conclude that managing the crisis aims not only to restore the pre-crisis state but rather to form a more healthy business environment. In addition, Gillen and Lall (2003) examine shock transmission in the airline industry after September 11. Their research attempts to identify three main propagation channels: the trade effect; the alliance effect; and the wake-up call effect.

The remainder of this chapter is organized as follows: Sect. 3.2 presents a brief description of the airline sector during the North American and Asian crises. In Sect. 3.3 we provide the theoretical model. The results and conclusion are presented in Sects. 3.4 and 3.5. This chapter represents the theoretical basis for the empirical analysis presented in Chap. 4.

3.2 Exogenous Demand Shifts: The American and Asian Crises

The September 11 terrorist attack on United States and the SARS epidemic in Asia had a strong impact throughout the airline sector. The North America crisis has been the most tragic shock that the industry has faced in its recent history. The SARS shock strongly hampered the carriers' expectation for the development of the Asian market. In the next two subsections we provide some facts and figures that describe the shocks and the subsequent reactions of the European carriers. The description is necessary to support some of the methodological decisions that have been taken in the econometric analysis.

3.2.1 The September 11 Terrorist Attack

On 11 September 2001, one Boeing of American Airlines and one of United Airlines were diverted by terrorists to crash on the Twin Towers in New York City, and a third Boeing of America Airlines was diverted to crash on the Pentagon in Washington. For security reasons the North American air space was closed for the next five days. Eight days after the terrorist attack the Lufthansa Chief Executive Officer Jurgen Weber, made the following statement on 19 September 2001:

> ...the losses incurred due to the closure of US and Canadian airspace, flight diversions, cancellations and drop in demand have made it necessary for companies to revise their profit forecast and capacity supply. The forecasting was dependent on an economy upswing in the last quarter of the year, which was no longer anticipated in the wake of the 11th September event. The aviation industry has been hit badly by the consequences of the terrorist attacks. It will require immense efforts on the part of Lufthansa staff if we are to avoid an operating loss this year. (www.lufthansa.com).

The revenue passenger kilometres (RPK)[2] and the available seat kilometres (ASK)[3] are two relevant market indicators to understand the impact of the crisis on the airline industries. The indicators refer to the transatlantic traffic generated by European carriers to North Atlantic destinations; they are seasonally adjusted and observed as a year-to-year index.

Before the terrorist attacks, the RPK between Europe and North America had a zero growth, afterwards RPK dropped significantly in October (−26 percent) and reached its lowest point in November (−33 percent). The European carriers' reacted to adjust their capacity in November (−15 percent). Afterwards the capacity reduction continued until January 2002, when it reached the lowest point of the crisis (−26 percent).

The indicators are plotted in Fig. 3.1. The two series are clearly affected by a strong downturn, in October for the RPK, and in November for ASK. The market had fully recovered from the crisis in terms of RPK in February 2003, and in terms of ASK in March 2003. In general, carriers reduced their capacity supply by cutting the frequencies and the aircraft size, or closing routes. For example, KLM adjusted its flights to the US by reducing weekly frequencies to New York (from 13 to 11), to San Francisco (from 7 to 6), to Miami (from 7 to 5), and to Detroit (from 4 to 3). It also closed the Amsterdam-Atlanta route, and reduced the aircraft size to Canada (Montreal: from Boeing 747 to Boeing 767; Toronto: from Boeing 747 to McDouglas 11). Table 3.1 presents the capacity reduction per carrier (ASK) as a year-to-year index. The index decreases to under 100[4] in the last quarter of 2001 (Oct–Dec) immediately after the September demand shift. Some carriers such

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[2] The RPK is the number of passengers who generated revenue (free travelers are excluded) normalized by the length of the journey in kilometres.

[3] The ASK is the number of seats offered by the carriers on a certain route multiplied the route length (in kilometres).

[4] The index is calculated as the current year value divided by previous year value and multiplied by 100. When the index is equal to 100, the current value is equal to the previous year value, when is lower than 100 it means that the current value is lower than the previous year value.

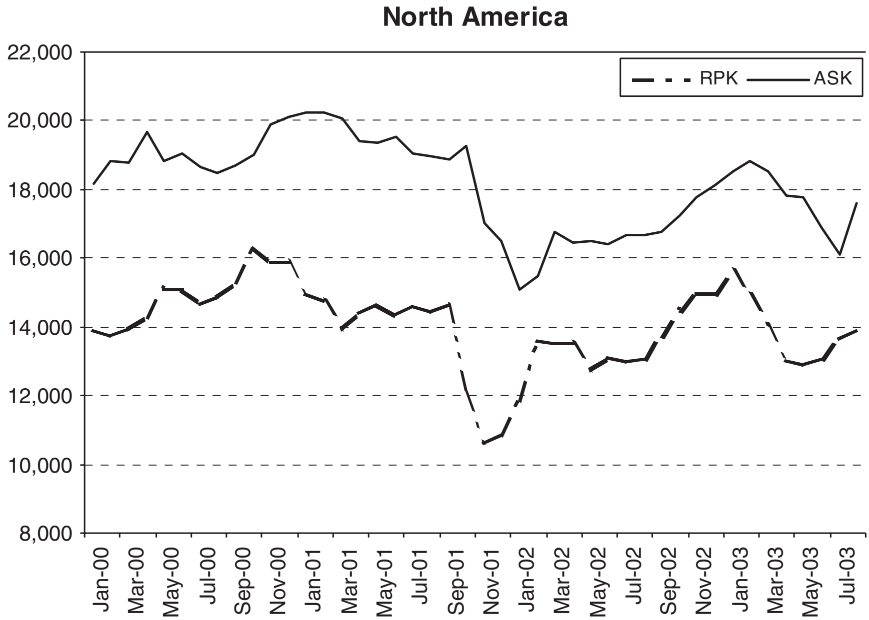

Fig. 3.1 The revenue passenger kilometres (RPKs) and the available seat kilometres (ASKs) development for the traffic flows from Europe to North America (Source: AEA seasonally adjusted)

Table 3.1 ASK (index versus previous year) for traffic flows from Europe to North America per carrier

Carrier	Jan–Mar 2001	Apr–Jun 2001	Jul–Sep 2001	Oct–Dec 2001	Jan–Mar 2002	Apr–Jun 2002	Jul–Sep 2002
Air France	115	116	103	87	81	85	95
Alitalia	106	93	89	70	61	52	55
British A.	96	85	83	79	87	96	99
Aer Lingus	106	119	106	89	–	–	–
Iberia	102	106	95	84	81	83	106
KLM	90	99	93	72	77	66	77
Lufthansa	112	109	104	83	78	86	95
Swiss	104	109	95	61	62	60	63
Austrian A.	137	142	136	80	62	45	47
SAS	101	107	112	96	97	105	109
Total	103	101	95	79	76	78	84

Source: AEA

as British Airways, Alitalia or KLM seemed to reduce their capacity already in September 2001 as the index fell lower than 100. Nevertheless, these indices presented the same negative growth even before the crisis. These carriers were already in a capacity reduction process regardless of the forthcoming crisis. On the contrary, other carriers such as Air France, Aer Lingus and SAS were above 100 in the third quarter since they registered a positive trend before the crisis. In this prospective, the indices cannot be compared among the carriers but only as trend over time. In the last quarter of 2001, the carriers reduced their capacity offer, and the cut ranged from −39 percent of Swiss[5] to −4 percent of SAS.

3.2.2 The SARS Epidemic

The severe acute respiratory syndrome (SARS) is a respiratory illness caused by a virus. SARS was first reported in Asia in February 2003. Over the next few months, the illness spread to more than two-dozen countries in North America, South America, Europe, and Asia. According to the World Health Organization, during the SARS outbreak of 2003, a total of 8,098 people worldwide became sick with SARS; and, of these, 774 died. Most of the SARS cases in Europe were among travellers returning from other parts of the world, particularly from Asia. As the main way that SARS appears to spread is by close person-to-person contact, fears of contagion and the official travel advice to defer non-essential travel generated a shock in the demand, mainly for air transport to Asia and Canada.

Before the epidemic spread, the RPK from Europe to Asia was still recovering from previous crises (September 11, the Afghanistan war, and the October 2002 Bali terrorist attack) and showed positive growth. After these crises, the negative trend was again evident in March (−8 percent), just one month after the first SARS case was reported. During the succeeding months, the demand sank (−22 percent in the April RPK), and reached its lowest point in May 2003 (−30 percent). The European carriers reaction is captured by the ASK index. The capacity adjustment started two months later in May 2003 (−15 percent) and continued in the next two months (June 2003 −15 percent, July −8 percent).

The two indicators are plotted in Fig. 3.2. The time path is clearly affected by the two big crises, i.e. September 11 and SARS. Both negative shocks can be detected in the plotted time series; nevertheless, the effects were different in terms of both magnitude and the recovery path to the pre-crisis situations. Due to the September 11 attack, the RPK decreased to the lowest value of 7,499, while the lowest point reached in the SARS crisis was even lower (6,403). In the first crisis, the downturn of the RPK came in October 2001. A minor shift was registered in December 2002 due to the announcement of the Iraqi war, which generated negative expectations of travel security and economic development in the Asian areas. In the second crisis, the drop was in March 2003 and became strong in April 2003.

The carrier's reaction is presented in Table 3.2 in terms of the ASK year-to-year index. In August 2003, the crisis did not seem to be completely absorbed by the market. Over the first quarter of 2003 (Jan–Mar), the carriers considered were still enjoying a phase of expansion, the only exception being British Airways which

[5] The name ‘Swiss’, as opposed to ‘Swiss Air’, has been adopted throughout this chapter, as Swiss Air went bankrupt after the September 11 crisis, after which a new airline with the name Swiss was created.

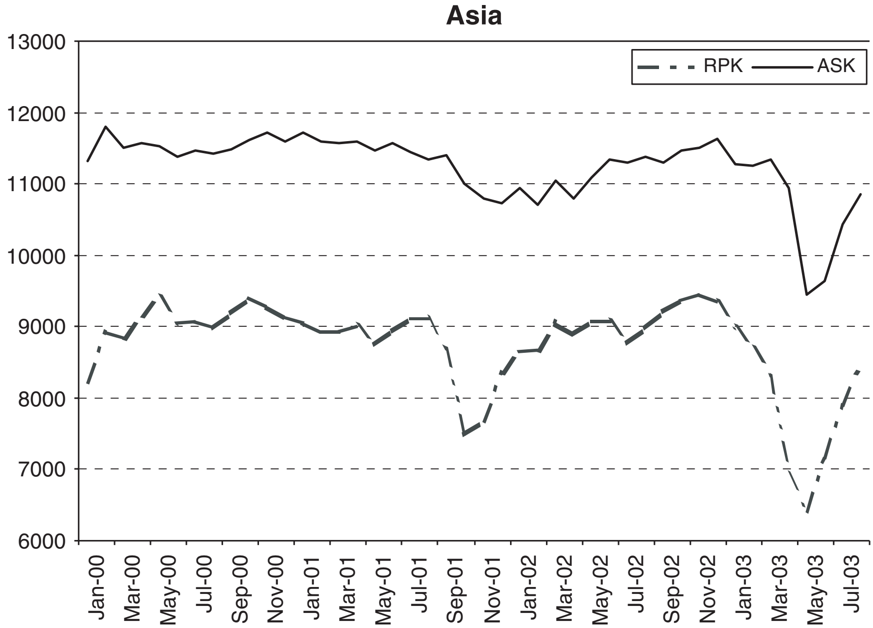

Fig. 3.2 The revenue passenger kilometres (RPKs) and the available seat kilometres (ASKs) development for traffic flows from Europe to Asia (Source: AEA seasonally adjusted)

Table 3.2 ASK (index versus previous year) for traffic flows from Europe to Asia

	Apr–Jun 2002	Jul–Sep 2002	Oct–Dec 2002	Jan–Mar 2003	Apr–Jun 2003	Jul 2003	Aug 2003
Air France	105	104	107	103	83	82	85
Alitalia	74	85	101	131	120	105	107
British Airways	81	87	86	85	92	105	105
KLM	95	99	100	107	92	94	102
Lufthansa	101	102	106	108	86	88	92
Swiss	69	69	99	106	82	79	83
Austrian Airlines	110	125	136	137	100	97	101
SAS	120	114	110	112	85	75	73
Total	93	96	102	104	91	92	95

Source: AEA

was stable for almost all 2002 with an index of 81–87. In the second quarter of 2003 (Apr–Jun), ASK fell drastically for every carrier, with different magnitudes, ranging from 18 percent for Swiss to 8 percent for KLM and British Airways.

Similarly to the previous crisis, European carriers reduced their capacity in term of frequencies, aircraft size and routes. Additionally, airlines also adjusted their capacity by introducing triangular services. The Asian routes are on average 3,000 km longer than the North American ones and passengers are willing to tolerate a stop service in order to keep the same number of frequencies. Triangular flights are one way for a carrier to introduce a temporary modification of capacity supply, as reported in a KLM press release:

> ... the capacity adjustments particularly on routes to Asia and North America are made in response to declining demand resulting from developments surrounding the SARS virus. All schedule adjustments are temporary... (www.klm.com).

The Dutch airline reduced their capacity by cutting the frequency on the routes: Amsterdam–Shanghai (from 5 to 4 weekly roundtrips),[6] Amsterdam–Beijing (from 4 to 2 weekly circle trips via Shanghai); Amsterdam–Hong Kong (from 7 to 4 weekly round trips) and Amsterdam–Singapore–Jakarta (from 7 to 5 weekly round trips).

Comparing the SARS crisis in Asia to that of September 11 in North America, we observe that the crises are similar in terms of shock magnitude but different in terms of time duration. Both recorded a demand reduction equal approximately to 30–36 percent, and while the September 11 crisis lasted for 17 months, that of SARS was only 6–7 months long. In terms of capacity reduction, the carriers also reacted similarly to both shocks. Nevertheless, the reaction to September 11 was drastic but delayed by two months, while the reaction to SARS seems quicker and limited (-15 percent capacity reduction versus an RPK reduction of 30 percent). The questions that arise are: How do the carriers react to crisis situations and how can this be modelled in order to explain their general behaviour?

3.3 Theoretical Model

We consider a duopolistic market[7] consisting of two firms: namely, A and B. They compete in quantities (capacities), and we assume that firms revise their capacity supply only rarely since, in modifying their flight supply, they incur adjustment costs.

The model is set in a continuous time framework, and firms are profit maximizers. To keep things simple, we assume that at date 0 there is an unpredicted negative shock (that is described as a temporary reduction of the demand), and that firms modify their capacity supply only twice: once when the shock has occurred and again when it ends. When managing the crises, the firms do not have interactive behaviour with the competitors as they focus mainly on their survivability. In what follows, we present a simplified version where we assume that the duration of the crisis is known just after the shock has occurred. At the end of the section, we informally present some extensions which do not substantially change the main results of the model. Therefore, we start by assuming no uncertainty regarding the duration

[6] A round trip flies there and back on the same route. A circle trip flies from the origin on the outward journey, stopping at one or more places on route, but it flies straight back from the final destination without stopping en route.

[7] In this model, we focus on a single market that corresponds to a single intercontinental route.

of the crisis, no financial constraints, and no differences in the adjustment costs. The timing of the game is as follows:

- (Stage 0) Before time 0, the market is in long-term equilibrium. That means the capacity that firms A and B have chosen is the solution of a Cournot game.[8] The outcome of this stage-game is J_0, K_0 and p_0, where J_0 and K_0 are, respectively, the capacity choice of firm A and B at Stage 0, and p_0 is the equilibrium price at Stage 0.
- *Stage 1*: At time 0, there is an unpredicted (negative) shock in the demand with a certain duration $\theta > 0$. Firms change their capacity.[9] The outcome is J_1, K_1 and p_1.
- *Stage 2*: At time θ, the negative shock ends. Firms modify their capacities with a cost that increases with the capacity change.[10] In this case, the outcome is J_2, K_2 and p_2.

We solve the model backwards, starting from Stage 2, and then we move to Stage 1. We will only focus on the behaviour of firm A, since there is an analogous solution for firm B. The overall profit of firm A can be described as the sum of the discounted instantaneous profits. We call π_1^A and π_2^A the instantaneous profit of firm A at Stage 1 and 2, respectively.[11] The overall profit for firm A, namely Π^A, is:

$$\Pi^A = \int_0^\theta \mathrm{e}^{-rt}\pi_1^A \mathrm{d}t + \int_\theta^\infty \mathrm{e}^{-rt}\pi_2^A \mathrm{d}t = r^{-1}\left(1-\mathrm{e}^{-rt}\right)\pi_1^A + r^{-1}\mathrm{e}^{-rt}\pi_2^A, \tag{3.1}$$

where r is the interest rate, and e^{-rt} is the discount factor.

The Stage 2 equilibrium is computed assuming that firms have already chosen their capacity in the first stage. The inverse demand in the second Stage 2 is $p_2 = a - Q_2$, where Q_2 is the quantity supplied by both firms. During the crisis period $(0,\theta)$, the demand was $p_1 = b - Q_1$ with $0 < b < a$. At time $t \in [\theta,\infty)$, firms A and B maximize their profit, given J_1 and K_1, where J_1 and K_1 are, respectively, the capacity choice of firm A and that of firm B in Stage 1. At time $t = \theta$, they choose the capacity J_2 and K_2 to maximize their profits.

In the Stage 2, the period profit of firm A is:

$$\pi_2^A = (b - c - J_2 - K_2)J_2 - D(J_1, J_2, \delta), \tag{3.2}$$

where c is the unit-cost for the installed capacity and $D(J_1,J_2,\delta) = (J_2 - J_1)^2$ are the (per-period) adjustment costs.[12] We define $J_2^* = J_2^*(J_1,K_1)$, the optimal capacity

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[8] Because no costs of adjustment are assumed in Stage 1, the equilibrium levels before time 0 do not have an impact on the choices in Stage 1 and 2, but we maintain this assumption because it is necessary to consistently compute the capacity change.

[9] For simplicity, in Stage 1, the capacity adjustment is costless.

[10] See, e. g., Gould (1968).

[11] Because firms can not change their capacity supply during these stages, their per period profit is constant.

[12] For technical reasons, we assume that the adjustment costs are persistent, i.e. they span the interval $[\theta,\infty)$. Similar results can be obtained under the assumption that these costs are only realized at time θ.

level in the second Stage 2, as a function of J_1 and K_1. Hence, after some computations, the solution of Stage 2 of the game is:

$$J_2^*(J_1,K_1) = \frac{(1+2\delta)(a-c)+4\delta(1+\delta)J_1-2\delta K_1}{4(1+\delta)^2-1}. \tag{3.3}$$

Note that the optimal level J_2^* is affected by the costs of adjustment and by the decisions taken in Stage 1: namely, J_1 and K_1. The Stage 1 instantaneous profit of firm A is given by:

$$\pi_1^A = (b-c-J_1-K_1)J_1. \tag{3.4}$$

The firms' behaviour in the Stage 1 is determined by the optimization of the overall profit described by Eq. 3.1. For firm A, this is equivalent to the maximization of the following equation:

$$\max_{J_1} R\pi_1^A(J_1,K_1)+\pi_2^A(J_2^*,K_2^*,D), \tag{3.5}$$

where $R=(1-\mathrm{e}^{-r\theta})/\mathrm{e}^{-r\theta}$ is the expected duration of the crisis,[13] $J_2^* = J_2^*(J_1,K_1)$ and $K_2^* = K_2^*(J_1,K_1)$ are the optimal capacity levels of A and B, respectively, in Stage 2, and D are the adjustment costs of A. The solution of this optimization problem is the reaction function of firm A in Stage 1.

The first-order condition implies that:

$$r\mathrm{e}^{rt}\frac{\mathrm{d}\Pi^A}{\mathrm{d}J_1} = R\frac{\mathrm{d}\pi_1^A}{\mathrm{d}J_1}+\frac{\mathrm{d}\pi_2^A}{\mathrm{d}J_1} = 0. \tag{3.6}$$

When firm A maximizes the overall profit it balances its choice between the short-term effect and long-term effect. The short-term effect is the traditional result of the duopoly theory: $\mathrm{d}\pi_1^A/\mathrm{d}J_1 = (b-c-2J_1-K_1)$, while the long-term effect

$$\frac{\mathrm{d}\pi_2^A}{\mathrm{d}J_1} = \frac{\partial\pi_2^A}{\partial J_1}+\frac{\partial\pi_2^A}{\partial J_2}\frac{\partial J_2^*}{\partial J_1}+\frac{\partial\pi_2^A}{\partial K_2}\frac{\partial K_2^*}{\partial J_1}+\frac{\partial\pi_2^A}{\partial D}\frac{\partial D}{\partial J_1} \tag{3.7}$$

is composed of 4 different impacts. The first and second terms of the RHS of Eq. 3.7 are null, because J_1 does not directly affect π_2^A, and because of the envelope theorem: $\partial\pi_2^A/\partial J_2 = 0$. The third term captures the strategic effect and corresponds to the impact of J_1 on π_2^A due to a change in K_2^*:

$$\frac{\partial\pi_2^A}{\partial K_2}\frac{\partial K_2^*}{\partial J_1} = J_2^*\frac{2\delta}{4(1+\delta)^2-1}.$$

The sign of the strategic effect is always positive because Stage 2 actions are strategic substitutes (i.e. the reaction curves are downward sloping[14]). In fact, through increasing the capacity in Stage 1, a firm forces its competitor to reduce its capacity

[13] The function R should not be confused with the parameter θ, which is the real duration of the crisis and it is unknown to the carrier. The function R is the duration of the crisis that the carrier expects.

[14] See Fudenberg and Tirole 1984, and Bulow et al. (1993).

in Stage 2. In the literature, this effect is called 'pre-emption'. In the limit case (when $\delta = 0$), the strategic effect is not present.

The fourth term corresponds to the impact of J_1 on π_2^A due to a change in D:

$$\frac{\partial \pi_2^A}{\partial D}\frac{\partial D}{\partial J_1} = 2\delta(J_2^* - J_1),$$

and is positive as soon as $J_2^* - J_1 > 0$. It captures the resistance of a firm in reducing its capacity in Stage 1 since it has to bear high costs in Stage 2 for increasing the capacity. Also this term is null when $\delta = 0$.

The presence of adjustment costs complicates the optimization problem. In fact, the equilibrium solution in the Stage 1 is characterized by strategic considerations as well as cost considerations regarding the choice of Stage 2. The optimization problem is clearly simplified when $\delta = 0$, where the equilibrium solutions are the usual ones of a static duopolistic game: $J_1^* = J_b = (b-c)/3$ and $J_2^* = J_a = (a-c)/3$. In the general case, when $\delta > 0$, the optimal solution J_1^* is given by:

$$J_1^* = \frac{1}{3}\frac{R(1+2\delta)(2\delta+3)^2(b-c)+8\delta(1+\delta)^2(a-c)}{R(1+2\delta)(2\delta+3)^2+8\delta(1+\delta)^2-\frac{2}{3}\delta(2\delta+3)}, \tag{3.8}$$

Rearranging the previous equation, we have:

$$J_1^* = (1+o)(\lambda J_b + (1-\lambda)J_a), \tag{3.9}$$

where

$$\lambda = \frac{R(1+2\delta)(2\delta+3)^2}{R(1+2\delta)(2\delta+3)^2+8\delta(1+\delta)^2}, \tag{3.10}$$

and

$$o = \frac{\frac{2}{3}(2\delta+3)}{R(1+2\delta)(2\delta+3)^2+8\delta(1+\delta)^2-\frac{2}{3}(2\delta+3)}. \tag{3.11}$$

In order to simplify the discussion of Eq. 3.9, we will focus on the second part of the equation.[15] The second bracket indicates that the solution is a combination of the long-term solution and the short-term solution of the static game. The weights λ and $(1-\lambda)$ depend on δ (the adjustment costs) and R (the duration of the crisis). Different values of these parameters modify the weights of the short- and long-term solution of the static problem. If λ is close to 0 (R low or δ high), the solution J_1^* is close to J_a, i.e. the long-term solution; on the other hand, if λ is close to 1, the solution J_1^* is close to J_b, i.e. the short-term solution.

Hereafter, we investigate the relationship between long-term and short-term profitability and the variation of the capacity supply.

[15] The first bracket is greater than 1 when $\delta > 0$, but is approximately 1 whenever R is not too small, so that we can neglect it from our discussion. In fact, $o < 0.01$ when $R > 0.6$ for every value of δ, and $o < 0.1$ when $R > 0.2$.

We define $\Delta S = J_1^* - J_0^*$ as the variation of the capacity supply, $\Delta P = (b-a)$ the fall in the short-term profitability, and $Y = (a-c)$ the long-term profitability. Using Eq. 3.8, after some computations, we have:

$$\Delta S = \frac{1}{3}\frac{R(1+2\delta)(2\delta+3)^2\Delta P + 8\delta(1+\delta)^2 Y}{R(1+2\delta)(2\delta+3)^2 + 8\delta(1+\delta)^2 - \frac{2}{3}(2\delta+3)}. \tag{3.12}$$

We define α_S and α_L as the reactivity of the capacity variation to a change of the short- and long-term indicator, respectively. They are defined as follows:

$$\alpha_S = \frac{\partial(\Delta S)}{\partial(\Delta P)} = \frac{1}{3}\frac{R(1+2\delta)(2\delta+3)^2}{R(1+2\delta)(2\delta+3)^2 + 8\delta(1+\delta)^2 - \frac{2}{3}\delta(2\delta+3)} \tag{3.13}$$

and

$$\alpha_L = \frac{\partial(\Delta S)}{\partial Y} = \frac{1}{3}\frac{8\delta(1+\delta)^2}{R(1+2\delta)(2\delta+3)^2 + 8\delta(1+\delta)^2 - \frac{2}{3}\delta(2\delta+3)}. \tag{3.14}$$

Hence, replacing α_S and α_L in Eq. 3.12, we have:

$$\Delta S = \alpha_S \Delta P + \alpha_L Y. \tag{3.15}$$

Equation 3.15 shows that the capacity reduction (or expansion) is a mixture of short- and long-term profitability,[16] and Eqs. 3.13 and 3.14 indicate that α_S and α_L depend on δ and R.

A change of the adjustment costs and of the duration of the crisis modifies the composition of the optimal reaction of the firms.

The ratio

$$\frac{\alpha_S}{\alpha_L} = \frac{1}{8}\frac{R(1+2\delta)(2\delta+3)^2}{\delta(1+\delta)^2}$$

provides some indications of the firm's responsiveness to a change in the adjustment costs. It is simple to verify that the ratio is decreasing in δ, meaning that an increase in the adjustment costs shifts the attention from the short-term to the long-term goals. Therefore, firms care more about the future situation since higher adjustment costs imply more pre-emption and more expenditure to adjust to the long-term equilibrium.

The ratio α_S/α_L can also be used in order to analyse the impact of the duration of the crisis on the strategy composition. When the duration is short, α_S/α_L is large, while when the duration is long, α_S/α_L is small. This point has a very simple interpretation. If the shock is long, each firm will focus on the crisis period by reacting to the demand reduction. If the shock is short, the decision can be based on the

[16] In Chap. 4, we will base our empirical analysis on Eq. 3.15. In Sect. 3.4, Fig. 3.3, we will provide a graphical representation of α_S and α_L as a function of R and δ. Note that the model we propose fits for the duopolistic case, but in the empirical part there are situations including different market structures, e.g. in the North American case there are some routes with more than two carriers. As qualitative results do not change, we assume that the model holds in any situation.

post-crisis perspective, and hence on the long-term market profitability. Therefore, when the duration is short the capacity reaction is driven by long-term profitability, while if the duration is long, the capacity reaction depends on short-term profitability. Analogously, an increase of the interest rate r affects the α_S/α_L ratio positively.

Finally, we have to stress that as δ increases the carriers are less flexible. When carriers have low adjustment costs, they react strongly to a shock, and when they have high adjustment costs they react weakly. We will clarify[17] this argument in Sect. 3.4.

In what follows, we present the main conclusions of the previous analysis in an informal way. We focus on four different situations: (1) when there is uncertainty about the crisis duration; (2) when carriers have different discount factors; (3) when firms have different adjustment costs; and (4) when firm B has a financial constraint. In these cases, we also observe different combinations of the short- and long-term indicators for the determination of the equilibrium choice.

First, we consider the case where the two firms have uncertainty about the duration of the crisis.[18] Each firm can base its predictions on its private information (for example, the result founded by the research team and by the task-force created to tackle the crisis). Each firm formulates its expectations independently from the other and chooses a capacity level. We assume that there are only two possible states of nature with known probabilities: $\theta = \{\theta_L, \theta_S\}$, where $\theta_L > \theta_S$.[19] We assume that each firm does not have knowledge of the opponent's expectations and bases its choice on its own information. If the firm expects $\theta = \theta_L$, it will focus more on the short-term aspects, and hence α_L is low and α_S is large. If the firm expects $\theta = \theta_S$, it will be the opposite: α_S is low and α_L large.

Second, firms may have different discount factors, for example $r_A > r_B$. This situation occurs when carrier A values its future profits more (and hence is more interested in being on the market in future) than carrier B. Clearly, carrier A will focus more on the long-term aspects and less on the short-term aspects than carrier B.

Third, we consider the case where firms have different adjustment costs, for example $\delta_A > \delta_B$. In this situation, firm A will be more reactive to the long-term, while firm B will be more reactive to the short-term.

Finally, we now assume that firm B cannot choose to react as before, since it has a financial constraint (that may depend on low liquidity or high pressure from

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[17] A formal interpretation of flexibility is as follows. Let $J^*(\delta, R)$ be the capacity when the adjustment costs are δ and the length of the crisis is R. For any δ and δ' such that $\delta' < \delta$, and for every $R \in (0, \infty)$, there is an $R' \in (0, \infty)$ such that

$$\text{(a)} \ \frac{\mathrm{d}}{\mathrm{d}a} J^*(\delta, R) < \frac{\mathrm{d}}{\mathrm{d}a} J^*(\delta', R')$$

and

$$\text{(b)} \ \frac{\mathrm{d}}{\mathrm{d}b} J^*(\delta, R) < \frac{\mathrm{d}}{\mathrm{d}b} J^*(\delta', R').$$

Moreover, under the same conditions, there is no R' such that both the inequalities hold if $\delta' > \delta$.

[18] See also Bashyam (1996).

[19] Where L stands for 'long' duration, and S for 'short' duration.

investors, high debts, and so on). In particular, firm *B* can find it difficult, all things being equal, to maintain high K_1^* in conditions of low short-term profitability, even if long-term profitability is high. Therefore, firm *B* is characterized by low reaction to long-term indicators and strong reaction to short-term indicators, which means high values of α_S and low values of α_L.

3.4 Results

The main outcomes of the theoretical model can be simulated by means of a three-dimensional scatter plot (Fig. 3.3). The sensitivity of the carriers to short- and long-term profitability is displayed, respectively, on the X and Y axis (base of plot). A point located in the upper-left side identifies a carrier with long-term goals. On the other hand, a point plotted in the lower-right side identifies a carrier which pursues short-term goals. Carriers plotted in the middle adopt a mixed conduct.

The graph shows three different curves, each one referring to a different level of expected duration of the crisis duration (or different interest rates[20]). The first line on the left side indicates a carrier with an expectation of a long crisis; the second line represents a carrier with an expectation of the medium-length crisis, and the

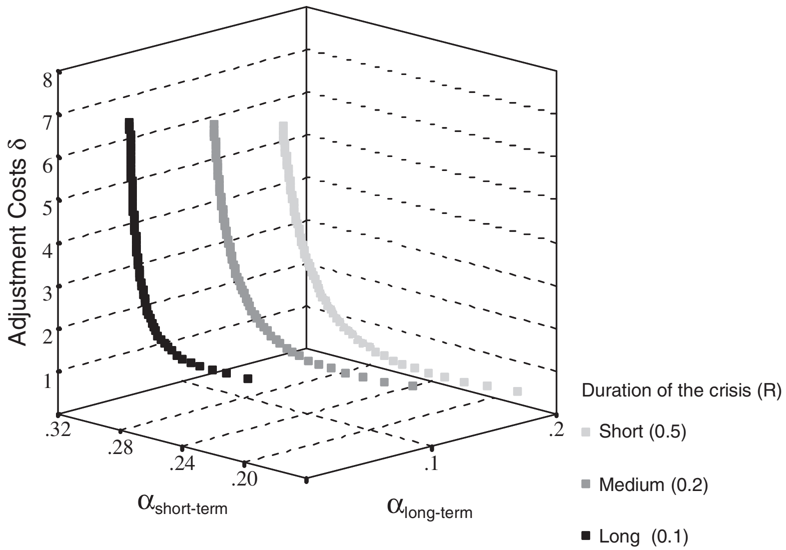

Fig. 3.3 Model simulation for expected short and long-term profitability reaction depending on δ (the adjustment costs) and *R* (expectation of the crisis duration)

[20] The results depend on different expectations of the duration of the crisis but, looking at the interest rate, the conclusions are exactly the same. In fact, the discount factor depends on both these variables and it is not possible to separate the two effects.

third line on the right side represents a carrier with an expectation of a short crisis. The points of each line identify carriers with different adjustment costs. The financial situation also modifies the location on the graph: the stronger is the financial constraint, the higher the sensitivity to short-term profitability, and the lower the sensitivity to long-term profitability. The main factors affecting the carriers' conduct and hence their positioning on the graph are their adjustment costs and expectation of the crisis duration. We expect that flexible carriers are located at the beginning of the curves, while non-flexible carriers are on the upper part of the curves.

3.5 Conclusions

This chapter has provided a theoretical analysis of the strategic conduct of European full-service carriers during the global crises in terms of short and long-term network strategy. In Chap. 2, we presented the network management as the process to develop and control the network (Sect. 2.4.2). The network management was described in terms of four levels: *network strategy*, *network design*, *alliances* and *network planning*. In this chapter, we referred to the short- and long-term strategy in order to analyse respectively, the network strategy and planning during the global crises.

In particular, we presented a dynamic game-theoretical framework organized in three stages, which are a time-continuous sequence of periods. In each period, carriers take operational actions (i.e. set the prices); choose their tactics (capacity supply); and follow a strategic plan (i.e. in the entire game they choose a strategy to solve the overall game). An important assumption of the model is the existence of positive adjustment costs, i.e. the costs required to re-expand capacity. Adjustment costs introduce rigidity in the carriers' conduct. Indeed, non-flexible carriers typically present a small reaction to short- and long-term variables. This behaviour results from the fact that a non-flexible carrier sets high capacity levels during the crisis to push its competitors out of the market and to reduce the set-up costs of re-entering. On the other hand, flexible carriers present high responsiveness to both short- and long-term profitability. They can be small during the crisis period to reduce the losses, and free to expand in the post-crisis period. Carriers' strategies are also affected by expectations of the crisis duration and on the strategic importance of the market. If a carrier expects the crisis to have a long duration (or the market is not strategically important), then its conduct shifts to the short-term variable. If the expected duration is short (or the market is strategically important), then the carrier bases its strategy on the long-term variable. In the next chapter, we will find some empirical evidence of these theoretical results. We will try to explain the carrier's capacity choices with two variables, which are proxies for short- and long-term profitability. These are the passenger reduction due to the shock, and the average revenue per passenger kilometre of the market.

Chapter 4
The Airlines Conduct during the Crises of 2001/2003[1]

4.1 Introduction

One of the conclusions of Chap. 3 was that, non-flexible carriers, i.e. carriers with high adjustment costs, typically present a small reaction to short- and long-term variables. This behaviour results from the fact that a non-flexible carrier sets high capacity levels during the crisis to push its competitors out of the market and to reduce the set-up costs of re-entering. On the other hand, flexible carriers present high responsiveness to both short- and long-term profitability. As described in Chap. 3 in the North American and the Asian crises, the typology of the shocks and the characteristics of the markets were different. Nevertheless, the empirical analysis of both crises should confirm the theoretical results presented in Chap. 3 that there is a trade-off between short- and long-term goals among carriers for both the first and the second crisis.

Specifically, we can explain the carrier's capacity choices with two variables: the passenger reduction due to the shock, and the expected profitability of the market. Finally, we test the theoretical conjecture that there is a positive relation between market shares and costs of adjustment, even if this result is clearer for the North American crisis than for the Asian crisis.

4.2 Econometric Analysis

The hypothesis that the capacity choice on a certain route depends on short- and long-term profitability is tested in two different markets: Asia and North America. The empirical procedure is divided into three steps: (1) the basic properties of the theoretical model are tested (the capacity–supply reaction to a demand shift and to

[1] An earlier version of this chapter together with Chap. 3 appeared as a joint article (Alderighi et al., 2004) in the *Journal of Air Transport Management* 10: 97–107, 2004.

the potential yield); (2) the impact of a demand shift is decomposed per carrier; and (3) the impact of the potential yield is decomposed per carrier.

4.2.1 The Database

Two databases referring, respectively, to the 11 September 2001 crisis and the SARS crisis were collected. They contain information on the number of passengers per city-pair (traffic flow), available seats, average revenue per destination and distance in kilometres from Europe to the top 10 North American and the top-20 Asian destinations. Data are related to European carriers, which are selected by network (max. 1 stop en route service) and high market share. Every carrier operates with a hub and spoke configuration. Therefore, the traffic flows have been aggregated, as described in the following example (see Fig. 4.1). One carrier flying to destination B carries passengers from the hub A and the spokes M, D, V. In order to determine the number of intercontinental passengers flying on the route A–B, we add up the passengers originating from points A, M, D and V.

Data on capacity supply is retrieved from the Official Airline Guide (OAG database). The yield information is collected from the Billing and Settlement Plan (BSP) database and concerns the average revenue generated from Europe to each North American and Asian destination.

On the basis of the above-mentioned data, we compute the following variables:

- ΔS_{ij}: CAPACITY (percentage variation of seats supplied) is the percentage variation of the number of seats offered by carrier i to destination j due to the crisis.
- Y_{ij}: YIELD (yield per available seat kilometre ASK before the crisis) is calculated as the total revenue r_j generated by the main European markets[2] to destination j divided by the total passengers p_j flown to destination j times the distance d_j. Finally, to better approximate the real yield (per flight), the expression is

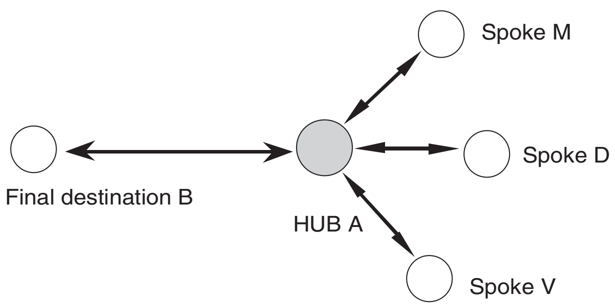

Fig. 4.1 A simplified hub-and-spoke airline network

[2] We included the following point of sales: Italy, Spain, Germany, United Kingdom, Ireland, France, The Netherlands, Austria, Switzerland, Belgium, Luxemburg.

corrected for the load factor (lf_{ij}), i.e. the percentage of the occupied seats in the aircraft of airline flying to destination. In the empirical analysis, we assumed that the YIELD per ASK (see Sect. 4.4.2) is the measure of the long-term profitability. Other authors have used a similar measure of long-term profitability. For instance, Bruning and Hu (1988) measured the profit by a passenger profitability index, which was the product of the revenue to cost ratio and the load factor. Indeed, information before the crisis is likely to be the basis to generate a forecast of the market situation after the crisis.
- ΔP_{ij}: PAX (percentage variation of bookings) is the percentage variation of bookings generated during the lowest downturn of the crisis for carrier i to destination j. This variable provides a measure of the exogenous demand shift.
- XX_i: Dummy variable designating airlines with AF = Air France, AZ = Alitalia, BA = British Airways, EI = Aer Lingus, KL = KLM, IB = Iberia, OS = Austrian Airlines, LH = Lufthansa, SK = SAS, LX = Swiss.

Table 4.1 provides a short description of those variables and the formulas used to calculate them for the two empirical analysis.

Table 4.2 presents some descriptive statistics of the main variables for both crises (North America, Asia). Specifically, the first two columns display the capacity and passenger percentage reduction per carriers for both crises. We observe for the September 11 crisis that Alitalia, Iberia, and Swiss faced the highest passenger reduction (about 35%) and as a consequence their capacity was decreased by 24% for Alitalia, and by 35% for Swiss, but increased by 1% for Iberia. The reason for the Iberia increase lies in the first reaction of Iberia. The Spanish carrier drastically reduced the frequencies to New York and switched the aircraft to operate to Miami instead. The third and fourth columns present, respectively, the market share and the number of destinations in the North America carrier's network. Lufthansa and British Airways are the major European players, with 10.8% and 10.1% of the share.

The eighth and ninth columns present, respectively, the number of destinations and the market share in the Asian carrier's network. The major players are British Airways, Air France and KLM, with 7.1%, 4.6% and 4%, respectively, of the market share, and 11, 14 and 12 destinations. Different market positions can influence the carrier strategy. If market share is a proxy variable of adjustment costs, then, in Asia, carriers can reduce their capacity at lower costs than they can in North America.

4.2.2 Empirical Model

Three econometric models are specified to test the hypothesis that capacity choice on a certain route depends on short- and long-term profitability.

Equation 4.1 relates the capacity change to the variation of the YIELD and PAX variables:

$$\Delta S_j = \alpha_0 + \alpha_1 Y_j + \Delta P_j + \varepsilon_j. \tag{4.1}$$

Table 4.1 Description of the variables used in the empirical analysis

Variable name	Variable description
ΔS_{ij}: CAPACITY Percentage variation of seats supplied	Total number of seats offered by carrier i to destination j during the crises versus the period before the crisis
Y_{ij}: YIELD Yield per available seat kilometre before crises	Total revenue divided by the total passengers flow from Europe to the destination j times the distance d_{ij} and the lf_{ij} for the carrier i
ΔP_{ij}: PAX Percentage variation of Passengers due to the crises	Percentage variation of bookings made during the lowest downturn of the crisis for the carrier i to the destination j versus the same period of previous year
XX_i: AIRLINES Dummy variable	Dummy variable designating the airlines i included in the analysis
Variable calculation for the September 11th analysis	**Variable calculation for the SARS epidemic analysis**
$\Delta S_{ij} = \frac{S_{ij}^{\text{NOV01}} - S_{ij}^{\text{SEP01}}}{S_{ij}^{\text{SEP01}}}$	$\Delta S_{ij} = \frac{S_{ij}^{\text{JUN03}} - S_{ij}^{\text{NOV02}}}{S_{ij}^{\text{NOV02}}}$
$Y_{ij} = \frac{r_{ij}^{\text{APR-AUG01}}}{p_{ij}^{\text{APR-AUG01}} d_j} lf_{ij}^{\text{APR-AUG01}}$	$Y_{ij} = \frac{r_{ij}^{\text{MAR02-FEB03}}}{p_{ij}^{\text{MAR02-FEB03}} d_j} lf_{ij}^{\text{MAR02-FEB03}}$
$\Delta P_{ij} = \frac{P_{ij}^{\text{NOV01}} - P_{ij}^{\text{NOV00}}}{P_{ij}^{\text{NOV00}}}$	$\Delta P_{ij} = \frac{P_{ij}^{\text{MAY02}} - P_{ij}^{\text{MAY02}}}{P_{ij}^{\text{MAY02}}}$
XX dummy: AF = Air France; AZ = Alitalia BA = British Airways EI = Aer Lingus; KL = KLM IB = Iberia; LH = Lufthansa SK = SAS; LX = Swiss	XX dummy: AF = Air France; AZ = Alitalia BA = British Airways; KL = KLM OS = Austrian Airlines; LH = Lufthansa LX = Swiss

In the next two equations, the specific reactions of the carriers to short-term and long-term profitability are decomposed by means of the dummy variables *XX*. In (4.2), the dummies are multiplied by the PAX variable:

$$\Delta S_j = \alpha_0 + \alpha_1 Y_j + \sum_j \beta_i \Delta P_j XX_i + \varepsilon_j. \tag{4.2}$$

In (4.3), the dummies are multiplied by the YIELD variable in order to decompose its impact per carrier:

$$\Delta S_j = \alpha_0 + \alpha_1 P_j + \sum_j \beta_i Y_j XX_i + \varepsilon_j. \tag{4.3}$$

The equations are estimated by means of Ordinary Least Squares, and the results are presented in Table 4.3. The adjusted R^2 value ranges from 0.27 to 0.56.

Table 4.2 Variation of seat supply, passenger reservations, market share and serviced airports per carrier due to the crises

Carrier	Sept.11				SARS			
	ΔS^a	ΔP^b	Airports[c]	MS[d]	ΔS^a	ΔP^b	Airports[e]	MS[f]
AirFrance	−18%	−20%	10	6.6%	−22%	−24%	14	4.6%
Alitalia	−24%	−36%	7	3.0%	−15%	−4%	3	1.8%
British A.	−17%	−22%	10	10.1%	4%	−23%	11	7.1%
Aer Lingus	−15%	−10%	5	1.6%				
Iberia	1%	−37%	3	1.8%				
Austrian A.					−19%	−49%	9	3.0%
KLM	−18%	−20%	10	5.2%	−12%	−28%	12	4.0%
Lufthansa	−8%	−16%	10	10.8%	−8%	−15%	13	3.4%
SAS	−12%	−6%	3	1.5%				
Swiss	−35%	−34%	8	3.2%	−11%	−25%	5	2.3%

Source: Elaboration of Official Airline Guide and KLM data
[a] ΔS = difference in number of seats supplied before and after the crises (see Table 4.1)
[b] ΔP = percentages difference in bookings before and after the crisis (see Table 4.1)
[c] Number of airports serviced in North America
[d] Market share = number of bookings/total market booking for April–June 2001
[e] Number of airports serviced in Asia
[f] Market share = number of bookings/total market booking for July 2002–February 2003

The R^2 is higher for the three SARS-related equations than for the equations referring to the September 11 crisis. The reasons can be either that the models better fit the SARS crisis than that of September 11, or they are related to a better data collection. In both cases, we can confirm the validity of our methodology to analyse two crises over different time periods and markets (North America vs. Asia). We take it as the first result that reinforces our theoretical conjectures. Furthermore, we now proceed to investigate the specific carriers' conduct.

Hereafter we compare the coefficients for each equation:

Equation (4.1): Both PAX and YIELD are significantly different from zero, and their magnitude is higher for the September 11 crisis than for that of the SARS. The PAX variable measures the passenger variation that occurred immediately after the crisis. As no carrier changed its capacity supply in the months after the crisis, PAX does not depend on the change in the capacity supply[3] as it captures an exogenous demand shift. Consequently, no identification problems are generated due to simultaneous changes in demand and supply behaviour. For the North American destinations, when the coefficient PAX equals 0.61, it means that a 10% reduction of the

[3] To be more precise, in certain cases, data on the PAX variation may present some endogeneity as some capacity variations had already occurred at the date on which we measure passenger reduction. Nevertheless, the endogeneity issue does not seem too severe since passengers usually take decisions in advance, and hence before capacity change. Passengers who have booked for a time schedule that is not available are re-allocated to another flight. Usually, for low fares, there is no reimbursement. For the highest fares, carriers usually provide extra benefits to counterbalance the discomfort of the change of departure time. Alternatively, we note that the carriers' decisions are based on the observed demand, as well as on the expected demand. Thus, we need to use the realized passenger demand as a proxy for the expected demand.

Table 4.3 Estimated coefficients of Eqs. 4.1–4.3 for the September 11 and SARS crises

Variable	Equation 4.1		Equation 4.2		Equation 4.3	
	Sept.11	SARS	Sept.11	SARS	Sept.11	SARS
Intercept	−0.37	−0.34	−0.45	−0.25	−0.43	−0.39
	(0.14)	(0.08)	(0.15)	(0.08)	(0.14)	(0.07)
YIELD	5.96	3.60	6.51	2.91	–	–
PAX	0.61	0.49	–	–	0.75	0.45
	(0.14)	(1.06)			(0.15)	(0.08)
AF	–	–	0.43	0.65	7.31	3.82
			(0.51)	(0.18)	(2.69)	(1.45)
AZ	–	–	0.62	−0.10	9.15	1.48
			(0.33)	(0.22)	(2.47)	(1.71)
BA	–	–	0.00	0.29	10.55	7.50
			(0.31)	(0.17)	(3.33)	(1.36)
EI	–	–	1.12	–	7.42	–
			(0.48)		(2.95)	
IB	–	–	1.19	–	8.96	–
			(0.40)		(6.12)	
OS	–	–	–	0.93	–	2.14
				(0.13)	(1.32)	
LH	–	–	0.43	0.44	5.75	4.48
			(0.54)	(1.70)	(2.4)	(1.26)
KL	–	–	0.70	0.39	5.81	5.49
			(0.29)	(0.21)	(2.09)	(1.68)
SK	–	–	0.45	–	6.10	–
			(0.71)		(3.49)	
LX	–	–	0.69	0.47	2.31	3.56
			(0.37)	(0.32)	(2.85)	(1.43)
Regression Statistics	$R^2 = 0.29$	$R^2 = 0.49$	$R^2 = 0.43$	$R^2 = 0.61$	$R^2 = 0.44$	$R^2 = 0.60$
	Adj$R^2 = .27$	Adj$R^2 = .47$	Adj$R^2 = .32$	Adj$R^2 = .56$	Adj$R^2 = .33$	Adj$R^2 = .55$
	Obs. = 67	Obs. = 70	Obs. = 67	Obs. = 70	Obs. = 67	Obs. = 70

Note: The standard error is in brackets
Dummy variable designating the airlines included in the analysis are abbreviated as follows:
AF = Air France; AZ = Alitalia: BA = British Airways; EI = Aer Lingus; KL = KLM; IB = Iberia; OS = Austrian Airlines; LH = Lufthansa; SK = SAS; LX = Swiss

total demand in the market induces the carriers to reduce their capacity by 6.1%. This value decreases to 4.9% for the Asian destinations. The YIELD coefficient is 5.7 for September 11 and 3.6 for SARS, which means that to have a capacity increase of 1%, the yield per passenger (average price) should increase by €12 on a flight of 6,500 km for North America and by €18 on a flight of the same length for Asia. This difference increases if we take into account that the average distance from Europe to North America is 6,500 km and to Asia 9,100 km. In the latter case, the yield per passenger has to increase by €24 in order to have a capacity increase of 1%.

Equation (4.2): The regression explains 43% and 61%, respectively, of the variance of the dependent variable although not all the coefficients are statistically significant at 90%. The dummy coefficients of the September 11 equation can be clustered in three groups with similar reactions to the demand shift (short-term reaction). The first group, composed of Air France, British Airways, Lufthansa and SAS, presented a low or null reaction, a second group including Alitalia, KLM and Swiss had a medium reaction, and a third group formed by Aer Lingus and Iberia had the strongest reaction. In the SARS equation, where the number of carriers is smaller, we are able to identify two groups, one, including British Airways, Lufthansa, KLM and Swiss, with a low reaction, and a second including Air France and Austrian Airlines with a stronger reaction. Therefore, Air France, KLM and Alitalia reacted differently to the SARS crisis than to the September 11 crisis. A theoretical interpretation of this result is provided in the next section.

Equation (4.3): The regression analysis explains, respectively, 44% and 60% of the variance of the dependent variable. As in (4.2), we identify three groups. The first group includes Swiss and Iberia, with no significant YIELD coefficients (low or null reaction); the second includes KLM, SAS, and Lufthansa with a medium reaction to the YIELD variable; and the last group, formed by Aer Lingus, Air France, Alitalia, British Airways, has a strong reaction. On the SARS equation we are able to identify one group including Air France, Austrian Airlines, Swiss and Lufthansa with a low reaction to long-term profitability and a second group including British Airways and KLM, with stronger reaction. In this case we notice that again KLM, Air France and Alitalia have reacted to this second crisis differently.

In the next section, the results are discussed and interpreted in relation to the theoretical framework, in order to draw a picture of the airlines' conduct during exogenous demand shift.

4.3 Results

As mentioned in the introduction to Chap. 3, market shares[4] are a proxy for the costs of adjustment. If we look at the market shares of the nine European carriers flying between Europe and the North Atlantic over the period April–June 2000, then Lufthansa and British Airways are the carriers with the highest adjustment costs in the North American market (with 10.8% and 10.1% of the market, respectively), followed by Air France (6.6%), KLM (5.2%), Swiss (3.2%), Alitalia (3.0%), and, finally, Iberia (1.8%), Aer Lingus (1.6%) and Scandinavian Airlines (1.5%).

In the Asian market, British Airways has the largest market share (7.1%,) followed by Air France (4.6%), KLM (4.0%), Lufthansa (3.4%), Austrian Airlines

[4] An alternative to this formulation is considering the cost of adjustment as reflecting the opportunity cost. This means that fleet flexibility, network structure and other relevant variables should also be included in the explanation of the adjustment costs. We limit our analysis to consider the carriers' market shares as a proxy for adjustment costs.

(3%), Swiss (2.3%) and Alitalia (1.8%). The relationship between market shares and adjustment costs seems less strong in the Asian market.[5]

Hereafter, we present the results of the econometric analysis. We assumed in the previous paragraphs that the YIELD variable is the measure of the long-term profitability, and the PAX variable is the measure of short-term profitability. Therefore, we can use the framework of Fig. 3.3 and display the PAX coefficients of (4.1) on the horizontal axis and the YIELD coefficients of (4.2) on the vertical axis. The estimated coefficients are plotted in Fig. 4.2. Black diamonds represent the carriers' reaction to the US crisis, and the white diamonds their reaction to Asian crisis.[6]

To investigate the functioning of the model, we focus on the carriers' reaction to the shock of September 11. Assuming a linking line is created between British Airways and Lufthansa, and moving out of the origin with other parallel lines, we can order the different behaviour of carriers depending on their flexibility. On the lowest line, we locate Lufthansa and British Airways. On the next lines, we locate Air France and KLM, followed by Alitalia. Aer Lingus and Iberia are located on the highest lines.

The behaviour of Swiss and Scandinavian Airlines does not fit the model. Scandinavian Airlines has 1.5% of the market share and should be plotted somewhere closer to Iberia and Aer Lingus. However, the Nordic carrier is plotted very close to Lufthansa. This might be explained by the commercial coordination among the carriers both being members of the Star Alliance. Apparently, SAS is mimicking the Lufthansa strategy and the partnership affects not only commercial activities but also strategic actions. The position of Swiss on the graph might be explained by the financial situation facing the carrier at the time of the American crisis. In fact, the theoretical model suggests that the financial constraints move carriers towards a short-term strategy. This is evident from the scatter: Swiss reacts to the crisis with a short-term strategy.

The crisis duration expectation is the second factor that affects the carrier conduct. In December 2001, no carrier revealed its network planning for the next 12 months. As crisis prediction is a strategic variable, the carriers tried as much as possible to avoid giving any external signal to their competitors. For this reason, it was impossible to collect reliable data to measure this variable. We have no choice but to assume that the theoretical model is correct, and make some kind of qualitative evaluation. From Fig. 4.2, we notice that British Airways expected a much shorter duration than Lufthansa. They lie on the same line, but have opposite behaviour. Air France and Alitalia were more optimistic than Lufthansa. If it is not the case,

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[5] An alternative to Eqs. 4.4 and 4.5 is to estimate the impact of market shares (*MS*) on the capacity choice as follows:

$$\Delta S = -0.49 + 5.56Y + 0.61\Delta P + 1.97MS \tag{4.4}$$

and

$$\Delta S = -0.40 + 3.53Y + 0.51\Delta P + 0.53MS, \tag{4.5}$$

respectively, for the September 11 and Asian crises. All the coefficients have the correct sign and are significant at 5% with the exception of *MS* for the Asian crisis (Eq. 4.5).

[6] Alitalia's conduct for the SARS crisis is outside the graph (the PAX coefficient is negative). We do not provide any interpretation of this result, but we note that Alitalia has only two routes.

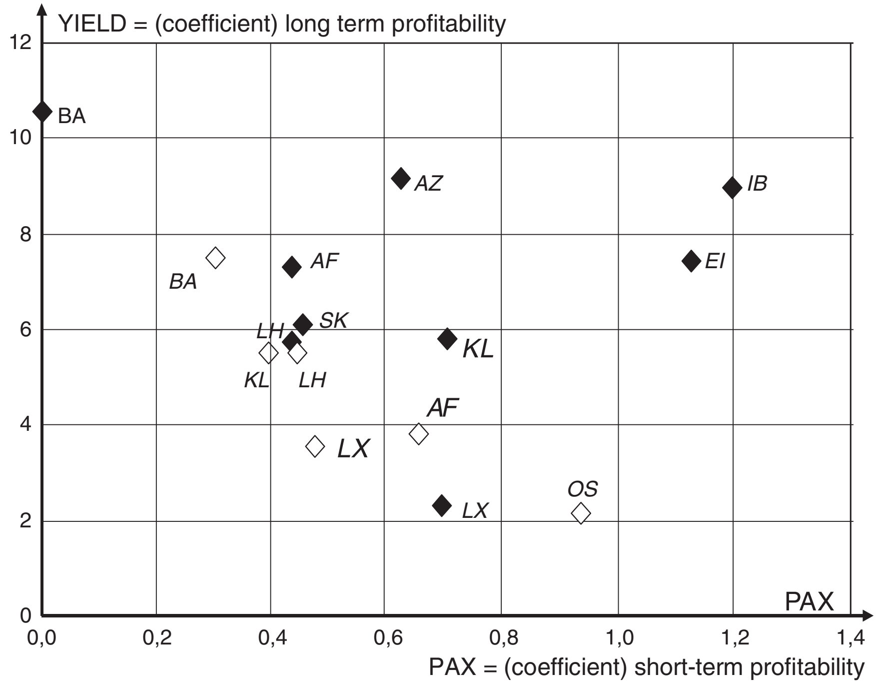

Fig. 4.2 A comparison of carrier's conduct in terms of short- and long-term reaction to crises. *Note*: The *black diamonds* indicate the carrier's reaction due to September 11, while the *white diamonds* indicate the carrier's reaction due to SARS. *Abbreviation*: *AF* Air France; *AZ* Alitalia; *BA* British Airways; *EI* Aer Lingus; *KL* KLM; *IB* Iberia; *OS* Austrian Airlines; *LH* Lufthansa; *SK* SAS; *LX* Swiss

the YIELD reaction of the two carriers should be lower than that of Lufthansa. The same considerations can be applied to the other carriers. For example, Iberia and Aer Lingus expected the crisis to have a longer duration than KLM, and KLM expected a shorter duration than that of Lufthansa. Swiss should have the shortest expected duration of the crisis but again its strategy might result from the financial problems of the company that forced its reaction in the short-term.

Alternatively, we can interpret a different positioning on the line as a different evaluation of the 'strategic' importance of the market. A carrier evaluating a market as 'very strategic' has a low discount rate on this market, and hence it will focus on the long-term more than the short-term returns. This could explain the positioning of British Airways with respect to the other large carriers. Since the North American market is very strategic for British Airways, it reacts only to long-term but not to short-term aspects.

Figure 4.2 also provides a representation of carriers' conduct induced by the Asian crisis. Before analysing specifically the behaviour of the carriers, we try to emphasize the main differences between the first and the second crisis. As a general remark, we observe that, compared with the North American crisis where only 1/3 of the capacity choice variation is explained by the PAX and the YIELD variables, in the Asian crisis about 2/3 of the capacity variation is explained by the same variables. This is because either better data was collected on the Asian crisis or because the carriers' strategies are based more on the short- and the long-term variable in the Asian crisis than in the North American crisis. If the second point is true, it may mean that carriers in the second crisis had gained experience from the previous crisis, and therefore they could better calibrate their strategies on short- and long-term parameters. There are also other interpretations of a better fit of the second model, such as that carriers in the North American market have a more complex strategy involving other variables more strongly than in the Asian market.

There are three main differences in the carriers' conduct in the two crises. First, the reaction in the Asian crisis was lower than in the North American crisis. This emerges by comparing column 1 with column 2 of Table 4.3, where PAX values are, respectively, 0.49 and 0.61, and YIELD values are, respectively, 3.60 and 5.96. On the graph, the white diamonds are closer to the origin than the black diamonds. Following our conceptual framework, it means that, on average, the adjustment costs of the carrier are higher in the Asian market.

Second, the reaction to the Asian crisis was focused on short-term aspects and not on long-term aspects. There are many explanations for this result. A first explanation that we do not entirely believe is that the expectation of the crisis duration was shorter for the American crisis than for the Asian crisis. This is true if we think that carriers underestimate the duration of the crisis in the first shock and overestimate its duration in the second shock. A slightly different interpretation can be provided by assuming that carriers can learn from the past, and thus a sort of mimicking behaviour of carriers emerges. Hence, British Airways having had a wrong reaction to the first shock decided to recalibrate its conduct in the second shock. KLM having been too much reactive to the PAX variable after September 11 chose to adopt a strategy similar to Lufthansa after the SARS epidemic. The same argument is valid for Swiss. Lufthansa having been right has decided not to change. A third explanation for the different behaviour in the two crises is given by the fact that Asian market is not so crucial as the North American market for European carriers. This explains the shift towards the short-term choice of British Airways and Air France. Finally, a more fundamental explanation for the short-term attention of carriers is in the differences of the markets. The Asian market is characterized by higher operating costs and lower margins, meaning that the reduction of profitability (revenue–costs) when there is a demand shift in the short term is higher for the Asian market than for the North American market. Moreover, the crises affecting the Asian market before March 2003 (i.e. not only September 11 but also the Afghanistan war and the October 2002 Bali terrorist attack) might have induced carriers not to focus on the long-term indicators.

Thirdly, it does not seem that there are important adjustment-cost differences among carriers since they lie very close to the same line. Just as in the American crisis, during the SARS epidemic, we see that there were some carriers which followed the ordering as expected from the model, but there are some exceptions. Here, British Airways, KLM and Lufthansa are on the same line, with Air France slightly higher and Austrian Airlines a little bit higher still. Swiss is out of the scheme and has the same behaviour as in the first shock. Financial constraints forced this carrier to focus on the short term rather than long term.

Applying the theoretical framework to detect the behaviour during the Asian crisis, we note that all carriers can be easily sorted in terms of expectation of the crisis duration. Austrian Airlines expected longer crisis duration than Air France. Lufthansa and KLM had similar expectations. Then British Airways expected the crisis would have a short duration. Finally, assuming that Swiss was financially constrained, its expected duration was closest to the expectations of Lufthansa and KLM. As already mentioned, the expectation of the crisis duration can be also interpreted as the strategic or non-strategic goals of the carriers.

Now we compare the conduct of the four main carriers in the two situations. First of all, we observe that Lufthansa did not change its behaviour. British Airways that was very optimistic in the North American crisis has changed its strategy, and aligned with one of other players. Also, KLM aligned with its main competitor, Lufthansa. These three carriers moved towards or maintained a balanced conduct by mixing short- and long-term goals. On the contrary, Air France did not seem to be confident of a quick recovery from the crisis and assumed a longer duration of the crisis.

4.4 Conclusions

Empirical analysis suggests that the theoretical model presented in Chap. 3 is useful to interpret both the North American and the Asian crises. The main differences we find for the two crisis situations are: the carriers' reaction to the Asian crisis was lower than in the North American crisis; it was focused on short-term aspects; and there were less adjustment-cost differences among carriers.

An open question is whether or not carriers learn from past events. We think that it is possible. If we assume that carriers base their strategies only on short- and long-term gains, we see that these two variables explained 2/3 of the capacity choice in the Asian crisis but only 1/3 in the North Atlantic crisis. Hence, carriers have been more consistent in managing the Asian crisis than the North American crisis. Further evidence comes from the behaviour of British Airways. In fact, it seems that British Airways modified its strategy by changing from a situation where it only cared about long-term variables towards a more balanced situation, closer to the Lufthansa/KLM strategy.

Part III
The Rise of Low-Cost Carriers

Chapter 5
Effects of LCC Entry on Pricing in Aviation[1]

We are what we repeatedly do.
Excellence then, is not an act, but a habit.

Aristotle

5.1 Introduction

A low-cost carrier (LCC) has been defined, in Chap. 2, as an airline designed to have a competitive advantage in terms of costs over a full-service carrier (FSC). An LCC relies on a very simple firm organization and logistic principles. In Chaps. 5 and 6 we try to explain the airline supply process by analysing the LCC versus the FSC network configuration. In contrast to the hub-and-spoke structure of the FSC, the LCC offers point-to-point connections from secondary airports, i.e. smaller airports – such as London Luton – that are less expensive in terms of landing tax and handling fee than bigger airports such as Heathrow or Manchester. The fleet generally includes one type of aircraft that operates more hours a day than the traditional carriers in order to maximize its utilization on a daily basis. The LCC product is not differentiated and the distribution is as simple as possible, by making use of Internet direct sales and electronic tickets. The resulting cost gap between the low-cost model and the FSC model allows the LCC to set airfares on average much lower than traditional carriers.

In order to understand why low-cost carriers have managed to expand in the airline market, it is also important to consider structural developments on the demand side. In general, the process of internationalization and globalization has increased not only the mobility of goods, but also of people. Trade agreements and an expansion of cargo transport have contributed to an increase in – or are related to – the high mobility of business travellers. Also, the behaviour of tourists has drastically

[1] An early version of this chapter was published as Discussion Paper 074/3 of the Tinbergen Institute, Amsterdam.

A. Cento, *The Airline Industry: Challenges in the 21st Century*,

changed. Travellers seem to be shifting to multiple and short holidays as opposed to traditional long stays, while also the loss of the glamour involved with flying – and hence lower service levels – is accepted by many travellers nowadays.

Therefore, this chapter investigates how the FSCs compete in price and respond to the entry of LCCs. We develop a model of airline competition, which accommodates various market structures, some of which include low-cost players. In Sect. 5.2.1, we recall some basic concepts concerning product differentiation and yield management techniques as described in Chap. 2. In Sect. 5.2.2, we propose a theoretical framework of airline competition, which accommodates different market structures. In the monopoly case (Sect. 5.2.3), we analyse the behaviour of an FSC, and use this case as a benchmark. In the symmetric duopoly case (Sect. 5.2.4), and asymmetric duopoly case (Sect. 5.2.4) we study the competition between two FSCs, and between one FSC and one LCC, respectively. The model is finally extended to the case of asymmetric oligopoly (Sect. 5.2.6), where the interaction between two FSCs and one LCC is considered. The overall results of the model for each market case are then compared and summarized.

We offer an empirical test of the theoretical model in Sect. 5.3. After presenting the main variables of the database (Sect. 5.3.1), we verify some of the theoretical outcomes by providing an estimation of the impact of traditional competitors and low-cost competitors on the fares of FSCs. We use monthly data on the airfares of Lufthansa, British Airways, Alitalia and KLM for the top-12 city-pairs from Italy to Europe (April 2001–July 2003). Contrary to what is done in other research projects, we do not consider average prices, but perform an analysis on the basis of 8 different classes of airfares. A first finding is that competition among traditional carriers affects the price levels of business and leisure segments asymmetrically. In moving from a monopoly to a symmetric duopoly, the business fares appear to decline more than the economy fares. The second interesting result is that LCCs affect all the airfares uniformly.

Section 5.4 makes some concluding remarks and suggestions for further research.

5.2 Pricing Models for Different Market Structure

5.2.1 Yield Management

In Chap. 2, we explained that the goal of yield management is to maximize the revenue of a carrier operating in a market with a perishable product given the limited aircraft capacity. Compared with other sectors, the airlines yield management is complicated by high demand fluctuations, consumer heterogeneity, and uncertainty about the traveller's departure date or destination. We identified two aspects of yield management: (1) customers are heterogeneous in travel behaviour or willingness-to-pay, and thus carriers can differentiate the product; (2) once the output is produced (availability of seats), costs can be considered sunk costs and thus the yield maximization problem coincides with the profit maximization. We called *traditional* *yield management* the set of techniques adopted by the FSCs and *simplified yield management* those adopted by the LCCs. Traditional yield management can be described by six simple principles: market segmentation; product differentiation; price setting; fences; availability control; and distribution. Simplified yield management differs radically from traditional yield management with respect to two elements. Segmentation is only applied through time of booking and choice of flight. The passenger who wishes to pay lower prices must book early, or on the flights for which there is less demand.[2] The product is not differentiated by additional services and fences which are removed from the airfares as no segmentation is applied. The simplified yield management techniques do not apply any explicit price discrimination, except for a dynamic pricing based on the departure date, while traditional yield management chooses the best combination of fares and conditions for each product category (quality) and for each passenger category.

5.2.2 Theoretical Framework

In this subsection we develop a theoretical model to analyse the airlines price competition. The framework is based on recent literature on product differentiation in oligopolistic markets.[3] Previous contributions such as Murphy (1977), Oren et al. (1983), Calem and Spulber (1984), and Holmes (1989) assumed no interdependencies among markets, i.e. business travellers do not demand the leisure products and vice-versa. However, contrary to those authors, we follow the approach of Wilson (1993), Rochet and Stole (2002) and Dessein (2003) who all developed a model with market interdependencies.[4] This approach is quite different from the traditional scheme, in that the firm's demand is not represented as a function of prices, but is expressed in terms of utility levels provided to consumers by the firms. In this set-up, Rochet and Stole proved that the assumption of interdependency does not affect the market equilibrium (both in terms of qualities and prices), when oligopolistic markets are characterized by symmetric firms.[5]

[2] As explained in Chap. 2, LCCs modify the selling price of each flight as a function of the departure date. If a price is too low, the flight will fill up early and higher-yielding late-booking business will be turned away. On the contrary, if the price is too high, the flight is at risk of departing with empty seats.

[3] Other authors, e.g. Carlton (1977) and Dana (1999a, 1999b) have focused on the complementary aspect, which involves price discrimination that concerns peak and off-peak pricing when demand is unknown.

[4] Many other authors have analysed this topic. Among these authors, it is worth, from a theoretical point of view, mentioning Ivaldi and Martimort (1994), Stole (1995), Armstrong (1996), Jamilton and Thisse (1997), Armstrong and Vickers (2001), Jensen (2001), Valletti (2002) and Dessein (2003). From an empirical point of view, it is worth mentioning Borenstein (1985), Berry (1992), Borenstein and Rose (1994), Mason (2000), McManus (2001) and Macskási (2003).

[5] Note that this result differs from that of the monopoly case, where the presence of interdependency affects the equilibrium (both in terms of quality and prices), (see Mussa and Rosen 1978). On the contrary, Alderighi (2004) shows that interdependency matters when we consider market structures with asymmetric firms.

Our model differs from the previous ones as it sets the problem in the traditional form (i.e. in terms of prices), but it takes into account the market interdependencies. This simplification is possible as we assume that qualities are exogenously determined as in traditional oligopolistic models. Hence, we arrive at our intermediate position between the traditional modelling approach and the one proposed by Wilson.

We assume that there are two types of firms: traditional firms (namely, L or R), and low-cost firms (namely, S or M). They differ with regard to two aspects. A traditional firm can offer products of two different qualities: q_1 and $q_2, q_1 < q_2$, with corresponding unit costs $c_1 < c_2$. A low-cost firm can only provide products of quality q_1 with costs $c_0 \leq c_1$. In other words, traditional firms can offer a full range of products but at higher cost, while low-cost firms can offer a restricted range of products but at lower cost.

Consumers are vertically heterogeneous and form two markets: the strong market (business travellers with a high willingness-to-pay: namely, t_2) and the weak market (leisure travellers with a low willingness-to-pay: namely, t_1). The size of the weak market is $\mu_1 = \mu$, and the size of the strong market is $\mu_2 = 1 - \mu$. Both types of consumer appreciate quality, although the consumers belonging to the strong market are more interested in quality than the others. Let $u_{il} = t_i q_l$ be the utility evaluation of a product of quality l by consumer i. Hence, we assume that:

$$u_{i2} > u_{i1} \quad \text{for } i = 1,2 \text{ and } u_{22} - u_{21} > u_{12} - u_{11} \tag{5.1}$$

Traditional firms design products of quality q_1 for the weak market, and products of quality q_2 for the strong market. In any case, since markets are interdependent, there can be diversion, i.e. a t_2-type consumer can be interested in a product designed for t_1. Let us call p_{1j} the price charged by firm j for q_1, and p_{2j} the price for q_2. To avoid diversion, firm j must choose p_{1j} and p_{2j}, so that the net utility of t_2, when he/she buys q_2, is at least equal to his/her net utility when he/she buys q_1. This means in formal terms: $u_{22} - p_{2j} \geq u_{21} - p_{1j}$. Note that this inequality may also be written as:

$$p_{2j} - p_{1j} \leq r, \tag{5.2}$$

where $r = u_{22} - u_{21}$. This condition is known as the 'incentive compatibility constraint'[6] (IC).

Consumers are also horizontally heterogeneous so that, ceteris paribus, some of them prefer to buy from firm L and others from firm R, S or M. In other words, consumers' preferences are heterogeneous with respect to the brand. Interpreting this in terms of spatial distribution of consumers, we can imagine that consumers

[6] The incentive compatibility constraint is said to be binding when a firm chooses the prices of high quality and low quality products in such a way that high willingness-to-pay consumers are indifferent to buying a high quality product at a high price and buying a low quality product at a low price. On the contrary, the incentive compatibility constraint is said to be slack when prices are set in such a way that consumers of the strong market will strictly prefer a high quality product to a low quality product.

are uniformly distributed on a unitary Hotelling (1929) segment, and that firms are located at different points on the line. We normalize the consumer mass to 1.

The unitary (transportation) cost of consuming a product, which differs horizontally from the consumer's ideal one is σ. Taking all these things into account, the utility of a consumer of type i located at x, who consumes a product of quality l from firm j located at y_j, is then equal to: $u_{il} - p_{lj} - \sigma|x - y_j|$.

We will analyse four different situations:

1. Monopoly: one traditional firm L on the market located at $y_L = 0$;
2. Symmetric duopoly: two traditional firms on the market; namely: L and R, located at $y_L = 0$ and $y_R = 1$;
3. Asymmetric duopoly: one traditional firm L and one low-cost firm S, located, respectively, at $y_L = 0$ and $y_S = 1$;
4. Asymmetric oligopoly: two traditional firms L and R, and one low-cost firm M, located, respectively, at $y_L = 0, y_R = 1$ and $y_M = 1/2$.

In this set-up, it is important to compute the consumer demand of firm $j = L, R, S, M$ in the market i, i.e. the number of consumers of type t_i who will buy from j. Let d_j and p_{lj} be, respectively, the distance of a selected consumer from firm j and the prices charged by firm j for a product of quality l. A consumer will buy a product of quality l from $j \neq k$, if $u_{il} - p_{lj} - \sigma d_j < u_{il} - p_{lk} - \sigma d_k$, where $k = 0, L, R, S$ and M, p_{lk} and d_k are, respectively, the price charged by and the distance from the competitor. When $k = 0$, the inequality captures the decision of not buying, i.e. $p_{l0} = u_{il}, d_0 = 0$.

Assume[7] that there is no diversion, i.e. firms charge prices so that the incentive compatibility constraint of (5.2) is satisfied. So, the demand for a product of quality q_l faced by the monopolist L in the market t_i with $l = i$ is:

$$D_{iL}(p_{iL}) = \mu_i \bigcup \left(\frac{u_{ii} - p_{iL}}{\sigma} \right), \tag{5.3}$$

where $\cup$ is the cumulative uniform distribution with support [0,1].

Now, in duopoly,[8] the demand for L in the market t_i is:

$$D_{iL}(p_{iL}, p_{ik}) = \mu_i \bigcup \left(\frac{1}{2} + \frac{p_{ik} - p_{iL}}{2\sigma} \right), \tag{5.4}$$

where $k = R, S, M$. Analogously, the demand for $j = R, S$ is:

$$D_{ij}(p_{ij}, p_{iL}) = \mu_i \bigcup \left(\frac{1}{2} + \frac{p_{iL} - p_{ij}}{2\sigma} \right). \tag{5.5}$$

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[7] We add a technical assumption in order to restrict the number of possible cases, thus focusing on the more interesting ones. We assume that a monopolist wants to serve all the customers of type t_2 and at least one half of type t_1. This corresponds to the assumption that consumers are not too differentiated horizontally and vertically. As a consequence, in the duopoly case both markets are completely covered.

[8] Also in this case we assume that firms will satisfy the incentive compatibility constraint.

As already noted, a low-cost firm is not able to offer a product of quality q_2, and hence it also has to offer a product of quality q_1 to consumers belonging to the strong market. Since the evaluation of a t_2-type consumer for a product of quality q_1 differs from the one of quality q_2 by an amount equal to $r = u_{22} - u_{21}$, the perceived price of a product of quality q_1 is $p_{2S} = p_{S1} + r$. In other words, p_{2S} indicates the price adjusted for the quality.

5.2.3 Monopoly

Using (5.2) and (5.3), we can write down the optimization problem of the monopolist L:

$$\max \sum_{i=1,2} D_{iL}(p_{iL})(p_{iL} - c_i), \quad \text{s.t.}\, p_{2j} - p_{1j} \leq r. \tag{5.6}$$

The monopoly framework produces a wide range of cases depending on whether it is optimal for the firm to partially or completely cover the markets, and whether or not the incentive compatibility constraint is binding.

In order to simplify the analysis, and considering the more interesting case, we solve the model assuming a partial coverage (at least half) of the weak market and a full coverage of the strong market when IC is binding. Under these assumptions, the optimization problem of the monopolist becomes as follows:

$$\max \mu \frac{u_{11} - p_{1L}}{\sigma}(p_{1L} - c_1) + (1 - \mu)(p_{1L} + r - c_2) \tag{5.7}$$

The first-order conditions imply that:

$$p_{1L} = \frac{1}{2}\left((c_1 + u_{21}) + \sigma \frac{1 - \mu}{\mu}\right), \quad \text{and} \quad p_{2L} = p_{1L} + r. \tag{5.8}$$

Clearly, prices are related to the variables of the model in the following way: (a) prices are increasing with costs; (b) (all) prices decline when the size of the weak market is large with respect to the size of the strong market; and (c) prices are increasing with the parameters that measure the horizontal heterogeneity.

5.2.4 Symmetric Duopoly

As we have already assumed, a firm will completely cover the strong market and at least half of the weak market. As a direct consequence, in the duopoly case, both markets are covered. The optimization problem of firm L is as follows:

$$\max \sum_{i=1,2} \mu_i \left(\frac{1}{2} + \frac{p_{ik} - p_{iL}}{2\sigma}\right)(p_{iL} - c_i). \tag{5.9}$$

We solve the model by assuming that the incentive compatibility constraint is slack, and then we check whether the constraint is satisfied. From the first-order conditions we have:

$$p_{iL} = \frac{1}{2}(c_i + p_{ik} + \sigma), \tag{5.10}$$

where $k = R$. By symmetry $p_{iL} = p_{iR}$, and hence:

$$p_{iL} = c_i + \sigma. \tag{5.11}$$

Consequently, the IC constraint is satisfied when:

$$c_2 - c_1 < r = u_{22} - u_{21}. \tag{5.12}$$

Condition (5.12) is satisfied when costs are not too different, and when weak and strong markets are sufficiently differentiated. It is worth noting[9] that, if $c_2 - c_1 > u_{22} - u_{21}$, then, for a firm, it is better to only produce quality q_1, as the costs to produce q_2 are higher than the advantages coming from the opportunity of charging different prices. Consequently, we assume that condition (5.12) is always satisfied, and hence IC is never binding in the duopoly case. Intuitively, competition is enough to reduce prices in the strong market more than in the weak market. In the next section, we will show that this is also the same for the asymmetric case, where the competition introduced by a low quality product is enough to limit the prices in the strong market.

5.2.5 Asymmetric Duopoly

In the asymmetric duopoly case, we assume that there is a traditional firm L, located at 0, and a low-cost firm, S, located at 1. The low-cost firm has a competitive advantage in costs, but it cannot provide the full range of products (quality q_2).

As in the previous case, we start by assuming that IC is not binding and then we check whether this is indeed the case. As one will see, when firm S sells in the strong market, IC is always slack. Depending on the level of vertical heterogeneity, S may, or may not, be able to sell on the strong market. We will focus on the first case. We know that firm S, as it cannot provide a high quality product for type t_2, offers the same quality product for both markets, which corresponds to q_1. Hence, firm S has only to choose a unique price for the same product offered to consumers of both the weak and strong market. The optimization problem of firm S is as follows:

$$\max \mu \left(\frac{1}{2} + \frac{p_{1L} - p_{1S}}{2\sigma}\right)(p_{1S} - c_0) + (1-\mu)\left(\frac{1}{2} + \frac{p_{2L} - p_{1S} - r}{2\sigma}\right)(p_{1S} - c_0). \tag{5.13}$$

[9] This result is not specific for the duopoly case, and it also holds for the monopoly case.

Note that the price charged by firm S in the strong market is p_{1S}, but it is perceived as $p_{1S}+r$, as it is adjusted for the expected quality q_2. The solution to the maximization problem is:

$$p_{1S} = \frac{1}{2}\left(c_0 + \sigma + \mu p_{1L} + (1-\mu)(p_{2L} - r)\right). \tag{5.14}$$

Using (5.5) we obtain:

$$\begin{aligned} p_{1S} &= \frac{2}{3}c_0 + \frac{1}{3}\omega + \sigma, \\ p_{1L} &= \frac{1}{3}c_0 + \frac{1}{2}c_1 + \frac{1}{6}\omega + \sigma, \\ p_{2L} &= \frac{1}{3}c_0 + \frac{1}{2}(c_2 + r) + \frac{1}{6}\omega + \sigma, \end{aligned} \tag{5.15}$$

where $\omega = \mu c_1 + (1-\mu)(c_2 - r)$.

From (5.15), we have that $p_{2L} - p_{1L} = \frac{1}{2}(c_2 - c_1 + r)$. This is the same result as for the duopoly case. Under condition (5.12), the incentive compatibility constraint is not binding. Moreover, it is worth mentioning that this result does not require that $c_0 \leq c_1$, and hence it refers to each situation where there is asymmetric competition, and not only to those situations where the traditional player competes with an opponent characterized by a competitive advantage in costs. It is interesting to analyse what happens to the market shares of S in the two markets:

$$MS_{1S} = D_{1S}(p_{1S}, p_{1L})/\mu = \frac{1}{2} + \left(\frac{1}{2}c_1 - \frac{1}{3}c_0 - \frac{1}{6}\omega\right)/(2\sigma), \tag{5.16}$$

$$MS_{2S} = D_{2S}(p_{1S}, p_{2L})/(1-\mu) = \frac{1}{2} + \left(\frac{1}{2}(c_2 + r) - \frac{1}{3}c_0 - \frac{1}{6}\omega\right)/(2\sigma). \tag{5.17}$$

In Fig. 5.1, we plot the graph of the market share MS_{1S} and MS_{2S} as a function of the willingness-to-pay ratio t_1/t_2 for $\sigma = 0.1$ (smooth lines), 0.2 (spotted lines) assuming that $t_i = \sqrt{u_{ii}}, c_i = u_{ii}/2, c_0 = 0.75 \cdot u_{11}, \mu = 0.7$, and $t_2 = 1$. The horizontal axis is the ratio t_1/t_2. If t_1/t_2 is low, then the weak and the strong market are strongly differentiated, and when t_1/t_2 is close to 1, there is low vertical heterogeneity. First, the market share of the low-cost firm in the weak market (smooth black line) is weakly affected by its parameters. Second, it appears that, for a low value of t_1/t_2, the product of S is not attractive for the strong market and its market share, MS_{2S}, is very small. When $\sigma = 0.1$ (small horizontal differentiation), the competition is intense so that the markets are more polarized. When t_1/t_2 is about 0.32, firm L retains all of the strong market.

As a final remark, if firm S does not sell products in the strong market, firm L is not free to charge a monopoly price because of potential competition of the products of firm S. Practically, firm L charges a price p_{2L} to exclude firm S, and hence $p_{2L} \leq p_{1S} + r + \sigma$.

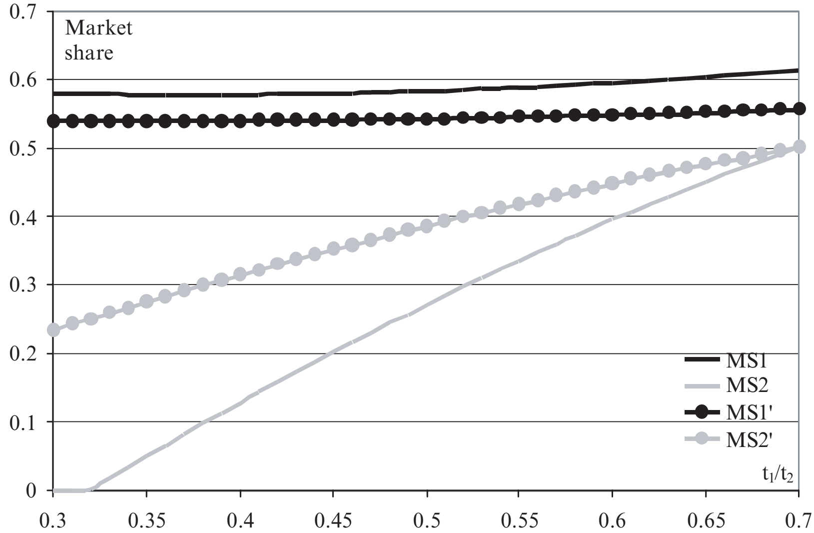

Fig. 5.1 Market shares simulation of a low-cost firm in the weak and strong market

5.2.6 Extension and General Outcomes

The previous set-up can be extended to assess the oligopoly market structure. One of the possible oligopoly situations is the case of three firms: namely, two traditional firms located at the extremes of the unitary segment L and R, and one low-cost firm, M, in the centre. When low-cost firms have a positive market share (i.e. the vertical differentiation is not too high), the results are similar to the previous ones:

$$p_{1M} = \frac{2}{3}c_0 + \frac{1}{3}\omega + \tilde{\sigma}$$

and

$$p_{1L} = p_{1R} = \frac{1}{3}c_0 + \frac{1}{2}c_1 + \frac{1}{6}\omega + \tilde{\sigma}, \quad p_{2L} = p_{2R} = \frac{1}{3}c_0 + \frac{1}{2}(c_2 + r) + \frac{1}{6}\omega + \tilde{\sigma}, \tag{5.18}$$

where $\omega = \mu c_1 + (1-\mu)(c_2 - r)$.

Equations (5.15)–(5.18) differ only for the term $\tilde{\sigma} = \sigma/2$. Therefore, prices are lower than asymmetric duopoly as the firms can assert less monopoly power (lower horizontal differentiation). Moreover, a strong market price in oligopoly equals the price in symmetric duopoly when there is strong vertical differentiation. However, there are no cases where oligopolistic prices are higher than duopolistic prices. In order to highlight the link between the theoretical model and the empirical results, in the next section we present a short summary of the main outcomes from the previous sections. Table 5.1 reports the prices per market structure and segment.

Table 5.1 Prices per market structure and segment

Market structure	Economy price (P1)	Business price (P2)
Monopoly	$p_{1L}^{mon} = \frac{1}{2}\left((c_1 + u_{21}) + \sigma\frac{1-\mu}{\mu}\right)$	$p_{2L}^{mon} = p_{1L}^{mon} + r$
Symmetric Duopoly	$p_{1L}^{sym} = p_{1R}^{sym} = c_1 + \sigma$	$p_{2L}^{sym} = p_{2R}^{sym} = c_2 + \sigma$
Asymmetric Duopoly	$p_{1S}^{asy} = \frac{2}{3}c_0 + \frac{1}{3}\omega + \sigma$	$p_{2L}^{asy} = \frac{1}{3}c_0 + \frac{1}{2}(c_2 + r) + \frac{1}{6}\omega + \sigma$
	$p_{1L}^{asy} = \frac{1}{3}c_0 + \frac{1}{2}c_1 + \frac{1}{6}\omega + \sigma$	
Oligopoly	$p_{1M}^{oly} = \frac{2}{3}c_0 + \frac{1}{3}\omega + \tilde{\sigma}$ $p_{1L}^{oly} = p_{1R}^{oly} = \frac{1}{3}c_0 + \frac{1}{2}c_1 + \frac{1}{6}\omega + \tilde{\sigma}$	$p_{2L}^{oly} = p_{2R}^{oly} = \frac{1}{3}c_0 + \frac{1}{2}(c_2 + r) + \frac{1}{6}\omega + \tilde{\sigma}$
	where $\omega = \mu c_1 + (1-\mu)(c_2 - r)$	

The following inequities hold:

$$\text{Weak market: } p_{1L}^{oly} < p_{1L}^{asy} < p_{1L}^{sym} < p_{1L}^{mon}; \tag{5.19}$$

$$\text{Strong market: } p_{2L}^{oly} < p_{2L}^{sym} < p_{2L}^{asy} < p_{2L}^{mon}. \tag{5.20}$$

Using (5.12) and $\omega = \mu c_1 + (1-\mu)(c_2 - r)$, we have that:

$$c_2 - r \leq \omega \leq c_1. \tag{5.21}$$

Combining (5.21) with the assumption that c_0 is not too small, we can prove the first two inequalities of (5.19) and (5.20). In order to prove the last inequalities, we require the assumption of full coverage of the strong market in the monopoly case (Sect. 3.5). This means that $u_{22} - p_{2L}^{mon} \geq \sigma$ or, after substituting for p_{2L}^{mon}:

$$u_{21} - c_1 \geq \frac{1+\mu}{\mu}\sigma. \tag{5.22}$$

Using condition (5.21) and (5.22), the results can be easily proved.

Finally, we have shown that the incentive compatibility constraint is binding only for the monopoly case. In the other market structures, the relaxed optimization problem proved that the IC is never binding. Moreover, we showed that the incentive compatibility constraint is never binding if condition (5.12) holds, i.e. when the costs of producing two qualities are not too different, and when weak and strong markets are sufficiently differentiated. This means that the price levels are the result of the competitive interaction (relaxed solution). As a result of the interdependence between the leisure and the business market, the LCC entry impacts the price levels of the business segment, even though it does not offer a full business product. Inequity (5.19) and (5.20) are empirically tested in the next section.

5.3 Evidence on Price Setting in Europe

In this section we investigate the pricing strategy of the FSC in relation to the LCC entry. In particular, we empirically test the inequalities (5.19) and (5.20), in order to compare the effects of traditional and low-cost competition on the airfares of the FSC.

5.3.1 The Database

Data were collected for selected intra-European, non-stop traffic flows.[10] We restricted the analysis to city-pairs between Italy and the main destinations in the Netherlands, Germany, and the UK. About 41 origins and destinations were selected, where one, two, or more carriers offer direct services. We observe the market dominance of the FSCs for most of the city-pairs. In particular, at least 80% of the market share is covered by one FSC for 11 city-pairs,[11] by one FSC and one LCC for 9 city-pairs, by two FSCs for 15 city-pairs and by two FSCs and one LCC for 5 city-pairs. Only for one city-pair (Milan-London) is 60% of the market equally covered by two FSCs, and the remaining 40% of market share is spread over other smaller carriers (including LCCs). We have selected four FSCs: Lufthansa, British Airways, Alitalia, and KLM.

All historical and current airfares that have been published in Italy were downloaded from the computer reservation system Galileo.[12] The historical data are necessary in order to compare the fares before and after the LCC entry. The sample contains monthly observations over the period April 2001–July 2003 for any available reservation class of Lufthansa, British Airways, Alitalia, and KLM, with a total of 14,151 airfares. Table 5.2 presents an overview of the number of observations per destination and carrier.

As discussed, yield management enables carriers to segment the market by offering fares with different price levels, rules and conditions. Any fare is linked to a specific reservation class (indicated by a capital letter) that carriers virtually create to allocate the optimal number of passengers on the aircraft. The database contains different numbers of subclasses per carrier that varies from 12 for British Airways to 9 for KLM belonging to two different aircraft cabins: economy and business. Subclasses are for different market segments. Carriers determine their own market segmentation and the relative subclass structure. We attempt to cluster similar subclasses in one unique class mapping. Table 5.3 presents the 8 identified clusters, of which 6 are in economy class and 2 are in business class.

[10] Analogously, Nero (1998), in order to analyze duopolistic competition, considers only non-stop direct service carriers.

[11] The remaining 20% of the market is covered by one or more different small carriers, including LCCs.

[12] The fares have been downloaded from the CRSs with the support of the KLM Revenue Management Department in Amsterdam.

Table 5.2 Number of observations in the sample by destination and carrier

Destinations	Alitalia	British A.	KLM	Lufthansa	Total
Amsterdam (AMS)	573		1,971		2,544
Birmingham (BHX)		863			863
Dusseldorf (DUS)	632			560	1,192
Frankfurt (FRA)	657			1,634	2,291
Hamburg (HAM)				212	212
London (LON)	973	2,083			3,056
Manchester (MAN)		680			680
Munich (MUC)	612			1,802	2,414
Stuttgart (STR)	443			457	900
Total	3,890	3,626	1,971	4,665	14,152

Table 5.3 Booking class mapping between booking sub-classes of carriers

Cabin service	Type of fare	Alitalia	KLM	British A.	Lufthansa
Economy cabin	Promotional	O-N	V-T	Q-N	W-V
	Discounted1	W-T	L	V-L	Q-H
	Discounted2	Q	K	M	M
	Economy1	B	B	K-H	B
	Economy2	M	S	B-I	B
	Unrestricted1	Y	Z	Y	Y
Business cabin	Unrestricted2	I	C	D	D
	Unrestricted3	C	J	J	C

Table 5.4 Descriptive statistics of the econometric model dependent variable (in euros)

Service cabin	Type of fare	Mean	Std. Dev.	Min.	Max.
Economy cabin	Promotional	167	33.9	99	295
	Discounted1	276	60.1	165	411
	Discounted2	361	58.7	240	494
	Economy1	454	102.3	300	732
	Economy2	580	100.3	320	838
	Unrestricted1	815	161.0	440	1,092
Business cabin	Unrestricted2	887	151.7	558	1,171
	Unrestricted3	898	207.5	574	1,459
Total	Total	498	255.7	99	1,459

The first cluster has been named *Promotional*, as it includes the lowest published fares of all four carriers. Then there are two discounted classes of tariffs and two economy classes. The three highest fare clusters have been named *Unrestricted1, 2, and 3,* as they are addressed mainly to business passengers who require maximum flexibility of travel conditions. In particular, *Unrestricted1* is addressed to the business passenger accommodated in the economy cabin. Table 5.4 provides some descriptive statistics about the fare clusters.

The literature on airfare pricing has identified a number of different factors, that affect the determination of the airfare. These factors include, for instance, network structure, type of plane, marketing alliances (Proussaloglou and Koppelman, 1995), hub dominance (Lijesen et al., 2004), and competition from other modes of transportation. Vowles (2000) modelled the airfares as depending on geographical factors, such as air distance from the two travel points, or market dominance, and specifically on the role of low-fare carriers.

We model the airfares as depending on geographical factors, demand factors and market competition, which is similar to the approach of Vowles. In particular, the market competition has been analysed in two modes: the competition among FSCs, and the competition with LCCs. This distinction is necessary to detect the possible differences between LCC and FSC impact on the airfares. The following variables have been considered:

1. *DIST*: the air distance from the origin to the destination represents an approximation of the carrier operation costs. We expect that there is a positive impact of the distance (measured in kilometres) on airfares, as any additional kilometre that an aircraft flies is reflected in additional costs for the carrier. Data on the distance are collected from the Official Airline Guide.
2. *GDP*: Gross domestic product per capita of the departure airport catchment's area is an indication of the passenger income and can therefore provide information of the passenger's willingness to pay. The average gross domestic product per inhabitant (in thousands of euros) of the Italian region where the origin airport is located has been included in this analysis. The source is Eurostat (2004), the regional statistics database.
3. H: the Herfindal-Hirshman index is a widely accepted indicator for concentration on a market. The index is defined as:

$$H = \sum_j x_j^2 \Big/ \left(\sum_j x_j \right)^2, \tag{5.23}$$

where x_j is defined as the output sold by company j, and the sum extends over all the FSCs operating in the market. In the airline industry, the output can be the number of passengers or revenues that are generated on a route. Those data are not available at the route level, and therefore the weekly flight frequency has been adopted as output indicator. We limit the H calculation to no-stop frequencies. This choice has no severe consequences for the results, as the market shares of indirect carriers are limited to a maximum of 5% for all the selected markets. The H index can range from 0 to 1. It equals 1 when there is only one monopolistic firm in the market, and it tends to zero when the number of firms becomes large. The H index is calculated for FSCs only, as we have decided to capture the impact of LCCs by a different variable. Therefore, this formulation of the H index can be considered as a measure of market concentration of the FSCs.
4. **LC:** the LCC dummy variable is equal to 1 when there is at least one LCC on the market, and 0 otherwise. It can be used to directly test the hypothesis of interdependency among markets. In fact, under this assumption, the low-cost entry has

an impact on both economy and business airfares. Within the sample, we have 12 city-pairs with the following LCCs: Ryanair, easyJet, Basiqair, Volare Web, British Midland, Air Berlin, Virgin Express, Hapag Lloyd Express.

5.3.2 Results

The database presented above has been used as input for estimating an aviation competition model. The econometric model is specified as follows:

$$FARE_j = \alpha_{0j} + \alpha_{1j}GDP_j + \alpha_{2j}DIST_j + \alpha_{3j}(1-H)_j + \alpha_{4j}LC_j + \alpha_{5j}(1-H)LC_j + \varepsilon_j, \quad j = 1,\ldots 8, \tag{5.24}$$

where *GDP* and *DIST* are included as difference from their means. The *H* index takes the form of $(1-H)$, in order to improve the result interpretation, i.e. in the case of a monopolistic situation its impact on the dependent variable FARE is null and the constant represents the monopolistic average price. In any other situation, $(1-H)$ is a measure of the strength of competition. Equation (5.19) also includes the term $(1-H)LC$ to include the interaction between the FSC and the LCC.

The model has been estimated for the 8 identified clusters by OLS. The estimation results are reported in Table 5.5.[13] All coefficients have the expected sign and

Table 5.5 Econometric model results

Type of fare	CONST	GDP	DIST	(1-*H*)	*LC*	(1-*H*) *LC*	R^2	Nr. obs.
Promotional	183.1	2.6	0.01	−27.9	−29.0	3.3*	0.22	1,436
	(112.5)	(9.0)	(5.00)	(−5.5)	(−9.5)	(0.5)		
Discounted1	304.8	4.8	0.02	−76.6	−40.2	38.7	0.16	2,330
	(152.3)	(11.7)	(6.24)	(−11.9)	(−10.4)	(4.1)		
Discounted2	395.3	5.1	0.02	−90.6	−59.5	78.6	0.12	1,743
	(160.5)	(10.9)	(3.9)	(−12.0)	(−13.4)	(7.2)		
Economy1	490.4	6.9	0.1	−98.7	−66.0	75.9	0.18	2,934
	(154.9)	(10.4)	(12.5)	(−8.9)	(−11.9)	(5.1)		
Economy2	606.8	3.8	0.1	−60.4	−62.3	51.0	0.18	2,534
	(194.4)	(7.8)	(21.9)	(−6.4)	(−8.9)	(3.1)		
Unrestricted1	892.8	5.5	0.3	−225.4	−45.8	59.7	0.53	1,375
	(134.9)	(4.3)	(29.5)	(−12.4)	(−4.0)	(2.3)		
Unrestricted2	977.3	7.5	0.4	−189.0	−74.9	60.5*	0.54	682
	(113.8)	(5.6)	(26.2)	(−8.1)	(−5.0)	(1.8)		
Unrestricted3	1,045.3	8.4	0.7	−128.1	23.5	−171.2	0.89	1,118
	(235.3)	(9.4)	(93.9)	(−9.6)	(2.2)	(−7.8)		

Note: *t*-statistic in brackets; * = not significantly different to zero at 5% of confidence

[13] Previous researchers have estimated a similar linear and log model using as the dependent variable the average fares of all subclasses. See, e.g., Brander and Zhang, 1993.

are significant at the 5% level, with the exception of the interaction effect $(1-H)LC$ in the first and seventh line. The first column (*CONST*) captures the average fare that a customer pays when there are neither low LCCs nor other FSCs on the market. As mentioned before, in this case both $(1-H)$ and LC are equal to 0. For instance, in the monopoly case, the *Promotional* fare equals on average €183 and the *Discounted1* is on average €305. The second and third columns (*DIST* and *GDP*) capture the impact of the distance and income on the fares.

The coefficient values of DIST increase, moving from the *Promotional1* (0.01) to *Unrestricted2* (0.36). This indicates that carriers set their fares in the weaker markets with less regard to costs, and in the stronger markets by focusing on costs. For instance, if the destination is 100 kilometres further than the average distance, then the average *Promotional* fare increases by only €2 and the *Unrestricted2* fare by €36. The latter fare cluster deserves particular consideration. The estimation[14] in Table 5.5 shows an explanatory power of DIST that dominates the commercial aspect of GDP and competition variables. This is due to the fact that carriers usually anchor prices of *Unrestricted3* to the IATA published fares. In order to control the IATA effect, and capture the real determinants, we have estimated a different specification of (5.24). The dependent variable is the difference between the official IATA fares and the fares of *Unrestricted3,* and the regression variables are the same as those of the previous estimations. The estimation, presented in (5.24), appears to be preferred both in terms of diagnostic results and parameter interpretability (R-squared=0.564: t-value below the coefficients).

$$FARE = \underset{(235.30)}{1028.5} - \underset{(12.32)}{5.1}GDP + \underset{(18.78)}{0.11}DIST - \underset{(-13.09)}{175.18}(1-H) + \underset{(-6.48)}{42.58}LC + \underset{(4.86)}{49.92}(1-H)LC \tag{5.25}$$

The constant of (5.25) is determined as the average of IATA fares plus the constant of the new estimation (38.5). Table 5.5 shows that GDP (as differences from its average) has a positive impact on price levels. Indeed, the coefficient values range from 2.6 for the *Promotional* fare to 7.46 for the *Unrestricted2* fare. This indicates that, if the regional GDP per capita of the departure airport is €1,000 higher than Italian GDP, the fares are €2.6 for the *Promotional*class or €7.46 for *Unrestricted 2* higher than the average.

The fourth column of Table 5.5 presents the coefficients for $(1-H)$. The negative sign of all coefficients indicates that, if the market is less concentrated (lower degree of competition), then the overall fare levels decrease. Alternatively, we can say that when there is only one carrier in the market it can set a fare premium. When a second FSC enters the route, the fares reduction is, on average, around €14 for the *Promotional* fare, from €35 to €50 to for *Discounted1–2* and *Economy 1–2*, €110 for the *Unrestricted1,* €95 for *Unrestricted2* and €88 for *Unrestricted3*. The

[14] The method to set the IATA fares started before the both US and EU market deregulation and were based on the air distance between the two travel points. Those fares are updated annually by the world IATA congress but the method is still based on the air-distances.

Unrestricted fares show the highest impact. Those are the business-related class where passengers are less price-elastic. We interpret this result as proof that carriers can exert monopoly power.

The fifth column of Table 5.5 represents the coefficients of the dummy LC, which are all significantly different from zero (except for *promotional* and *Unrestricted2*) with negative sign. Their values range from –€30 for the *promotional* up to –€74 for *Unrestricted2* with an average of about –€54. The impact of LCC entrance can be finally determined by also considering the interactive factor (sixth column). In fact, only in the case where the LCC enters a monopolistic market (the interactive effect is null) does the LC coefficient represent the airfares reduction of the FSC. In the case of symmetric duopoly (two FSCs are present in the market), the LCC impact is equal to the LC coefficients minus the interactive coefficients divided by 2.[15]

The average fares forecast by the empirical model are presented and compared in Table 5.6 per class and market structure: monopolistic market (one FSC): symmetric duopoly (two FSCs): asymmetric duopoly (one FSC and one LCC): and asymmetric oligopoly (two FSCs and one LCC). The levels decrease as the number of carriers operating in the market increases, i.e. the prices in the monopoly market are higher than those of the duopoly and oligopoly markets for any class of service. The fares are sorted in such a way that seems to respect the inequalities (5.19) and (5.20) presented in Sect. 5.2.6 for almost all figures. Those inequalities seem to hold for all classes of reservation with respect to both the business and the leisure product. Moreover, considering the monopoly as being the benchmark or the starting point from which to compare the other three cases, we can plot the fare differences as in Fig. 5.2.

The presence of a traditional competitor (symmetric duopoly) affects the price levels of the two segments (business and leisure) differently. In particular, we find that prices decrease about €40 for leisure classes and about €100 for business classes. Hence, the competition of traditional carriers seems to significantly reduce

Table 5.6 Average fares (€) per class of service and different market structures

Class of service	Monopoly	Symmetric duopoly	Asymmetric duopoly	Asymmetric oligopoly
Promotional	183	169	154	142
Discounted1	305	266	265	246
Discounted2	395	350	336	330
Economy1	490	441	424	413
Economy2	607	577	544	540
Unrestricted1	893	780	847	764
Unrestricted2	977	883	902	838
Unrestricted3	1,028	940	985	923

[15] In the case of asymmetric oligopoly, we assume that H is equal to 0.5 and $LC = 1$, so the interactive effect is 0.5.

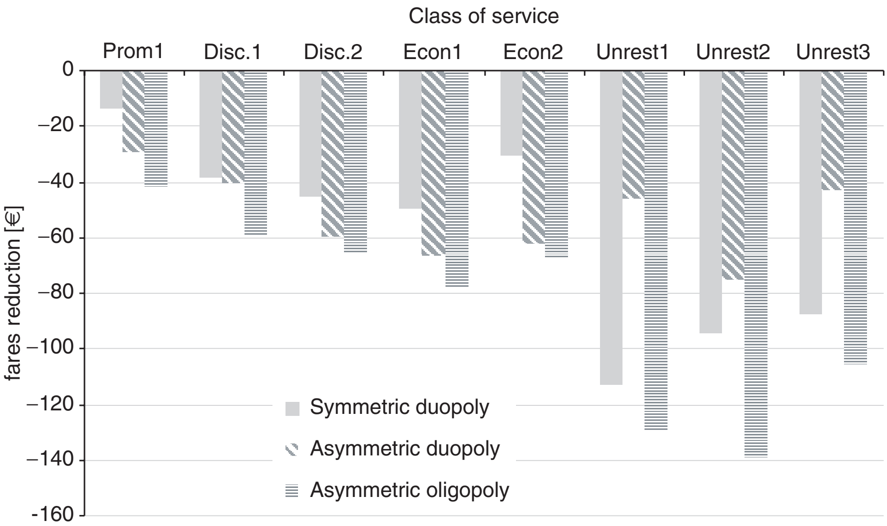

Fig. 5.2 Airfares reduction (€) per class of service and different market competition

the prices of the business fares. In the case of the entry of LCCs (asymmetric duopoly), the impact seems to be homogeneous on all classes of fares, that is a decrease of around €55.

This result corroborates the theoretical assumption of market interdependence between the weak and the strong market. Indeed, the entrance of LCCs impacts the price levels of both the business and the leisure segment, even thought the LCCs do not offer a full business service. As a final remark, it is worth noting that the interdependency of markets directly determines on the internal organization of the marketing division. In a context of competition among FSCs, the assumption of interdependency or separation among markets does not make any difference, as IC is not binding. On the other hand, when we analyse an asymmetric context, even if IC is not binding, pricing strategies on the business market and on the leisure market have to be coordinated. From an organizational perspective, the carriers can have separate teams devoted to the leisure and business market. In the case of LCC competition, these units have to coordinate their marketing actions.

These results also suggest a different interpretation of the reduction of prices in the business segment, even if it is ruled out from the theoretical model. Traditional carriers, once they observe that they are losing traffic on the leisure market, are obliged to reduce their fares on that market, but they also need to change all other fares in order to maintain the right 'buy-up' to satisfy the incentive compatibility constraint.

5.4 Conclusions

This chapter has investigated the pricing response of full-service carriers (FSCs) when low-cost carriers (LCCs) enter the market. We used monthly data on city-pairs from Italy to three European countries (Germany, United Kingdom, and the Netherlands) including airfares for four different carriers (Alitalia, Lufthansa, British Airways, and KLM). We found that, when an LCC enters a specific route, the direct incumbent firms react by reducing the fares for all available leisure and business fares. We also provide an interpretation in terms of the direct competition of LCCs in the FSC business segment. This point is quite important as it corroborates the assumption that the weak and the strong market are interdependent. On the other hand, competition among two FSCs is characterized by asymmetric behaviour. They strongly compete on the business market and weakly compete on the leisure market. In a context of competition among FSCs, the assumption of interdependency or separation among markets does not make any difference, as the incentive compatibility constraint (IC) is not binding. But, conversely, when we analyse an asymmetric context, even if the IC is not binding, pricing strategies on the business market and on the leisure market have to be coordinated. As expected, the impact of the LCC on prices is higher when it enters a monopolistic market than a market already characterized by competition.

Finally, the overall results suggest new possible streams of research. The theoretical model results can be empirically tested in terms of market shares and low-cost fares. Nevertheless, the specific impact of the product characteristics, both horizontally (departure time, airport access, etc.) and vertically (ground and on-board services, travel conditions for each passenger category, etc.) might be the subject of future analyses. From a theoretical perspective, it remains open to verify in which duopoly conditions the IC is taken into account by carriers for airfare setting, in addition to the interactive market competition.

Chapter 6
Network Competition: the Coexistence of Hub-And-Spoke and Point-To-Point Systems[1]

6.1 Introduction

The deregulation of the aviation market in the United States in 1978 has intensely affected the airlines' network configuration. As described in Chap. 2, a number of 'trunkline' carriers have rapidly reorganized their network structures from point-to-point (PP) systems into hub-and-spoke (HS) systems. In the EU the deregulation process produced similar results, although its effect on the market was not so radical. European carriers had already concentrated intercontinental flights into an HS structure, while they developed a mixed HS and PP network for shorter distances (national and international flights). The low-cost carriers (LCCs) model boomed in both the US and the EU thanks also to lower operational costs and a simplified business model. In Chap. 2 we showed that the LCCs' cost advantage is the outcome of a streamlined production process in contrast to the complexity of the hub-and-spoke system of the FSC. Thus, in this chapter we compare the FSC business model and the new LCC business model in terms of their network configuration. Here the analysis is performed from a theoretical point of view, while the empirical application will be carried out in Chap. 7. We examine a game-theoretical context where carriers are allowed to play three different strategies: point-to-point (PP), hub-and-spoke (HS), or multi-hub (MH), and we identify the conditions under which asymmetric equilibriums may exist. We further discuss how the outcomes of the model can be used to describe the observed coexistence of different business models.[2]

Before liberalization, the HS network in Europe developed out of the former national flag carriers and took advantage of operating in a regulated industry: bilateral agreements, protected markets, and set prices. Indeed, the former bilateral

[1] An earlier version of this chapter appeared in the *Journal of Air Transport Management* 11: 328–334, 2005.

[2] The recent paper of Takebayashi and Kanafani (2005) is similar to our analysis. The authors developed a model to simulate contemporary competition between HS and PP carriers. In particular, they focus on the transition from the strategies of the HS carriers to the PP strategy. Kita et al. (2005) is one of the few papers in the aviation literature that adopt a game theory approach to analyses the formation process of airline networks.

regime of air service agreements had already led to the development of hubs. In this context, the only available international freedom was what is called the 6th freedom, i.e. the right to provide transport services between two countries, other than the country where the aircraft is registered across its territory (see Appendix I). In other words, this is the possibility to connect two countries via the national hubs. Furthermore, major airlines developed the concept of 'network design', i.e. the process of optimizing capacity supply to match the forecasted demand. On the basis of this strategy, carriers bundle more and more traffic flows into their hub by feeding and de-feeding operations. The airline's unit cost is therefore reduced, as grouping passengers with the same travel origin but different destinations allows the realization of economies of density on both feeder flights and connecting flights to the final destinations. Even though the EU deregulation has introduced the 7th and 8th freedoms, the carriers that have effectively taken benefit from them remain limited. One expected effect would have been what Berechman and de Wit (1996) stated in their paper, i.e. the carrier would select a specific hub so as to maximize profits. However the hubs are still located in the original country of the carriers.

The point-to-point (PP) network of an LCC is operated by a simple fleet with a limited variety of types of aircraft which are very cost-efficient (Boeing 737 or Airbus 320/319). The considerable cost reduction of LCCs comes from an intensive use of the aircraft: the aircraft of an LCC is in the air, on average, more hours a day compared with the traditional carriers. This generates higher productivity of aircraft and crew. Moreover, lower maintenance costs, due to simpler fleets and lower landing/ground handling fees negotiated with secondary airports without congestion problems, also cause relevant differences in the production process. In the present chapter, the economic feasibility of different connectivity structures (HS, PP, MH) will be an analysed for both LCCs and FSCs.

6.2 The Theoretical Model

We analyse here a simple symmetric network which has four nodes (cities). Two nodes are located in a domestic country and two in a foreign one. In the domestic country, there is a big city, H, and a small one, S. The big city is a candidate to be a Hub in an HS network and the small city is a candidate to be a Spoke. Similarly, we call H* and S*, respectively, the big and the small city in the foreign country (see Fig. 6.1).

The consumer's demand for flights between the cities depends on the size and distance of the towns and the price charged by the carriers. We assume that the reservation price in each market is normalized to 1, and that the potential size of each market (given by the number of passengers when the price is set equal to zero) is as follows: $h > m = n > l$ and $d = f > m$. These assumptions are consistent with the predictions of gravity models which suggest that traffic flows are positively proportional to the size of the cities and negatively proportional to the distance.

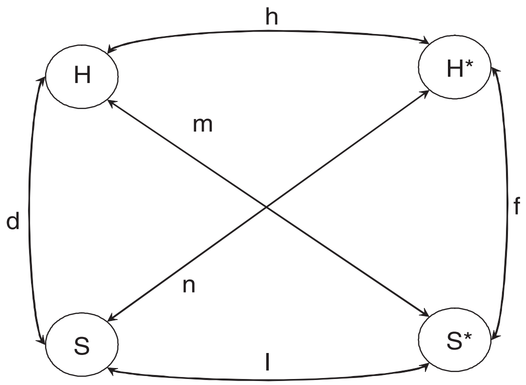

Fig. 6.1 Airline markets in a four-node network

The demand is linear, that is, if the price in the route r is p_r, the inverse demand is $p_r = 1 - \frac{1}{r}q_r$.

On the supply side, we assume that there are 2 carriers: a domestic FSC carrier, and a foreign LCC carrier. Each carrier owns 4 planes of size a, and it can choose among 3 different network structures:

- P: *Point-to-Point*: each carrier allocates one plane on the main routes originating from its country. Carrier 1 covers the routes d, m, n and h, while carrier 2 covers f, n, m, and h.
- H: *Hub-and-Spoke*: each carrier allocates two planes on the domestic route and the other two planes on the routes originating from the Hub H. The domestic carrier covers d (with two planes) and m and h (with one plane each), whilst the foreign carrier covers f (with two planes) and n and h (with one plane each).
- M: *Multi-Hub-and-Spoke*: each carrier allocates two planes in the domestic market and two planes to connect the main cities. The domestic carrier covers d and h, while the other carrier covers f and h.

We confine our analyses to these three network structures. We have also tested for alternative configurations, but this does not enrich the outcome of the analysis.

To deal with this model we need to make strong assumptions on pricing policies of carriers and preferences of passengers. First, we assume that carriers offer all their capacity to the market (i.e. planes fly full if possible). Hence, the price a carrier receives for its service only depends on market demand, and the carrier does not have a monopoly power. We also assume that carriers charge a price for each route separately, and they cannot give a discount or charge a premium for connected flights. Here, we are not interested in the pricing strategy of the carrier, but only in the network strategy of the carrier. We know that a carrier can increase its profits by using more complex pricing policies, but the result we obtain must be thought of as a benchmark case.

Secondly, it is assumed that the airfare is the only variable on which consumers base their decision. There is neither a frequency premium nor a discount for stops.

And finally, we assume that carriers have already chosen their network structures, to allocate their planes on the network. The issue centres on the question how the market determines prices and passenger flows.

6.2.1 The Pricing Rule

The rule for allocating passenger flows on the network, and consequently obtaining prices, rests on the hypothesis of no arbitrage: passengers, who want to fly from one city to another, will choose the least-cost combination of routes. As an example, the price formation is described when the domestic carrier chooses network $P1$ and the other carrier chooses network $P2$. First of all, we identify the number of planes on each route. There is one plane on route d provided by the domestic carrier, and two planes on route m, n and h. Note that l is not served directly. We assign the flows to each route and the remainder freely on the network. For example, passengers belonging to l can be assumed to choose d plus n and f plus m. Symmetry allows us to assume that half of these passengers will choose the first way of travel and half the second way.

To solve the model exercise, we have to assign numerical values to the parameters. We assume that the capacity of each plane is $a = 3/2$, and that the dimensions of the routes are:$d = f = h = 4$, $m = n = 3$ and $l = 2$. The problem can then be specified (where p_i is the price for the route i; q_i the demand for travelling in the route i; i are the routesd, f, h, m, n, l).

Demand side:

$$p_d = 1 - \frac{1}{4}q_d, p_f = 1 - \frac{1}{4}q_f, p_l = 1 - \frac{1}{2}q_l,$$
$$p_m = 1 - \frac{1}{3}q_m, p_n = 1 - \frac{1}{3}q_n, p_h = 1 - \frac{1}{4}q_h,$$

Supply side:

$$q_d + \frac{1}{2}q_l = \frac{3}{2}, q_f + \frac{1}{2}q_l = \frac{3}{2}, q_m + \frac{1}{2}q_l = 2 \cdot \frac{3}{2};$$
$$q_n + \frac{1}{2}q_l = 2 \cdot \frac{3}{2}, q_h = 2 \cdot \frac{3}{2}.$$

The no-arbitrage condition is:

$$p_l = p_d + p_m.$$

The following prices are obtained $p_d = p_f = 13/19$, $p_h = 1/4$, $p_l = 29/38$, and $p_m = p_n = 3/38$. Now we immediately notice that passengers d and f can choose n plus h and m plus h, respectively, and save money. This implies that there is room for arbitrage. To cross out the opportunity of arbitrage, the flows d and f can be partially re-routed till the prices on the direct and indirect link are the same. Hence, to solve the model we impose the condition that the prices of indirect flights are at least as high as the price of the direct flight. The problem is now as follows:

Supply side:

$$
\begin{aligned}
q_d - \delta q_d + \frac{1}{2} q_l &= \frac{3}{2}, \\
q_f - \varphi q_f + \frac{1}{2} q_l &= \frac{3}{2}, \\
q_m + \frac{1}{2} q_l + \varphi q_f &= 2 \cdot \frac{3}{2}, \\
q_n + \frac{1}{2} q_l + \delta q_d &= 2 \cdot \frac{3}{2}, \\
q_h + \delta q_d + \varphi q_f &= 2 \cdot \frac{3}{2}.
\end{aligned}
$$

The no-arbitrage condition is:

$$
\begin{aligned}
p_l &= p_d + p_m, \\
p_d &= p_n + p_h, \\
p_f &= p_m + p_h.
\end{aligned}
$$

The solution to the new problem is:

$$
p_d = p_f = \frac{49}{82},\ p_h = \frac{34}{82},\ p_l = \frac{64}{82},\ \text{and } p_m = p_n = \frac{15}{82}.
$$

In this case, it is not possible to gain more by changing the routes and, hence these are the equilibrium prices. The computation of profit is quite simple, as we assume that all seats are taken. Hence the profit is just the sum of the price on each route times the capacity offer (number of provided seats times capacity of the plane). Hence, the profit of carrier *1* is:

$$
p_d \cdot a + p_h \cdot a + p_m \cdot a + p_n \cdot a = \frac{339}{164} = 2.067.
$$

The same holds for carrier 2. In general, this solution can also be presented as a linear programming problem where total passenger expenditure is minimized subject to demand and supply side constraints and a no-arbitrage condition. This fact is appealing, as the solution is welfare-maximizing and the equilibrium is unique. The linear programming problem is:

$$
\min \sum_{r \in (d,f,m,n,l,h)} p_r \cdot a \cdot s_r
$$

subject to: $r \cdot p_r = r - q_r, \forall r = d, f, m, n, l, h$

We define $V_r, W_r,\ \forall r = d, f, m, n, l, h$ the number of indirect passengers on the route r in connection from the adjacent routes.

Demand side:

$$
\begin{aligned}
&q_d - V_d - W_d + V_m + W_n + W_l + W_h = a \cdot s_d \\
&q_f - V_f - W_f + W_m + V_n + V_l + V_h = a \cdot s_f \\
&q_m - V_m - W_m + V_d + W_f + W_l + V_h = a \cdot s_m \\
&q_n - V_n - W_n + W_d + V_n + V_l + W_h = a \cdot s_n \\
&q_l - V_l - W_l + V_d + V_f + V_m + V_n = a \cdot s_l \\
&q_h - V_h - W_h + W_d + W_f + W_m + W_n = a \cdot s_h
\end{aligned}
$$

Supply side:

$$
\begin{aligned}
&p_d \le p_m + p_l, p_d \le p_n + p_h \\
&p_f \le p_m + p_h, p_f \le p_n + p_l \\
&p_m \le p_d + p_l, p_m \le p_f + p_h \\
&p_n \le p_f + p_l, p_n \le p_d + p_h \\
&p_l \le p_m + p_d, p_l \le p_n + p_f \\
&p_h \le p_m + p_f, p_h \le p_n + p_d
\end{aligned}
$$

The no-arbitrage condition is:

$$q_r, p_r, V_r, W_r \ge 0, \forall r = d, f, m, n, l, h. \text{ (positive constraints)}$$

and V_r, W_r, $\forall r = d, f, m, n, l, h$ are the indirect passengers.

The problem has been solved using the software OPL studio 5.13. Thanks to the linearity of constraints and of the objective function, solution prices and quantities are unique, and consequently the profit of both firms is unique. Uniqueness is a very appealing result for economists investigating network games, as there are often multiple equilibria.

6.2.2 The Equilibrium of the Game

We assume that each carrier can choose a particular structure independently of the choice of its opponent. In total, this may generate 9 possible configurations. Excluding the symmetric ones, we finally have 6 possible results).

Table 6.1 summarizes the pay-off results of the two carriers when the capacity of each plane is $a = 3/2$, and the size of the markets are: $d = h = 4$, $m = 3$ and

Table 6.1 Pay-off matrix; reference case

	P2		H2		M2	
P1	(2.067	2.067)	(2.477	2.087)	(2.326	1.124)
H1	(2.087	2.477)	(2.085	2.085)	(2.466	1.380)
M1	(1.124	2.326)	(1.380	2.466)	(1.846	1.846)

Note: Underlining indicates Nash equilibrium

Table 6.2 Pay-off matrix with small domestic market

	P2		H2		M2	
P1	(1.964	1.964)	(2.391	1.884)	(2.209	1.011)
H1	(1.884	2.391)	(1.974	1.974)	(2.384	1.331)
M1	(1.011	2.209)	(1.331	2.384)	(1.787	1.787)

Note: Underlining indicates Nash equilibrium

Table 6.3 Pay-off matrix after introduction of a connecting service

	P2		H2		M2	
P1	(2.352	1.773)	(2.662	1.519)	(2.637	1.119)
H1	(1.894	2.287)	(2.250	1.875)	(3.100	1.110)
M1	(1.438	2.317)	(1.760	2.451)	(2.221	1.846)

Note: Underlining indicates Nash equilibrium

$l = 2$ (reference case. There appear to be two Nash equilibria: P1–H2 and H1–P2. The pay-offs concerning P1–P2 and H1–H2 are both lower than the pay-offs concerning the Nash solutions. Hence, a symmetric PP or a symmetric HS structure cannot be implemented, even under collusion.

In order to analyse the robustness of the result, the size of the domestic market is changed. If we expand the size of the domestic market of the two carriers, i.e. if we replace $d = f = 4$ with $d = f = 4.5$ or more, we obtain similar results. When the domestic market is small $d = f = 3.5$, then the PP solution can be implemented (see Table 6.2). Note that the pay-offs in the case of P1–P2 are the same for H1–H2, but the HS equilibrium can be implemented under collusion.

Table 6.3 summarizes the pay-offs of the two carriers when the domestic carrier introduces a flight on the route S–S*. The analysis is similar for the foreign carrier. If carriers are free to change the network, the equilibrium is (P1 + L, P2). That means that both carriers move to a PP configuration (reference case).

If the preceding equilibrium is P1–H2, Carrier 1 has no incentive to add a flight, as its pay-off reduces from 2.477 to 2.352, while it has a small incentive (2.352–2.087) if it is in the equilibrium situation H1–P2. Hence, if the costs of buying a new carrier are sufficiently high, none of the carriers will decide to invest in a new carrier. Note that, if we do not permit a carrier to modify its network, but only to add a flight on route l, the carrier choosing the HS configuration also has a reduction in pay-off compared with the previous equilibrium.

Figure 6.2 depicts the different equilibrium strategies obtained by varying the size of the domestic and foreign market from 3 to 5. In general, we note that when a carrier's own market is small, the carrier will play a PP strategy and when its own market is large it will play an HS strategy. When the domestic market is large for both carriers, an asymmetric equilibrium emerges. The symmetric HS strategy is sustainable only under collusion, and when the size of both the domestic and the foreign market is small and similar.

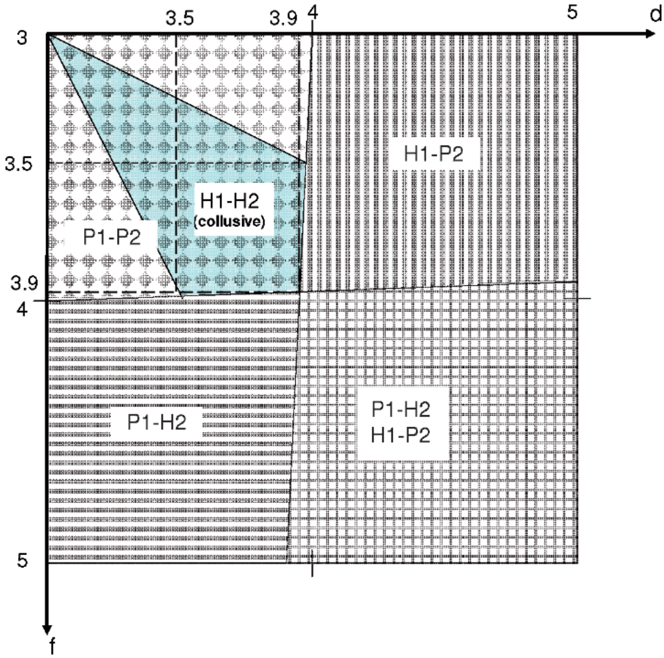

Fig. 6.2 The solution of the network game depending on *d* and *f*

6.2.3 Alternative Pricing Rules

In this chapter we choose to evaluate a firm's profit as a result of welfare maximization, which corresponds to the minimal profit it gains, given the network configuration. Real profits are upper-bounded by first-degree price discrimination profits and lower-bounded by consumer surplus maximization profits.

The choice of the latter indicator is based on the following reasons. First, competition may limit the possibility of price discrimination and surplus extraction. Average prices on routes where there is competition are, ceteris paribus, lower than on routes where there is no competition.

Second, there are some difficulties in assigning consumers' surplus when dealing with connecting passengers. For example, if an indirect flight is provided by different carriers, each carrier would like to extract all the rent (difference between the consumers' willingness-to-pay and their sum of the competitive prices). Third, even when we assume that carriers split the profit evenly, some problems remain. In fact, in this linear programming setting, we obtain a unique solution for quantities and prices but not for passenger' flows on indirect routes. Differences in passenger' flows on indirect routes have no impact on profit, when calculated assuming lack of monopoly power. However, these differences may affect profit returns under first-degree price discrimination.

The model assumes that, in the price setting, carriers have no monopoly power, so that they are implicitly consumer surplus maximizers or welfare maximizers rather than profit maximizers. We provide a brief argument to reconcile the welfare maximization assumption with the profit maximizing behavior.

To keep things simple, the following example can be considered where there is only one carrier: namely, 1, and one market: namely, d. Assume that the market size is $d = 4$, and the capacity supplied is $a \cdot s_d = 1.5 \cdot 2 = 3$. Welfare maximization implies that $p_d = 0.25$, $q_d = 3$, the profit of the firm is 0.75, and the consumer surplus is 1.125. Alternatively, if carrier 1 has all the monopoly power but it cannot practice price discrimination, it sets $p_d = 0.50$ and $q_d = 2$, and the profit is 1.00, while the consumer surplus is 0.50. In addition to this, consider a case where carrier 1 can practise first-degree price discrimination. In this situation, the firm sets personalized prices for each consumer and extracts all the consumer surplus. The first consumer will pay 1.00, the second one will pay a little less than 1.00, and the last consumer will pay 0.25. The profit of the firm is now given by $0.25 \cdot 3 + 0.5 \cdot 0.75 \cdot 3 = 1.875$, and the consumer surplus is nil. It is a well-established result that, under first-degree price discrimination, the firm gains the maximum profit and concurrently welfare is maximized. Contrary to the first part of this example, the surplus is now given to the firm. Hence, the profit maximizing behaviour of a firm is consistent with the welfare maximization choice when it is assumed that firms will extract all the consumer rent.

Indeed, revenue management techniques employed by airline companies usually pursue this goal. Carriers try to segment customers according to their willingness-to-pay. They charge higher fares to higher willingness-to-pay consumers and lower fares to the others. The market segmentation is quite sophisticated, as carriers charge about 10 different fares for each origin-destination. However, this is not a guarantee that they are able to extract the entire consumer surplus.

In Table 6.4 we provide the pay-off matrix computed under the assumption that carriers practice price discrimination. We assume that carriers continue to price discriminate (even if they are on the same route), that the consumer surplus is split evenly, and that flows on indirect flights are symmetric whenever possible. Table 6.4 uses the same values on the market size of Table 6.1. In this case, as well as in the previous one, we observe two asymmetric equilibria.

Table 6.4 Pay-off matrix when firms price-discriminate

	P2		H2		M2	
P1	(3.759	3.759)	<u>(4.100</u>	<u>3.768)</u>	(4.066	3.348)
H1	<u>(3.768</u>	<u>4.100)</u>	(3.957	3.957)	(3.916	3.397)
M1	(3.348	4.066)	(3.397	3.916)	(3.346	3.346)

Note: Underlining indicates Nash equilibrium

6.3 Conclusions

In the previous section, we presented a rather simple model with two carriers and four cities (two large and two small ones). Carriers are allowed to play three different strategies: point-to-point (PP), hub-and-spoke (HS), or multi-hub (MH). We find that two main equilibrium outcomes emerge, depending on the size of the internal market. First, when the internal markets are small, the PP network strategy is played by both carriers, and, for a specific subset of parameters, a collusive equilibrium in an HS configuration can be implemented. Second, when the size of the internal markets is large, asymmetric configurations, where one carrier chooses an HS strategy and the other chooses a PP strategy, are the only stable equilibria. The main result of the chapter is that there can be an existence between an HS and a PP network, and this result seems to be quite robust to variations in parameter and pricing rules.

Before relating the outcome of the model to the current situation in the aviation sector, it is worth emphasizing that the results are obtained through a rather stylized model under stringent assumptions: carriers offer all their capacity to the market (i.e. planes fly full if possible). Hence, the price a carrier receives for its service only depends on market demand, and the carrier does not have a monopoly power. Carriers charge a price for each route separately, and they cannot give a discount or charge a premium for connected flights. We know that a carrier can increase its profits by using more complex pricing policies, but the result we obtain must be thought of as a benchmark case. We also assumed that the airfare is the only variable on which consumers base their decision. There is neither a frequency premium nor a discount for stops. And, finally, we assume that carriers have already chosen their network structures, in order to allocate their planes on the network.

The economic literature identifies two main elements affecting the choice network configuration: first, the spatial distribution of demand for direct flights among different towns, and second, the overall dimension of the market and the opportunity to exploit economies of density. The first factor is related to the choice of the HS network when the spatial distribution is uneven and the location of hubs is in large concentrations. The second factor concerns the choice of an HS network when the market is small, i.e. when the need to exploit the economies of density is stronger.

The driving forces behind our model are the differences in market size for the various city-pair combinations. This is an element that seems to have received less attention in most models presented in the airline literature. Most theoretical models address the problem of a network configuration in terms of economies of scale and density. These factors can stimulate HS networks in small markets and a PP configuration when markets are large enough. However, our model shows that when the traffic flows to an airport are large, i.e. the internal markets are large, the incumbent firm develops its hub in this airport and pushes the LCC to operate in smaller ones. Indeed, we observe, at least in Europe, that most HS carriers, such as Lufthansa or Air France, have already developed their hub in large cities (Frankfurt, Munich and Paris). Smaller cities with small traffic flows are left to LCC operations.

There is another important but as yet insufficiently addressed aspect, which suggests the coexistence of HS and PP in European aviation systems. It is noteworthy that FSCs are stuck with the HS configuration to sustain the supply of intercontinental flights. It still seems impossible to fill a Boeing 777 or an Airbus 330 for an intercontinental destination without an HS strategy. A carrier will still need to bundle demand from several origins. The feeder system is critical here, not only for charging intercontinental flights but also for the intra-European traffic flows. Hence, the choice of FSCs to provide intercontinental flights reinforces and preserves the HS configuration.

Chapter 7
New Measures to Compare Network Configurations of Full-Service and Low-Cost Carriers

7.1 Introduction

Traditional analyses of airline networks have attempted to measure the network configuration by means of variables such as traffic distribution or flight frequency concentration (McShan 1986; Caves et al. 1984; Toh and Higgins 1985; Reynolds-Feighan 1994, 1998, 2001; Bowen 2002). These methodologies have mainly addressed the issue of describing and classifying networks in terms of measures of geographical concentration, but they have not addressed this issue as a comparison of real network configurations with ideal HS and PP structures. Although geographical concentration and network configuration are related concepts, they are not coincident. Geographical concentration indices, such as the Gini or the Theil indices, provide a measure of how strong the frequency concentration is in the main airports. HS and PP measures of network configuration do indeed depend upon the shape of the network and the connectivity of airports.

Comparing the previous definitions, it emerges that geographical concentration measures do not take into account airport connectivity, and hence they may fail to detect important differences in HS and PP structure. In empirical analysis, airport concentration in PP and HS networks may be quite similar, although there are strong differences in the role of large airports in these structures. In the PP system, large airports are 'technical bases', while in the HS system, they are 'hubs'. A base is mainly designed to offer direct flights, while a hub plays the role of connecting node. Geographical concentration indices differ from a measure of network configuration in another respect. When a network structure is complex (as in reality), including multi-hubs or a mixed PP and HS strategy, the concentration indices record high values for all types of structure and fail to discriminate clearly between different network shapes.

The PP and HS network structures have received a set of similar and acceptable definitions in the transport literature. Reynolds-Feighan (2001) identified the HS configuration of a carrier when there is a high concentration level of air traffic in both space and time by means of coordination of the timetables. However, while a substantial number of studies on airline network configurations have focused on the spatial dimension, only a small number of empirical studies have attempted to measure the temporal dimension of airline networks. Some examples of theoretical and empirical investigation of hub connectivity are Bootsma (1997), Dennis (1998), Rietveld and Brons (2001), Veldhuis and Kroes (2002), and Burghouwt and de Wit (2003).

In this respect, our study aims to provide new measures for assessing airline network configurations in order to effectively investigate the complexity of modern carriers' network design and, if possible, to account for differences between LCC and FSC networks in Europe. This is a relatively new research attempt, with only a few notable previous exceptions. First, the problem addressed is to measure the network configuration in terms of the HS versus the PP network, and not only the hub concentration. Second, both the spatial and the temporal dimension are assessed and combined in one picture in order to reach a broader and more complete description of the network configuration. Third, the study applies empirical methods originating from social network analysis, i.e. the Freeman index and what is termed the 'Bonacich approach'.

The chapter is organized as follows. In Sect. 7.2 we explore the network configurations of European FSCs and LCCs over the last 8 years. We review different measures of spatial configuration, i.e. the traditional measures used by the transport literature, such as the Gini concentration index (Sect. 7.2.1), and those developed by social network analysis (the Freeman and the Bonacich centrality indices in Sects. 7.2.2 and 7.2.3). Finally, we provide an operational measure to capture time-based centrality (Sect. 7.2.4) that we call the 'connectivity ratio'. In Sect. 7.3, we present the overall results of the analysis. Section 7.4 we briefly present the recent researches on network connectivity in the sociology, geography and graph theory[1] that could offer new insights in the analysis of airline networks. Section 7.5 concludes the chapter.

7.2 Network Measures

In this section, we attempt to assess the network configuration of four large European FSCs and four European LCCs over the past eight years. Following Reynolds-Feighan (2001), we identify the HS configuration of a carrier when there is a high concentration level of air traffic in both space and time. In contrast, a network is PP-structured when traffic flows are temporally and spatially dispersed. From an empirical point of view, we expect that a PP network will show low levels of temporal concentration (i.e. flights are not organized to make connections with other flights) but not necessarily low levels of spatial concentration (due to the organization in bases). However, an HS structure is a network spatially and temporally

[1] These researches started from the work of Barábasi and Albert 1999; Albert and Barábasi 2000. See, for a review, Gorman, 2005; Patuelli et al. 2006; Schintler et al. 2005a, b.

Table 7.1 The airline network configuration matrix (Source: Burghouwt 2005)

Level of spatial concentration	Level of temporal concentration at the hub	
	Coordinated	*Random*
Concentrated	Hub-and-Spoke	Random radial
De-concentrated	Coordinated chain	Point-to-Point

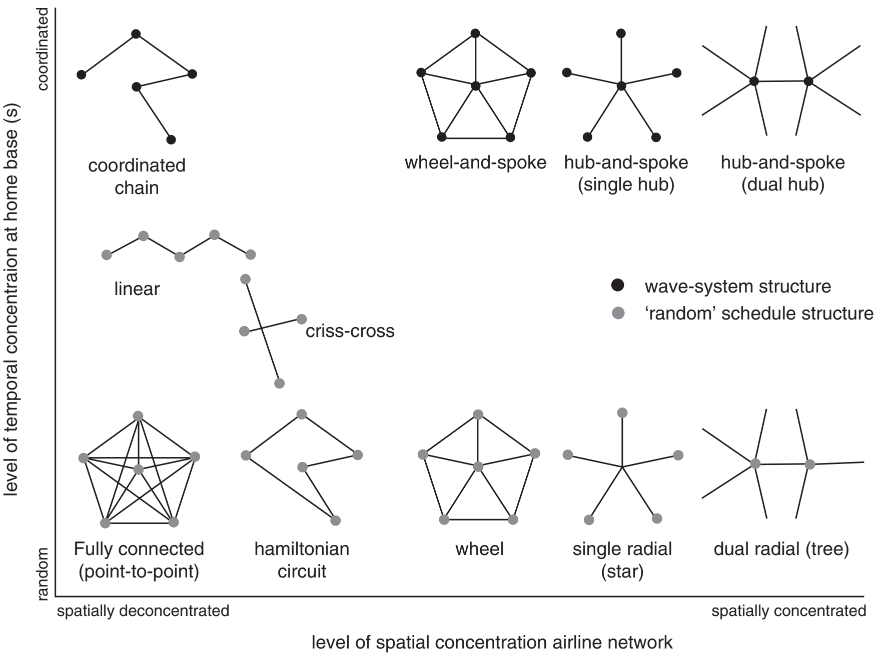

Fig. 7.1 Network configurations (Source: Burghouwt 2005)

concentrated in one or a few airports, called 'hubs', where the flight schedule is organized in wave systems in order to have the maximum number of flight connections.

Burghouwt (2005) describes four extreme network configurations that can be identified (see Table 7.1) and many 'intermediate' networks may exist. The HS and PP configurations are two extreme networks among many possible types. Figure 7.1 presents some possible configurations to describe the networks empirically.

Burghouwt et al. (2003) measure air traffic at an airport by the number of supplied seats per week. We believe that this variable can be somewhat misleading if applied to intra-European flows. Although it provides a good indicator for the size of the network nodes, in our specific analysis of the intra-European network it can be a biased measure of the spatial configuration measure for at least two reasons. First, the number of supplied seats is the result of the whole network optimization including intra-European and intercontinental flows. In the HS network design, the size of the aircraft is decided on the basis of the sum of local and connecting traffic to both

European and intercontinental destinations. However, if the analysis is restricted to intra-Europe, then the intercontinental seats supply will be erroneously included in the data. The second reason lies in the dynamics of demand over time, which is taken into account to determine the optimal levels of seat supply, i.e. the aircraft size is enlarged for some limited period of time during the year but the frequency of flights remains fixed. In order to reduce the effect of these factors, we propose to use the number of flights per week at the airport instead of the number of seats per week. We will now present the results of the Gini, Freeman and Bonacich indices, as well as the results of the temporal concentration analysis.

7.2.1 The Gini Concentration Index

The Gini index of concentration is defined as:

$$G = \frac{1}{2n^2\bar{y}} \sum_i \sum_j \mid y_i - y_j \mid,$$

where y_i and y_j (air traffic at i or j) are ranked in increasing order; $\bar{y} = \sum_i y_i / n$ is the mean of the weekly frequency; and n is the number of airports in the airline network. According to Burghouwt et al. (2003), the Gini index increases with the number of airports in an airline network n. The maximum value of the index is as follows:

$$\hat{G} = 1 - \frac{2}{n}.$$

This maximum Gini-index can therefore be observed for an HS network with all traffic concentrated in one HS route. Burghouwt et al. corrected the Gini index for the size of the airline network (number of airports) by dividing G by its maximum value. With the normalized Gini, it is possible to compare the spatial structure of airline networks independent of network size.

Data on flight schedules, such as departure and destination airport, flight frequency and seat capacity, are extracted from the OAG database. Data refers to three years 1996–2000–2004 for the summer season schedule (a representative week in August) and for intra-European flights. Intercontinental flights have been excluded, since they fall outside of the scope of this paper. Based on total weekly frequencies in 2004, we selected the four largest national carriers: Lufthansa German Airlines, Air France, British Airways, Iberia, and the four largest LCCs: Ryanair, easyJet, Air Berlin, and Virgin Express.[2]

Figure 7.2 presents the normalized Gini index for the selected carriers in the years 1996, 2000, and 2004. FSCs appear to have a higher concentration index than LCCs. This indicates a more unequal spread of air frequencies over the network.

[2] Ryanair data are included in the OAG database only until 2000, therefore, in our analysis, the data for 2004 are missing. Virgin Express, Air Berlin and easyJet are included in the OAG database for 1996.

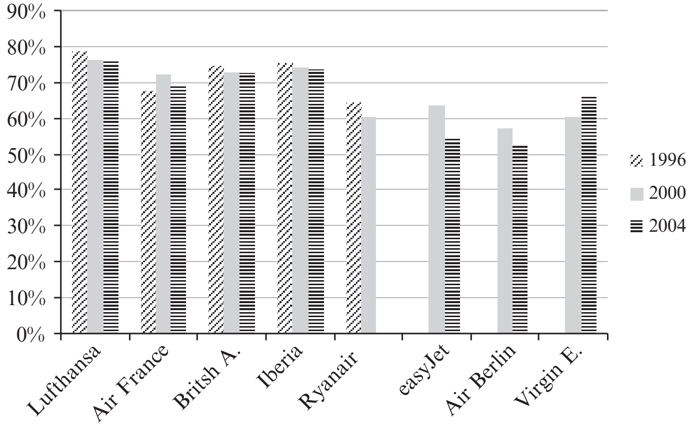

Fig. 7.2 Normalized Gini concentration index for European airlines (author elaborations)

This may be the consequence of having single- or multiple-hub networks, where many legs are connected.

The difference between the four FSCs, in terms of concentration indexes for intra-EU traffic, appears to be small. They range between 0.69 (Air France in 2004 before the merger with KLM) and 0.78 (Lufthansa in 1996). Lufthansa has the highest concentration index in each period. The index levels of FSCs have been quite stable between 1996 and 2004.

The LCCs have a lower concentration than the FSCs, which decreases over the three periods. The indices vary between 0.66 (Virgin Express in 2004) and 0.53 (Air Berlin in 2004).

The Gini concentration index is a measure of inequality of air frequencies between all pairs of airports in a given airline network. In general, the Gini index increases if the carrier reduces frequency between spoke airports in order to concentrate its network on one primary airport, the hub (HS strategy), or grows by the creation of a second hub (multi-HS strategy). However, it also increases if one or a few routes gain importance in terms of relative frequency compared with the other routes, irrespective of whether these are PP or HS legs.

7.2.2 The Freeman Network Centrality Index

The Freeman (1979) centrality index has been developed in the context of social network analysis and measures the network shape as degree of inequality in a network with respect to a perfect star network. We consider the star network as the pure HS network, and thus the Freeman centrality index is a measure of similarity to an HS configuration. To the best of our knowledge, there are no previous applications of this centrality index to measure airline network configurations in the transport literature.

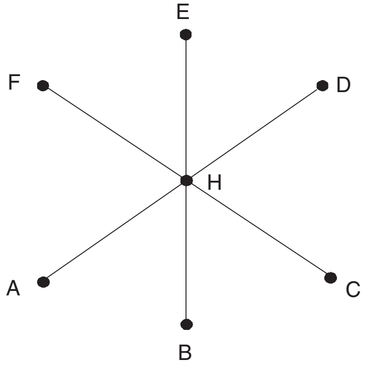

Fig. 7.3 Star network

The literature on social network analysis proposes an operational set of methodologies to describe network complexity. The concept of network centrality is one of the fundamental properties of social structures that can be applied to airline network analysis. The centrality of a node in a network is a measure of the structural importance of the node. Describing the multiplicity of centrality measures is beyond the scope of this study (for a detailed review, we refer readers to Hanneman 2001; or Wasserman and Faust 1994).

The centrality concept we use in this study is known as *betweenness centrality*. Consider the star network presented in Fig. 7.3. Node H in the centre has an advantage in the star network as it falls *between* all pairs of nodes while no other nodes fall between H and other nodes. If a passenger located in H wants to reach F, he/she may simply do it via a direct link. If a passenger in F wants to reach B, he/she needs to travel via H. This is also the basic concept of an HS network where H is the hub and the other nodes are the spokes. The structurally advantaged position of H is due to the fact that it falls between all the other nodes.

The measures of betweenness are based on the assumption that information is passed from one point to another only along the shortest paths linking them (as usually also happens for travellers). A path is an alternating sequence of points and lines, beginning at a point and ending at a point, and which does not visit any point more than once. Usually, there is more than one path connecting the initial and the final point, and these paths have the same or different lengths. In graph theory, the geodesic distance between two points is defined as the length of the shortest path between them.[3] The betweenness $C_B(x_i)$ of a point x_i, therefore, requires an examination of the geodesics linking pairs of other points. If g_{jk} is the number of geodesics linking points x_j and x_k in a network, and $g_{jk}(x_i)$ is the number of such paths that contain point x_i then:

[3] Geodesic distance is defined in mathematics as the shortest line between two points on a mathematically defined surface (as a straight line on a plane or an arc of a great circle on a sphere). Based on the geodesic distance betweenness centrality is defined as the number of geodesic paths that pass through a node.

$$b_{jk}(x_i) = \frac{g_{jk}(x_i)}{g_{jk}},$$

is the proportion of geodesics linking x_j and x_k that contain x_i.

To determine the centrality of point x_i, we sum all these values for all unordered pairs of points where $j < k$ and $j \neq k \neq i$:

$$C_B(x_i) = \sum_{j<k}^{n} \sum_{j<k}^{n} b_{jk}(x_i).$$

This provides a measure of the overall centrality of point x_i in the network. $C_B(x_i)$ is dependent on the size of the network over which it is calculated. What is needed is a measure that is relative to its maximum value in terms of the number of points in its network.

Freeman (1977) demonstrated that the maximum value taken by $C_B(x_i)$ is achieved only by the central point in a star. It is:

$$\frac{n^2 - 3n + 2}{2}.$$

Therefore, the relative centrality of any point in a graph may be expressed as the ratio:

$$C'_B(x_i) = \frac{2C_B(x_i)}{n^2 - 3n + 2},$$

which is a normalized measure that varies between 0 and 1 and may be compared between networks. A star or wheel, for example, of any size will have a centre point with $C'_B(x_i) = 1$; all other points will yield $C'_B(x_i) = 0$. Both $C_B(x_i)$, $C'_B(x_i)$ are measures of point centrality based on the structural attribute of the betweenness of point x. Let x^* be the node with highest centrality, and then the Freeman centrality index of the network is as follows:

$$C_B = \frac{\sum_{i=1}^{n} [C'_B(x^*) - C'_B(x_i)]}{n-1},$$

$$C_B = \frac{\sum_{i=0}^{n} \left[\frac{C_B(x^*)}{n^2-3n+2} - \frac{C_B(x_i)}{n^2-3n+2}\right]}{n-1},$$

$$C_B = \frac{\sum_{i}^{n} [C_B(x^*) - C_B(x_i)]}{(n-1)(n^2 - 3n + 2)},$$

$$C_B = \frac{\sum_{i}^{n} [C_B(x^*) - C_B(x_i)]}{(n^3 - 4n^2 + 5n - 2)},$$

where the last equality emerges after substituting $C'_B(x_i)$ in the original definition.

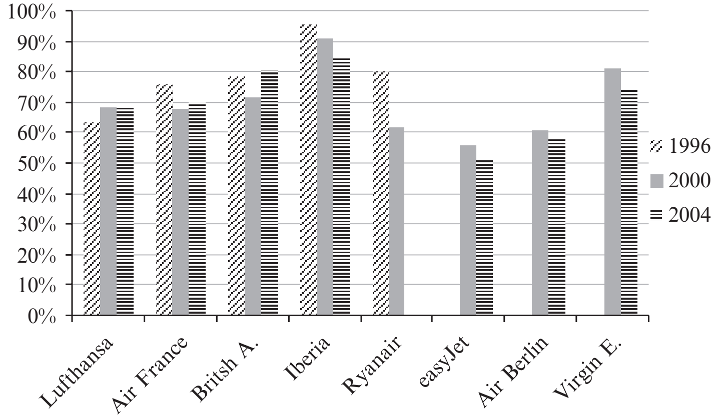

Fig. 7.4 Freeman centrality index for European airlines

The Freeman network centrality index expresses the degree of inequality or variance in our network as a percentage of a perfect star network of the same size. This measure takes 1 for a star (pure HS configuration) and 0 for a complete graph (pure PP configuration). These characteristics ensure that it can be employed to detect HS vs. PP configurations.

Figure 7.4 presents the Freeman centrality index calculated for the eight selected carriers.[4] The index shows, like the Gini index, that there is a substantially higher amount of centralization in FSC networks than in the LCC configuration. That is, the centrality of a few nodes varies rather substantially, and this means that, overall, spatial centralization is usually stronger in an FSC network than in the network of LCCs.

However, a few differences are also remarkable. The Freeman index detects Lufthansa as the least centralized network among FSCs, while the Gini considers that carrier as the most concentrated network. This means that there is less inequality in the nodes' centrality compared with, for example, Iberia. This suggests that, overall, Iberia's network is more similar to a 'star' network. The fact that the Lufthansa network is separated into two hubs, i.e. Frankfurt and Munich, may explain this. In general, the Freeman index does not present relevant variations over time for both FSCs and LCCs. The only exception is the big decrease in the index for Ryanair from 1996 to 2000. In 1996 this carrier operated only 10 airports linked to Dublin and Stansted. The decrease of the Freeman index for Ryanair may be due to the rapid development of the network during the late 1990s as a result of increased of point-to-point links.

[4] The Freeman index has been calculated with UCINET 6 for Windows: Software for Social Network Analysis, Borgatti et al., 2002.

7.2.3 The Freeman Index versus the Gini Index

The Gini index seems to have limited power to describe the HS spatial configuration, and to be quite stable over time, even though modifications may have occurred in the network configurations. It is worth noting that the Gini index fails to detect the difference between HS and PP. The index ranges between 0 and 1. In the case of a pure PP network it takes the value 0, but with a pure HS it assumes the value 0.5. In several forms of multi-HS, the Gini index assumes the value 0.5, which fails to detect the spatial morphology. The difference between the Gini and the Freeman index can be explained by the examples presented in Fig. 7.5.

It is clear that there is a relation between the frequency concentration and Gini index value (panel A vs. C and panel E vs. F and G), but it is obvious that there is no unique relation between the spatial morphology and the index value. Panels E and G have the same index value = 0.63. Another similar example is panels D, H and I that have G = 0.5, even though the spatial configurations are different (linear versus perfect hub-and-spoke). On the other hand, the Freeman index measures the network shape as the degree of inequality in a network with respect to a perfect star network, i.e. the pure HS. Indeed in both panel A or C, the Freeman index is equal to 1 while in the perfect PP network (panel B), it is equal to 0. Moreover, the Freeman index seems not to be affected by the concentration of the frequencies (panel E versus F) but by the network morphology (panel D versus E or H versus I). Finally, the Freeman index is particularly suitable to measure network centrality as it captures the spatial economic behaviour of passengers. In fact, it assigns a high centrality to those nodes that are more often visited by 'geodesic paths'. Geodesic paths are the shortest paths that link two nodes and also those paths which passengers would like to choose when they travel in order to minimize their total travel time or the number of connections.

In addition, from the market efficiency perspective, the geodesic paths minimize the network costs and hence individually maximize the social welfare. We therefore propose the Freeman index as a better measure for network morphology in terms of the HS or the PP network.

7.2.4 The Bonacich 'Global' and 'Local' Centrality

Bonacich (1972) proposed what is called the eigenvector measure of centrality. Eigenvector centrality is defined as the principal eigenvector of the matrix that represents the network (adjacency matrix). The defining equation of an eigenvector is:

$$\lambda \mathrm{v} = \mathrm{Av},$$

where A is the matrix representing the network: λ is the eigenvalue; and v is the eigenvector. The equation lends itself to the interpretation that a node which has a high eigenvector score is one that is adjacent to nodes that have high scores. In order

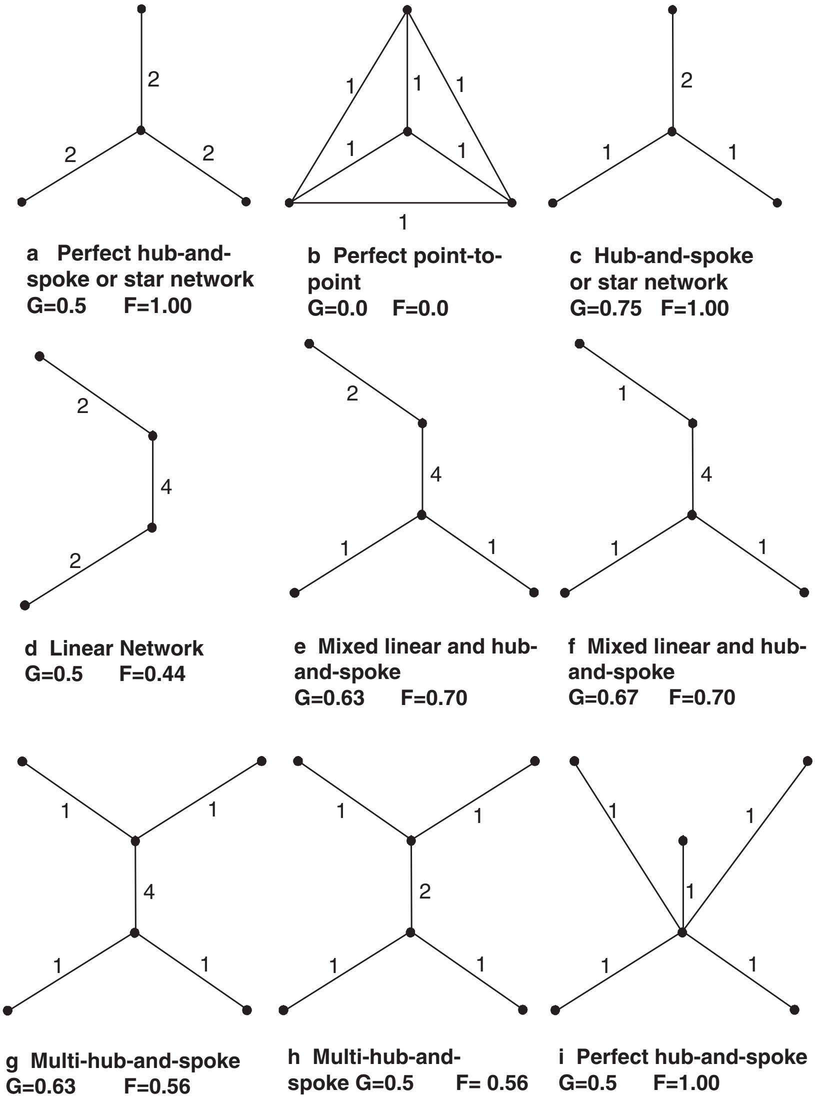

Fig. 7.5 Examples of normalized Gini concentration index (G) and Freeman betweenness centrality index (F) values

to identify the eigenvalue and the eigenvector, a factor analysis is applied on the network value matrix.[5] This approach aims to identify the most central node (i.e. the

[5] The adjacency matrix that represents the network contains 1 when there is a link between the nodes, and 0 otherwise. In the value matrix, the 1 is replaced by a measure of the strength of the link. In our case, the value matrix is constructed with the number of weekly frequencies between the airports.

one with the smallest distance from others) in terms of the 'global' or 'overall' structure of the network, and pays less attention to patterns that are more 'local'. Thus, the Bonacich method identifies the local and sub-local network structures, such as a national or regional network, versus the global network configurations. When the network is represented in matrix form, each dimension identified by the factor analysis corresponds to the corresponding matrix eigenvector. The location of each node with respect to each dimension is therefore identified by the eigenvalues of the eigenvector. Usually, the first factor or dimension captures the 'global' aspects of distances among nodes; the second and the subsequent dimensions capture more specific and local substructures.

The factor analysis is carried out for the eight carriers under consideration. The factors explaining cumulatively about 70% of the overall variation are reported in Table 7.2 (see Hanneman 2001). A complete overview of factor analysis output and the first eigenvector values are presented in Appendix V.

The first factor indicates how much of the overall pattern of distances among airports can be seen as reflecting the global network (the first eigenvalue). Other factors tell us about more local or additional patterns such as the domestic network or the point-to-point local structure.

The global centrality is distributed on the network nodes and is measured with the value of each node of the first eigenvector. Higher values of global centrality indicate that the nodes are 'more central' to the global pattern of distances among all of the nodes, lower values indicate that nodes are more peripheral. The values of the first eigenvector (first factor) are presented in Table 7.3.

Lufthansa and Air France present no dominant global pattern of distance. Indeed, we can identify three main structures for the German carrier (three factors explain around 70% of the distance variation) in 1996 and two in 2004. Lufthansa appears to have strengthened its global structure in 2004, meaning a rationalization of the network. From Table 7.3, we see that Munich and Frankfurt act as central hubs. In 1996, Frankfurt was the most central hub, followed by Munich, Berlin, Hamburg and Düsseldorf which all show a lower centrality. In 2000 and 2004, we observe

Table 7.2 Factor analysis results: cumulative variance (%)

	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
Flag Carriers	Lufthansa			Iberia			British Airways			Air France		
Factor1	58	56	63	81	74	68	38	41	34	62	47	42
Factor2	66	66	72				52	55	46	69	73	68
Factor3	72	73					60	64	54			
Factor4							66	71	60			
LCC	easyJet			Air Berlin			Virgin Express			Ryanair		
Factor1		100	39		54	40		100	86	86	70	NA
Factor2			54		65	55			100			
Factor3			65		72	64						
Factor4			74			71						

Table 7.3 Airports' 'global' centrality (author elaborations)

	1996		2000		2004
Lufthansa					
Frankfurt	63.3	Frankfurt	68.7	Munich	68.7
Munich	52.6	Munich	57.1	Frankfurt	66.0
Berlin-Tegel	51.3	Berlin-Tegel	42.3	Berlin-Tegel	41.3
Hamburg	48.0	Hamburg	45.3	Hamburg	38.9
Dusseldorf	42.8	Dusseldorf	40.9	Dusseldorf	38.7
AirFrance					
Paris-C. De Gaulle	98.2	Paris-Orly Field	69.3	Paris-C. De Gaulle	71.9
Nice-Cote D'Azur	31.7	Paris-C. De Gaulle	61.5	Paris-Orly Field	57.7
London-Heathrow	29.9	Marseille	42.4	Nice-Cote D'Azur	42.0
Milan-Linate	25.3	Toulouse	41.8	Toulouse	34.9
Geneva-Geneve Cointrin	24.6	Lyon	36.2	Lyon	33.1
British Airways					
London-Heathrow	77.7	London-Heathrow	71.2	London-Heathrow	79.4
Manchester	48.8	Manchester	49.7	Manchester	52.1
Glasgow	39.3	London-Gatwick	43.8	Edinburgh	39.1
Edinburgh	37.8	Edinburgh	38.2	London-Gatwick	37.5
London-Gatwick	35.6	Glasgow	37.8	Glasgow	36.8
Iberia					
Madrid	90.1	Madrid	87.7	Madrid	83.4
Barcelona	65.5	Barcelona	73.0	Barcelona	80.0
Palma Mallorca	29.0	Palma Mallorca	29.4	Palma Mallorca	31.5
Malaga	22.0	Valencia	28.0	Valencia	28.3
Valencia	20.8	Bilbao	20.0	Malaga	23.3
Ryanair					
Dublin	95.0	London-Stansted	82.3		
London-Stansted	81.0	Dublin	80.0		
Glasgow-Prestwick	37.4	Glasgow-Prestwick	38.3		
Manchester	29.7	Hamburg-Blankensee	37.6		
Birmingham	26.8	Venice-Treviso	24.1		
easyJet					
		London-Stansted	100.0	London-Luton	59.9
		Copenhagen	39.3	Amsterdam	44.3
		Milan-Malpensa	39.3	London-Stansted	43.8
		Malaga	34.6	Nice-Cote D'Azur	39.0
		Rome-Ciampino	33.0	London-Gatwick	37.6
AirBerlin					
		Palma Mallorca	87.2	Palma Mallorca	73.6
		Paderborn	47.3	Dusseldorf	52.0
		Berlin-Tegel	45.7	Berlin-Tegel	45.5
		Muenster	40.7	Vienna	44.0
		Cologne	40.5	London-Stansted	33.3
Virgin Express					
		Brussels	100	Brussels	99.8
		London-Heathrow	65.6	Nice-Cote D'Azur	43.8
		Barcelona	51.2	Barcelona	36.8
		Rome-Fiumicino	50.1	Athens	36.8
		London-Gatwick	21.1	Malaga	36.8

Note: The centrality is measured by the values of the first eigenvector as derived from the factor analysis. Only the top 5 values are reported

Munich becoming as central as Frankfurt with the other three airports reducing their centrality scores. We invite the reader to find a visual confirmation in the geographical maps presented in Appendix IV. In 1996 Berlin, Hamburg, and Düsseldorf offered 28, 39 and 44 destinations, respectively, while in 2004 these destinations decreased to 11, 20, and 35. Munich increased its links from 62 to 82.[6] We can thus conclude that Lufthansa has pursued a multi-hub strategy still have a relevant number of airports with point-to-point connections in Europe. Regarding Air France, the local and global factors capture the differences in the domestic network and intra-Europe network. In 1996, Paris, Charles de Gaulle was the unique hub for both domestic and international routes. In 2000 and 2004, we observe the rapid development of Paris Orly airport. The French carriers freed up capacity in Charles de Gaulle by deploying all domestic capacity in Orly. Today, this second hub offers a well-developed domestic network and a relatively small number of European destinations. This means that Charles de Gaulle is the hub for intra-Europe and intercontinental connecting traffic, and Orly is mainly the airport for PP domestic traffic between French airports and Paris.

The British Airways network is characterized by four principal factors indicating that this network is more complex than that of Lufthansa and Air France. While London Heathrow acts as the central hub, other airports such as Manchester, Glasgow, and Edinburgh represent European central bases that do not act as connecting hubs. In 1996, the second hub London-Gatwick was less central than these bases. In 2000 and 2004, Gatwick did not develop enough to become the second hub for a European network. Manchester is still today the second base for British Airways. This airport is not a hub, but a basis for PP connections. Similarly, Glasgow and Edinburgh are still network bases for PP links in Europe. Although British Airways designs its global network around the two London airports, Heathrow works as the central hub for intra-European network more than Gatwick.

Finally, the Iberia network is described by one global structure, with Madrid as the first and Barcelona as the second hub for both domestic and intra-European network. These are much more central than any other airport, and similar in number of connections and destinations. As captured by the Freeman centrality index, the Spanish carrier shows a clear dual-hubs radial network.

LCCs have only recently entered the European market, and only data from 2004 allow cross-comparison. Both easyJet and Air Berlin present four principal factors indicating the presence of many local structures. No global structure dominates the network. It was in the late 1990s that EasyJet started to operate from London Stansted and – by the merge with Go low-cost airline – it increased the centrality of London Luton, Amsterdam, Nice, London Gatwick and Liverpool. The Air Berlin network is central in one of the most popular resort destinations from Germany, that is Palma de Mallorca, followed by the capital Berlin, Vienna and London Stansted. An obvious shortcoming of the centrality index for the LCCs is that it assumes that

[6] It is remarkable that in terms of the number of destinations in the network of Lufthansa, Berlin is the most decreasing airport, where the low-cost Air Berlin developed one of the biggest bases.

there are connecting flights, whereas in most cases there are no such connections because the hubs are only technical bases. This point will be examined in more detail the next section.

7.2.5 Temporal Concentration of HS versus PP

The previous sections have investigated how the spatial dimension of European airline networks has changed between 1996 and 2004. Although the Freeman index seems to be a more adequate measure than the Gini index, we have found only a few elements to differentiate the network organization of FSCs from that of LCCs. In this section, we show that, by extending the analysis to the temporal dimension, some differences will emerge.

The temporal configuration, according to Bootsma (1997), can be defined as the ‘number and quality of indirect connections offered by an airline or alliance by adopting a wave-system structure in the airline flight schedule’.

Ideally, the HS maximum number of city-pairs with n airports is equal to $n(n-1)/2$, and the total number of direct routes between the hubs and the spokes is $(n-1)$. Therefore, the number of city-pairs connected by an indirect service is equal to $n(n-1)/2-(n-1)=(n-1)(n-2)/2$. The ratio between the indirect and the total number of connections is $(n-2)/n$, which is equal to 1 for $n \to \infty$. It means that, for a high number of airports included in the HS network, the indirect connections tend to be equal to the total number of possible connections, and the number of direct connections becomes, relatively speaking, very small or irrelevant.

In the real world, carriers face the logistic problem of designing their wave structure in order to maximize the connectivity under a certain number of constraints. Burghouwt and de Wit (2003) provide an analysis of the changes in temporal dimension of airline network configurations in Europe between 1990 and 1999. They highlight that the elements that determine the connection waves are: the airport capacity (i.e. the maximum number of the flights that can be scheduled per time period); the minimum connection time (mct) at the airline hub; the maximum connection time (MCT); and the routing or circuity factor (cf). The mct is required to allow passengers and baggage to transfer between two flights, as well as to turn around the aircraft. Indirect connections not meeting the mct-criterion cannot be considered as realistic ones. Minimum connection times are unique for every hub airport and are reported in the Official Airline Guide (OAG).

From the demand side, not every connection is attractive for the travellers. The longer the connection time, the less attractive it is. In this respect, Bootsma (1997) has defined standard MCT for different types of connections: the quality thresholds (see Table 7.4). In our study, we focus only on Europe–Europe type of connections, and we have chosen a minimum connection time of 45 minutes and a maximum connection time of 180 minutes (note that the city-pairs connected with more than two connecting flights are excluded from the analysis).

Table 7.4 Connection quality thresholds (in minutes) for different types of connections

Type of connection	Texcellent	Tgood	Tpoor
Europe–Europe	90	120	180
Europe–Intercontinental	120	180	300
Intercontinental–Intercontinental	120	240	720

(*Source*: Bootsma 1997, p. 68.)

The routing or circuity factor (cf) of the connections can be defined as $cf = IDT\,/\,DTT$, where IDT is the actual in-flight time indirect connection, and DTT is the estimated in-flight time of the direct connection. The maximum routing factor is typically 1.25 (Bootsma 1997). The maximum *cf* excludes the 'back-tracking routes', such as Milan–Paris–Nice or Manchester–Amsterdam–London. Even though the carriers' network is accidentally able to offer these connections, the passengers perceive them as not attractive, especially if there are direct flight alternatives offered by other carriers.

Figure 7.6 presents the actual flight distribution of Lufthansa in Frankfurt and easyJet in London Gatwick. In Frankfurt, we can identify a clear wave-system structure, with four waves: two in the morning, one in the afternoon, and one in the evening. The waves for departures and arrivals almost overlap, most probably as result of the connections design. In contrast, in London Gatwick, we can not identify any wave structure, but instead can observe one departure peak in the morning and two arrival peaks in the late afternoon and evening.

Our analysis of the temporal dimension does not aim to study the wave-system structure for each carrier and airport, like Burghouwt and de Wit (2003) did, but to identify the carrier networks with a significant indirect connectivity. In particular, the analysis of the temporal dimension is based on the ratio between the direct and indirect connections supplied by the HS structure versus the PP structure.

The ratio is calculated in terms of number of frequencies and city-pairs supplied. City-pairs are counted as indirectly-connected within a network if they can be reached through the hub with a connecting time of between 45 and 180min, and maximum routing factor equal to 1.25, based on published schedules. City-pairs with direct service are put in the direct-service category indicating the number of frequency flights linking them.

The connectivity ratio provides a measure of the hub connectivity, and, consequently, the number of real city-pair combinations supplied by the carriers. Table 7.5 presents the network composition and the hub connectivity for the FSCs and the LCCs. Specifically, it presents the number of frequencies supplied from spokes to hubs, between the hubs, between the spokes, and the connectivity evaluation. The same calculation is carried out in terms of flight frequencies between the city-pairs. Hence, two connectivity ratios are calculated, i.e. the number of one-stop city-pairs and the frequency of these indirect connections, both divided by the total concerned.

Lufthansa appears to have increased the number of HS connections and decreased the PP links (spokes-to-spokes). The frequency connectivity ratio has

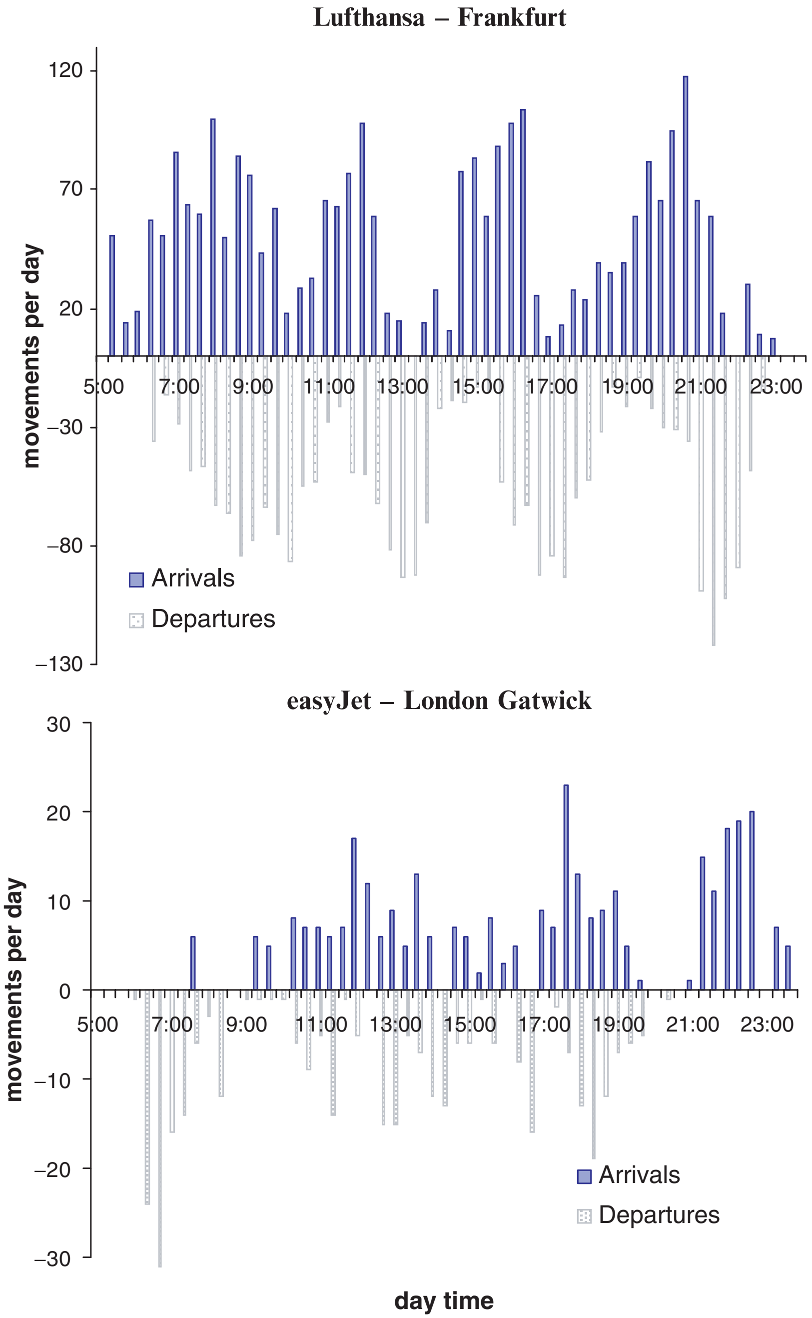

Fig. 7.6 Number of departure/arrivals for an FSC and an LCC in 2005

Table 7.5 FSC and LCC network composition and hubs connectivity

	Lufthansa			Air France			British Airways			Iberia		
	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
Frequency of flights												
Spoke to hub	2,678	3,248	4,010	1,075	3,119	2,960	2,061	2,410	2,198	1,047	2,359	2,750
Hub to hub	84	85	85	0	0	0	0	0	0	217	275	198
Spoke to spoke	1,977	1,989	1,414	215	1,194	1,350	1,482	2,004	1,351	196	450	680
Total	4,739	5,322	5,509	1,290	4,313	4,310	3,543	4,414	3,549	1,460	3,084	3,628
Number of connected city-pairs												
Directly connected	304	404	251	71	164	197	231	251	214	103	152	221
Indirectly connected	2,122	2,819	3,340	706	1,769	1,893	1,214	1,245	974	271	1,027	1,259
Total	2,426	3,223	3,591	777	1,933	2,090	1,445	1,496	1,188	374	1,179	1,480
Frequency of connected city-pairs (weekly)												
Directly connected	4,739	5,322	5,509	1,290	4,313	4,310	3,543	4,414	3,549	1,460	3,084	3,628
Indirectly connected	21,292	39,553	51,163	7,121	20,447	23,472	9,243	1,2182	9,775	2,610	12,833	15,755
Total	26,031	44,875	56,672	8,411	24,760	27,782	12,786	16,596	13,324	4,070	15,917	19,383
Connectivity ratio												
% indirectly connected city-pairs	87	87	93	91	91	91	84	83	82	72	87	85
% indirectly connected frequencies	82	88	90	85	83	84	72	73	73	64	81	81
	easyJet			Ryanair			AirBerlin			Virgin Express		
	1996	2000	2004	1996	2000	2004	1996	2000	2004	1996	2000	2004
Number of connected city-pairs												
Directly connected	–	36	73	8	37	–	–	122	28	–	5	14
Indirectly connected	–	5	–	–	1	–	–	2	4	–	5	8
Total	–	41	73	8	38	–	–	124	32	–	10	22
Frequency of connected city-pairs (weekly)												
Directly connected	–	657	1,613	263	656	–	–	266	292	–	29	192
Indirectly connected	–	67	–	–	3	–	–	3	37	–	12	53
Total	–	724	1,613	262	659	–	–	269	329	–	41	245
Connectivity ratio												
% indirectly connected city-pairs	–	13	0	0	3	–	–	2	14	–	52	38
% indirectly connected frequencies	–	9	0	0	0	–	–	1	11	–	30	22

increased over the years from 82% to 90%, meaning that 90% of all connections in Europe take place via the hubs. Over the years, Air France has maintained the frequency connectivity ratio at stable level at about 85%. Despite the development of Paris Orly, transfer traffic is mainly concentrated in Charles de Gaulle. British Airways has the lowest frequency connectivity ratio, around 70%, meaning that 30% of its network is PP. The British carrier has a mixed HS and PP structure. Finally, Iberia started in 1996 with a relatively small network covering only 375 city-pairs versus the 2,427 of Lufthansa but then grew to 1,480 city-pairs with almost 20,000 connections. Consequently, the connectivity ratio increased from 64% to 81%.

LCCs have a very low connectivity ratio: in 2004 easyJet offered only PP connections, thus being a pure PP network. Similar results exist for Ryanair. Differently, Air Berlin and Virgin Express have developed a mixed HS and PP strategy. Those carriers fly to the primary city airports such as Milan Linate, Amsterdam Schiphol or Berlin Tegel, whenever possible, but they still negotiate lower fees when not making use of the airport service components. However, they avoid congested hubs by using a secondary airport such as Milan Orio al Serio or London Stansted. In general, their network strategy is still focused on PP connections, principally viewing transfer passengers as a coincidental consequence of the network.

7.3 Network Organization

In this section, we analyse the overall network organization in terms of spatial and temporal concentration. In Fig. 7.7, we plot the Freeman index and frequency connectivity ratio in order to identify the network organization of FSCs and LCCs. The two dimensions are useful to detect the differences between the HS and PP choices. The ideal HS configuration is in the North-East of the graph, and the ideal PP configuration is in the South-West of the graph. We see that FSCs are characterized by high temporal and spatial concentration, while LCCs have an almost zero temporal concentration but high spatial concentration. This means that the temporal dimension provides a clear distinction between FSCs and LCCs, whilst the spatial dimension can be useful to identify the peculiarities within groups.

Among the FSCs, we see that Lufthansa has the highest temporal concentration. This may be explained by the development of the second hub Munich and by the high degree of timetable coordination in Frankfurt (see Rietveld and Brons 2001). On the other hand, it records the lowest spatial concentration, meaning that there is still a considerable number of PP connections. Both time and spatial concentration have increased from 1996 to 2004, indicating that, although the German carrier presents a mixed PP and multi-HS network, it has pursued a clear HS network choice. British Airways shows the lowest time concentration due to the centrality of Manchester and Edinburgh acting as PP bases. Moreover, British Airways has not developed Gatwick as a second hub like Munich has for Lufthansa. A second reason is the capacity problems of Heathrow that prevent hub operations (see Rietveld and Brons 2001).

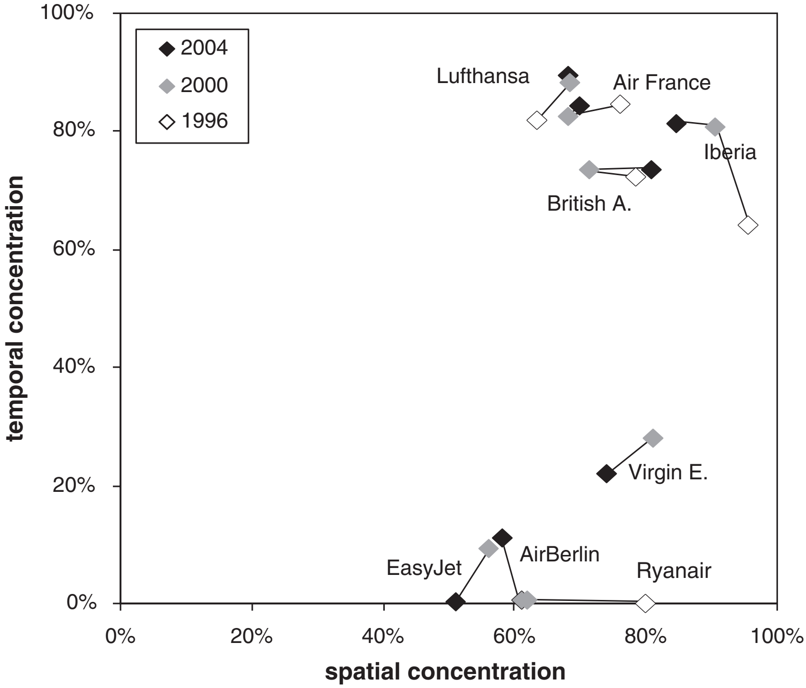

Fig. 7.7 Network configuration of FSCs and LCCs

The network design has not changed considerably over the periods considered. Iberia is the most spatially-concentrated HS network. The development of Barcelona as a second hub for both domestic and intra-European network with no relevant PP international connections (exceptions are some domestic PP links) has increased the spatial concentration but decreased the temporal concentration.

Finally, Air France has reduced the spatial concentration since it freed up capacity in Charles de Gaulle by deploying all its domestic capacity in Orly. Therefore, Charles de Gaulle has developed as the hub for intra-Europe and inter-continental connecting traffic, while Orly has mainly became the airport for PP domestic flights.

The LCC results show that there are some different network strategies adopted by the four selected LCCs. First, we notice that Virgin Express and Air Berlin are offering a modest percentage of connecting flights and not only PP links. Moreover, they operate from primary airports, sell via travel agents, and have a frequent flyer programme and in-flight entertainment. Air Berlin also offers two classes: on board, and pre-assigned seats. In contrast, Ryanair and easyJet do not offer any flight connection and result as a pure PP network carrier. They do not offer any services (or offer them separately at extra cost), while Ryanair uses under-utilized secondary and tertiary airports. Services can often be acquired separately by the passengers to replicate the full service of flag carriers. Even some of the most characteristic rules and conditions attached to the airfares of flag carriers, such as the possibility of reservation changes or the one-way ticket fare, can also be purchased with the LCC.[7]

7.4 Network Connectivity Models: A New Outlook

In the last few years, a new stream of research on complex networks has emerged from geography and network analysis to be applied in the field of social science, biology, economics and telecommunications (see Barábasi and Albert 1999; Albert and Barábasi 2000; Amaral et al. 2000; Gorman and Kulkarni 2000, 2004; Gorman 2005; Schintler et al. 2005a; Patuelli et al. 2006). This stream of research analyses the position of nodes (e.g. cities, hubs), as well as the diffusion patterns of flows in complex networks, with emphasis on route length, nodal clustering, and connectivity distributions (such as power-law and exponential). The concepts of 'Random Network' (RN), 'Small World' (SW) and 'Scale Free' (SF) networks have been introduced and empirically investigated (see, e.g., Barábasi and Oltvai 2004; Reggiani and Vinciguerra 2006).

Watt and Strogatz (1998) argue that complex networks appeared not to have a random formation, but instead are locally-organized structures of nodes or clusters, leading to SW networks. These SW networks tend to have a connectivity distribution with an inverse relationship between the number of nodes and the number of connecting links. In contrast, the random distribution shows a tailed distribution with an exponentially declining probability to find connected nodes. In the case of incremental growth in a complex network, new nodes are more likely to connect with the existing well-linked nodes. Consequently, hubs tend to reinforce themselves. The emerging vertex connectivity distribution seems to follow a power law, where the exponent coefficient varies between 2 and 3. These latter topologies of networks are called SF networks.

Schintler et al. (2005b) consider the HS airline networks as a practical example of an SF network. As is known, the HS network shows preferential connectivity to the major airport hubs from the minor airports (called 'spoke airports'); while the major airports are highly interconnected. In the HS network there are in general one, two or in rare case a few hub airports, which have the majority of connections in the global airline network. From a technical perspective, Schintler et al. argue that the airline network connectivity distributions do not quite fit a power law but they have an exponential cut-off, because there is a physical constraint on the number of planes an airport can handle, which prevents a complete power-law fit (Amaral et al. 2000). Further research on the configuration of airline network could adopt

[7] Primary airports' operations can be considered as an additional service, as they often reduce passenger travel costs from the city to the airport.

these connectivity models in order to detect their actual topology and its development in recent years.

Reggiani and Vinciguerra (2006) have highlighted the importance of identifying the spatial-economic-policy factors, which lead to the development/persistence of SF networks in real systems, because of the strong characteristics of robustness and vulnerability inherent to the SF networks. In cases of random attacks on the nodes, the SF network will strongly persist, as a random attack will probably damage nodes that have only a few connections. However, in the case of an attack against the main hubs, the network will easily become fragmented. On the contrary, the RN (mainly referring to the point-to-point airline network) is weak against a random attack which would cause the split of the network. Gorman et al. (2006) simulated damage to a few major hubs, demonstrating that, in the case of SF networks, this would provoke the crash of the whole system. In the airline industry the importance of identifying the spatial hubs is crucial to prevent competitive disadvantages. As presented in Chap. 2, developing a network hub in a certain airport creates an entry barrier to potential competition at this airport. This has often been argued to be a limitation to the market competition. In this perspective, further research is needed in order to define the right trade-off between competition and the vulnerability of the HS network.

7.5 Conclusions

In this chapter, we have provided new measures for assessing airline network configurations, in order to investigate the complexity of modern carriers' network design, and explain the differences between LCC and FSC networks in Europe. The network configuration (HS, PP, and more complex structures) was assessed in terms of spatial and temporal concentration. We evaluated the spatial dimension by means of the Gini and Freeman indices. The Freeman index is preferred to the Gini for at least two reasons. First, it is able to detect the network morphology in terms of the reference structures, i.e. it takes a value 1 for a pure HS and 0 for a pure PP. In contrast, the Gini index seems to be appropriate to measure the flight frequency concentration but not the spatial configuration. In this respect, the Gini assumes the value 0 for the pure PP, but 0.5 for a pure HS, or even for a different spatial configuration such as multi-HS. Second, the Freeman index captures the economic behaviour of passengers. The Freeman centrality index assigns high centrality to those nodes which passengers would like to choose to visit in order to minimize their total travel time or the number of connections. We also use the Bonacich method to identify the global structure as well as the national and regional substructures of the network.

The analysis of the temporal dimension is based on the frequency connectivity ratio (i.e. the share of indirect connecting flights in the total number of flights connecting each city-pair). The empirical analysis demonstrates that the temporal dimension provides a clear distinction between FSCs and LCCs, while the spatial dimension helps to identify the differences within groups. We find some evidences that the FSCs have developed their networks as mixed multi-HS and PP systems with a strong dominance of the HS. These configurations vary from Iberia, which is the most spatially-concentrated HS network with a dual-hub radial network (Barcelona and Madrid), to British Airways which offers the most mixed HS and PP network configuration. In particular, the British Airways network is organized such that London Heathrow is the main hub, and Manchester, Glasgow and Edinburgh are bases with several direct connections to European and domestic destinations. The Lufthansa network developed into a dual hubs-and-spoke with mixed PP structure. Specifically, the hubs are Munich and Frankfurt and the bases with PP connections are Berlin, Hamburg and Düsseldorf. Finally, the Air France network (before the KLM merger) is classified as a single-HS configuration with Charles de Gaulle as the hub for intra-European and intercontinental traffic, with Paris Orly airport acting as a PP airport base for domestic traffic within France.

In addition, our results reveal that LCCs have a lower centrality than FSCs, mainly for the temporal dimension and slightly lower for the spatial dimension. Time-based measures proved to be able to differentiate the airline market. The empirical evidence is that the FSCs have developed a multi-HS network strategy, while the LCCs show a considerable orientation towards a PP network growth. However, the analysis shows variations among LCCs' network configurations. While Ryanair and easyJet have developed a pure PP structure, Virgin Express and Air Berlin offer a modest percentage of connecting flights in Brussels and Berlin. However, the connectivity ratio of Virgin has grown in recent years, and it is possible that, if this trend continues in the coming years, the bases of this LCC could turn into small hubs as is already happening in the US for Airtrain in Atlanta or Frontier in Denver.

Further researches on the airlines network configuration could adopt the recently developed connectivity models in order to detect their actual topology and its development in the last years. Moreover, the importance of identifying the spatial hubs is crucial to prevent competitive disadvantages. Further studies are needed in order to define the right trade-off between competition and vulnerability of the HS network.

Part IV
Conclusions

Chapter 8
Retrospect and Prospect

Live as if your were to die tomorrow.
Learn as if you were to live forever.

Mahatma Gandhi

8.1 The Objective and Research Questions

The current evolution of the aviation sector in Europe can be described in terms of the combination of two main factors. The first concerns the liberalization process which began in the EU during the 1990s and was then succeeded by the boom of the low-cost carriers. This process has radically modified the competitive environment where traditional airlines operate. The nature of competition has changed as new entrants or potential entrants have different business models, especially concerning the network organization (i.e. low-cost carriers). The second factor is related to specific exogenous factors such as terrorism, epidemics, and globalization that have pushed the aviation industry into a ‘perfect storm’. The main concern is whether this model, successful during the 1980s and 1990s, is now sustainable in a market crowded by low-cost carriers. Within this frame of discussion, *the objective of this study is to analyse the new strategic conduct of the full-service carriers (FSCs) in a more liberalized European market in terms of how they cope with global economic crises and increased competition with low-cost carriers (LCCs)*. Three important research questions have been addressed:

1. How can FSCs react in the short-term to survive the global crises and still maintain a long-term network strategy? Specifically, how did the European carriers cope with the recent global crises?
2. How did the FSCs compete in pricing and how did they react to the LCCs’ entry?
3. Is the hub-and-spoke configuration still a possible network strategy when competing with point-to-point network operations? Can we empirically detect the network design of European carriers?

This chapter summarizes and reflects on the empirical results in order to answer to the research questions. This is organized in two parts: the summary of the study (Sect. 8.2) and some final remarks and recommendations for further research (Sect. 8.3).

8.2 Summary and Conclusions

The book is organized in three parts that are summarized in the next subsections with regard to their aims and results.

8.2.1 The Airline Industry in Perspective

Part I (Chaps. 1 and 2) provides the background of the research and describes some important elements of the airline industry. We present a concise analysis of the main *characteristics* and changes in the aviation sector, mainly from the supply side, which followed the market deregulation.

The deregulation effects on the industry have been broadly analysed by several authors looking specifically at the effect on one aspect or another of the industry, such as network development, pricing behaviour, airlines-airports relations, and alliances. We briefly present all of these elements in the new perspective, that of the airlines strategy and business model. Indeed, after the deregulation, we can identify three main airline business models: full-service carriers (FSCs), low-cost carriers (LCCs), and charter carriers (CCs). Thus, in Chap. 1 we attempt to provide a concise but complete panorama of the key elements of each business model emerging after the EU deregulation.

The process of deregulation and the subsequent process of privatization have induced important changes in the strategy of the airlines. First, the former state-owned carriers have developed hub-and-spoke networks and, through the international alliances, a multi-hub-and-spokes system. Sophisticated yield management techniques were adopted in order to control aircraft seat availability and to provide an even more differentiated product. The result of this process is a business model, which we refer to as the full-service carrier (FSC) model.

Second, the low-cost carrier (LCC) business model has experienced fast growth in Europe after the deregulation. LCCs have successfully designed a focused, simple operating model around a point-to-point, no-frills product. They did not suffer as much as the FSCs from the crisis in the air transport industry after September 11, thanks to the low fare levels that still attract many passengers and the diversion of passengers away from risk destinations (North America and Asia) towards the intra-European market. Although, every model characteristic still plays an important role in providing the cost advantages to LCCs, the most relevant success factors are related to the network configuration and the streamlined production processes and not, as one might believe, from the 'no frills' or no-product differentiation. The conclusions of this part are:

1. *LCCs can provide some important cost lessons for FSCs*. There are still large cost differences between FSC and LCCs both in EU end US, though the nature of the gap can differ between the US and the EU. For example, there is less of a difference in infrastructure costs in the US than, in other regions, with less opportunity for LCCs to concentrate on secondary airports. The size and spread of the cost gap highlights that there are several areas, from distribution to aircraft utilization, where the network airlines can move closer to an LCC approach in order to lower costs.
2. *Greater Cost Efficiency is already being achieved by FSCs*. US and European FSCs have managed to make progress in lower their unit costs (and particularly non-fuel unit costs) since 2001. A reduction in distribution and overhead costs has been the main driver. Cost efficiency is also being achieved by merger or acquisitions (M&A). The acquisition of KLM Royal Dutch Airlines by Air France in 2004 has shown its rivals what can be achieved with greater economy of scales in the highly fragmented industry.
3. *The Hub-and-Spoke model can, however, also provide some competitive advantages*. The higher product quality that can be offered by FSCs (e.g. comfort, more convenient airports, personal rewards through loyalty schemes) can be used to attract customers willing-to-pay a premium for the additional service. FSCs do still have advantages within their own business model by for distance using multiple aircraft types to adjust capacity to prevailing demand conditions on different routes. In addition, the airline network itself provides several advantages over LCCs on many routes. For example, over half of all European long-haul traffic originates from short-haul traffic on feeder routes, thus, FSCs can benefit from a higher level of economy of scope.

8.2.2 Coping with Crises in the Airline Industry

Part II is dedicated to the first research question. In recent years two terrible events have characterized the world economy: the September 11 terrorist attack on the Twin Towers in New York and on the Pentagon in Washington in 2001, and the SARS epidemic in East Asia which began in February 2003. These events produced two dramatic crises. By analysing these two important demand shifts, we are able to detect some determinants of the carrier's strategies (internal policy, expectations for the evolution of the markets, etc.) and its specific characteristics (structure of the network, adjustment costs, financial situation). The idea behind our approach is simple and innovative. It is simple because we think that the carriers should have the same conduct during the crisis as during the no-crisis period, i.e. profit maximization. It is innovative – we believe – for at least two reasons.

The first reason is that the survivability maybe addressed at first glance as a short-term problem and therefore can be solved by maximizing the short-term profit.

However, we think that the carrier conduct should be modelled in terms of both the short- and the long-term profit maximization problem. This approach is supported by the assumption of the presence of *adjustment costs:* that is, carriers encounter costs in changing the network configuration, so that their choice to close a route and re-open it after the crises is both a short- and a long-term decision. In each period, carriers take operational actions (i.e. they choose a price), choose their network plan (corresponding to a capacity offer) and, in the entire game, they follow a broader strategic plan (i.e. the network strategy to solve the overall game). Adjustment costs introduce rigidity in the carriers' conduct. Indeed, non-flexible carriers typically display a small reaction to short- and long-term variables. This behaviour results from the fact that a non-flexible carrier sets high capacity levels during the crisis to push its competitors out of the market and to reduce the set-up costs of re-entering. On the other hand, flexible carriers present high responsiveness to both short- and long-term profitability. They can be small during the crisis period to reduce their losses, and free to expand in the post-crisis period. Carriers' strategies are also affected by expectations of the crisis duration and of the strategic importance of the market. If a carrier expects the crisis to have a long duration (or the market is not strategically important), then its conduct shifts to the short-term variable. If the expected duration is short (or the market is strategically important), then the carrier bases its strategy on the long-term variable. Adjustment costs also induce carriers to behave strategically: a carrier that increases (or decreases) the capacity during the crisis period forces its competitor to reduce its capacity offer in the post-crisis period. This phenomenon is known in the literature as *pre-emption*. The right mix of short- and long-term actions depends upon the importance and duration of the shock.

The second reason why our approach is innovative is that the maximization problem is presented in Chap. 3 in a dynamic game-theoretical framework organized into three stages, which are a time-continuous sequence of periods (pre-crisis, crisis, post-crisis).

From an empirical point of view (Chap. 4), we test the outcomes of our game theory model by measuring the variation in the carrier's capacity supply and explaining it by an econometric model based on two variables: the passenger reduction due to the shock, and the carrier's expected profitability of the market, i.e. short- and long-term indicators, respectively. The analysis suggests that the theoretical model presented in Chap. 3 is a valid tool to interpret both the North American and the Asian crises. The main differences we find for the two crisis situations are: (1) the carriers' reaction to the Asian crisis was lower than in the North American crisis; (2) it was focused on short-term aspects; and (3) there were less adjustment costs differences among carriers. In more details:

(1) The capacity supply reaction in the Asian crisis was smaller than in the North American crisis. The magnitude of the North American crisis was much bigger than the Asian one. However, controlling this effect and following our conceptual framework means that, on average, the adjustment costs of carriers are higher in the Asian market than in the North American one.
(2) The reaction to the Asian crisis was focused on short-term aspects and not on long-term aspects. It might be that carriers underestimated the duration of the

crisis in the first shock and overestimated the duration of the crisis in the second shock. A slightly different interpretation can be provided by assuming that carriers in the second crisis had gained experience of the previous crisis and thus they could better calibrate their strategies on short- and long-term parameters. Hence, British Airways not having had the optimal reaction to the first shock decided to recalibrate its conduct in the second shock. In contrast, KLM having been much too reactive to the short-term variable after September 11 chose to adopt a strategy similar to Lufthansa after the SARS epidemic. We can also interpret the results as a different evaluation of the 'strategic' importance of the market. A carrier evaluating a market as 'very strategic' has a low discount rate on this market, and hence it will focus on the long-term more than the on short-term returns. This could explain the positioning of British Airways with respect to the other large carriers.

(3) It does not seem that there are important adjustment-cost differences among carriers. We note that all carriers can be easily classified only in terms of expectation of the crisis duration. Austrian Airlines expected a longer crisis duration than Air France. Lufthansa and KLM have similar expectations. On the other hand, British Airways expected a much shorter duration of the crisis than Lufthansa. Swiss should have had the shortest expected duration of the crisis but its strategy might result from the financial problems of the company that forced its reaction in the short term.

8.2.3 The Rise of Low-Cost Carriers

Part III is dedicated to answering the second and third research questions. Specifically, the second question is discussed in Chap. 5, which investigates how the FSCs price-compete and respond to the entry of LCCs. We develop a model of airline competition which accommodates various market structures, some of which include low-cost players.

The framework is based on the recent literature on product differentiation in oligopolistic markets. We can identify two approaches to this problem in the literature: the traditional one, which models the firm's demand as a function of prices and assume no interdependencies among markets, i.e. business travellers do not demand the leisure products and vice-versa; and the approach of Wilson (1993), Rochet and Stole (2002) and Dessein (2003) who all develop a model with market interdependencies, where the firm's demand is expressed in terms of utility levels provided to consumers by the firms.

Our model differs from the previous ones as it sets the problem in the traditional form (i.e. in terms of prices), but it takes into account the market interdependencies. This simplification is possible as we assume that qualities are exogenously determined as in traditional oligopolistic models. Hence, we arrive at our intermediate position between the traditional modelling approach and the one proposed by Wilson and others. We assume that the customers are horizontally and vertically heterogeneous, i.e. in real terms different passengers live at different distances from the airports and they are sensitive to product qualities such as business and economy service. Another assumption is that there are two types of firms: the FSCs and the LCCs, which differ according to two aspects, the first type of firm can produce different product qualities, and the second type of firm produces only one level of quality at lower costs than the FSC. We proved that the FSC sets the price depending on the market structure as follows:

- Economy market: $p_{1L}^{olygopoly} < p_{1L}^{asy-duopoly} < p_{1L}^{sym-duopoly} < p_{1L}^{monopoly}$
- Business market: $p_{2L}^{olygopoly} < p_{2L}^{sym-duopoly} < p_{2L}^{asy-duopoly} < p_{2L}^{monopoly}$

Where the *olygopoly* stands for a market with at least two FSCs and one LCC competing with each other in providing direct service on the same city-pair routes; *asy-duopoly* stands for a market with one FSC and one LCC competing; *sym-duopoly* stands for a market with two FSCs competing; *monopoly* stands for a market with one FSC operating with direct service on the city-pair routes.

We empirically tested the above inequities by using a sample of monthly data on city-pairs from Italy to three European countries (Germany, the UK, and the Netherlands) including airfares for four different carriers (Alitalia, Lufthansa, British Airways, and KLM). Differently to what is done in other research studies where price dispersion or average prices have been analysed, we perform our econometric estimation on the basis of eight market segments (six in economy class and two in business class) and four market structures (monopoly, symmetric duopoly, asymmetric duopoly, and oligopoly). We found that, when an LCC enters a specific route, the direct incumbent firms react by reducing the fares for all available leisure and business fares. We also provide an interpretation in terms of the direct competition of the LCC on the FSC business segment. This point is quite important as it corroborates the assumption that the leisure and business markets are interdependent. On the other hand, competition between two FSCs is characterized by asymmetric behaviour. They strongly compete on the business market and weakly compete on the leisure market. In a context of competition among FSCs, the assumption of interdependency or separation among markets does not make any difference, as the incentive compatibility constraint (IC) is not binding. But, conversely, when we analyse an asymmetric context, even if the IC is not binding, pricing strategies on the business market and on the leisure markets have to be coordinated. As expected, the impact of the LCC on prices is higher when it enters a monopolistic market rather than a market already characterized by competition.

Chapters 6 and 7 address the third research question. In Chap. 6, we approach the problem from the theoretical prospective of a carrier that has to decide its best network strategy. In the literature, this problem is often faced as a single carrier that maximizes its profit (or minimizes its costs). We propose to examine the problem with a game-theory approach where different carriers play their strategy depending on the possible strategy of their competitors. We assume that the carriers play three different network strategies: point-to-point (PP), hub-and-spoke (HS) or multi-hub (MH) and we identify the conditions under which Nash a-symmetric equilibriums may exist, i.e. PP with HS or PP with MH.

We find that two main equilibrium outcomes emerge, depending on the size of the domestic market which is related to the air-traffic freedoms (specifically the sixth one). This is an element that seems to have received less attention in most models presented in the airline literature. Most theoretical models address the problem of a network configuration in terms of economies of scale and density. These factors can stimulate HS networks in small markets and a PP configuration when markets are large enough. However, our model shows that when the traffic flows to an airport are large, i.e. the internal markets are large, the incumbent firm develops its hub in this airport and pushes the LCC to operate in smaller ones. Indeed, we observe, at least in Europe, that most HS carriers, such as Lufthansa or Air France, have already developed their hub in large cities (Frankfurt, Munich and Paris). Smaller cities with small traffic flows are left to LCC operations.

In the first if those equilibriums, when the internal markets are small, the PP network strategy is played by both carriers, and for a specific subset of parameters, a collusive equilibrium in an HS configuration can be implemented. In the second equilibrium, when the size of the internal markets is large, asymmetric configurations, where one carrier chooses an HS strategy and the other chooses a PP strategy, are the only stable equilibrium. The main result of the chapter is that the HS and PP network can coexist, and this result seems to be quite robust to variations in parameters and pricing rules.

Chapter 7 aims to offer new measures to assess airline network configurations, with a view to effectively analysing the complexity of modern carriers' network design. Reynolds-Feighan (2001) identified the HS configuration of a carrier when there is a high concentration level of air traffic in both space (geographical dimension) and time (temporal dimension) by means of coordination of the timetables. However, while a substantial number of research studies on airline network configurations have focused on the spatial dimension, only a relatively small number of empirical studies have attempted to measure the temporal dimension of airline networks. Traditional analyses of airline networks have measured the network configuration by means of concentration indices of traffic or flight frequency. These indicators, such as the Gini index, usually play a role in measuring the degree of hub-and-spoke vs. point-to-point structures, but they tend to produce poor results in more complex network settings (i.e. multi-hub, multi-base, or mixed configurations). In this chapter, we study the network configuration in the airline sector, by taking into account both spatial and temporal dimensions. The spatial dimension is measured by using the Freeman and Bonacich centrality indices, originating from social science research, which both seem to produce more meaningful results than the Gini concentration index in terms of their capability to detect geographical shapes. The temporal dimension is measured here by a connectivity ratio, i.e. the share of indirect connections over the total number of connections. With the help of these indicators, the configuration of the FSCs and the LCCs in Europe is investigated. Our results show that the temporal dimension provides a clear distinction between FSCs and LCCs, while the spatial dimension appears to be useful to identify the peculiarities within groups.

We find some evidence that the FSCs have developed their networks as mixed multi-HS and PP systems with a strong dominance of the HS. These configurations vary from Iberia, which is the most spatially-concentrated HS network with a dual-hub radial network (Barcelona and Madrid), to British Airways which offers the most mixed HS and PP network configuration. In particular, the British Airways network is organized such that London Heathrow is the main hub, and Manchester, Glasgow and Edinburgh are bases with several direct connections to European and domestic destinations. The Lufthansa network developed into a dual hub-and-spoke with mixed PP structure. Specifically, the hubs are Munich and Frankfurt, and the bases with PP connections are Berlin, Hamburg and Düsseldorf. Finally, the Air France network (before the KLM merger) is classified as a single-HS configuration with Charles de Gaulle as the hub for intra-European and intercontinental traffic, and with Paris Orly airport acting as a PP airport base for domestic traffic within France.

In addition, our results reveal that LCCs have a lower centrality than FSCs, mainly for the temporal dimension and slightly lower for the spatial dimensions. Time-based measures proved to be able to differentiate the airline market. The empirical evidence is that the FSCs have developed a multi-HS network strategy, while the LCCs show a considerable orientation towards a PP network growth. However, the analysis shows variations among LCCs' network configurations. While Ryanair and easyJet developed a pure PP structure, Virgin Express and Air Berlin offer a modest percentage of connecting flights in Brussels and Berlin. However, the connectivity ratio of Virgin has grown in recent years, and it is possible that the bases of this LCC could turn into small hubs, if this trend continues in the coming years.

8.3 Prospects for Further Research

The results of our study are proposed as stepping stones leading to new research perspectives.

With regard to the pricing policy, there are two empirical areas of new research. The first concerns the specific impact on the pricing policy of the product characteristics, both horizontally (departure time, airport access, etc.) and vertically (ground and on-board services, travel conditions for each passenger category, etc.). Our research has found that, when an LCC enters a specific route, the direct incumbent firms react by reducing all available leisure and business fares. From a theoretical point of view, this result confirms the hypothesis that the weak market and the strong market are interdependent.

More specifically, in Chap. 5 we have shown mathematically that in the asymmetric duopoly case, the incentive compatibility constraint of the FSC is slack (provided that the costs of producing two qualities are not too different, and when weak and strong markets are sufficiently differentiated), i.e. the price charged by the FSC in the strong market is not affected by the risk of diversion of high willingness-to-pay consumers towards products designed for lower willingness-to-pay consumers but it is affected by the competition from the LCC product designed for the weak market.

The competitive pressure of the LCC reduces the price charged by the FSC in the weak market (as expected) but it is sufficiently tough to reduce the price in the strong market in such a way that the incentive constraint is not binding. Hence, LCC pricing has a direct effect on FSC pricing policy in both markets. Note that simultaneous competition of a single (low-cost) product line both in the weak and strong markets has an additional effect on the pricing policies of the traditional firm. Indeed, the traditional firm is obliged to charge prices jointly in the leisure and business market as the low-cost firm maximizes its profits on both markets simultaneously.

If these theoretical findings are correct, we may observe that the FSC would not be able to continue with the traditional revenue management when competing with the LCC. Hence, it is important to investigate the effectiveness of the current travel rules, conditions, fences, etc. in this new competitive environment and to evaluate the new pricing rules of FSCs. There are already a few examples of FSCs adopting some of the LCC price best practices. SAS has introduced one-way fares or British Airways has deleted the minimum stay rule from their pricing structure and introduced one way fares to European destinations. Econometric studies may investigate in this direction.

The second area on pricing policy that deserves further research concerns the LCC yield management. There are hardly any empirical works in the literature on the price setting of LCC. In Chap. 5 the equations explain the FSC airfare with a dummy for LCC entry, but a more extensive econometric analysis may include the LCC price levels or explain the LCC entry by a discrete choice model.

Finally, the competition between FSCs and LCCs can be analysed in terms of product attributes rather then pricing. For example, an FSC may respond to LCC market entry by competing more on seat leg-space, or focusing more on the value of its intercontinental network to customers. Thus, response is across product attributes or product differentiation rather than pricing.[1]

From a theoretical perspective, the network configuration deserves further research. An extension of the model presented in Chap. 6 could be based on an enrichment of the network game by having players with different business models and with a large number of airports in the network (instead of just four). Indeed, the model we presented is sufficiently flexible to accommodate carriers with different pricing strategies and cost structures (FSC vs. LCC) and to include a penalty for stops or bad connections. Moreover, the network configuration can be analysed in terms of the interrelation between short, medium and long haul and how, for example, the competition of LCCs on the short-haul market may modify the offer of the FSC on the long-haul market. There are a few signals from the market that LCCs are entering the long-haul market (an example is Oasis Air connecting Hong Kong to Europe) or, furthermore, that the bases of the LCCs could turn into small hubs in the future (our research has proved that Virgin has increased the connectivity of the Brussels airport in recent years).

[1] The proposal to analyze the FSC reaction to LCC competition in terms of product attributes has resulted from a discussion with Prof. Ruud Frambach of Free University of Amsterdam.

The aviation sector presents many characteristics in common with the other network industries. As shown in the literature, the game theory approaches may result in multiple-equilibriums solutions, and this gives room for public intervention to affect or reduce the sets of the outcoming equilibriums of the game. In this connection, questions that need to be addressed are: what is the consequence on welfare of one outcome with respect to another? Is it possible for the regional and national government to reach a more favourable equilibrium?

The question whether the FSCs need to review their business model to continue to operate in this competitive environment needs further investigation. FSCs could both reduce the cost gaps with LCCs and their sensitivity to the pressure of economic, competitive and exogenous elements. In Europe, carriers can employ two parallel approaches: airlines may choose to introduce low-cost subsidiaries in order to participate immediately in growth markets that their core operations cannot access with their currently high cost structures, while simultaneously redesigning their model to compete effectively with the threat of LCCs. The business model restructuring depends on the customer market that is actually targeted most successfully by the carriers. It would be interesting to see whether the targeted market (in terms of homogeneity and focus on leisure or business) affects their success in responding to LCC market entry. In this respect it is interesting to see that carriers such as Lufthansa seem to focus increasingly on the business (high-end) market by introducing a special jet service with only the business cabin, but also plans to expand its lower-fare strategy for European flights.[2]

New research may investigate the cost structure of the FSC versus the LCC, and where an effective restructuring of FSCs can be achieved without giving up the critical service and coverage attributes of its model. In the literature, it is shown that many of the cost gaps inherent in the HS system are associated with its complex business processes, rather than with the 'frills' it offers travellers. LCCs such as Ryanair or easyJet in the EU or Southwest Airlines in the US have demonstrated that these complexity costs do not have to be. An airline can provide some of the benefits of the HS network without incurring many of the HS costs. Aer Lingus is the most significant example of FSC restructuring its business model. Aer Lingus faced a significant challenge to survive in the new environment after September 11, from with its main short-haul competitor Ryanair. The reaction of the board of Aer Lingus to the new environment was the creation of a survival plan for the company which was unveiled in 2001. Its main objectives were to create a more efficient business model, implement a significant cost-reduction programme, reduce staff numbers by one-third, and radically change the way they do business. It was ironically close to the low fares model and was a transformation of Aer Lingus that was deemed necessary, and, as Willie Walsh (CEO) pointed out, goes beyond mere survival to improve competitiveness and increase profitability (Aer Lingus Annual Report, 2001). Aer Lingus had to implement some low-cost principles and redefine itself as a quasi-low-cost carrier facing a prominent competitor, Ryanair.

[2] The proposal to reconsider the FSC business model based on the customer market that is actually targeted most successfully by the carriers has resulted from a discussion with Prof. Ruud Frambach of Free University of Amsterdam.

Willie Walsh, known as a miracle worker for the Aer Lingus plan, is today the new chief executive of British Airways. Will he restructure this company?

Moreover, we observe that a group of FSCs are not restructuring their business model but are merging to exploit higher levels of economies of scale. In 2004 KLM and Air France created the first cross-border merger in Europe. New consolidations are now being undertaken between Lufthansa and Swiss or in the US between American West and US Airways. Will the LCC and FSC model converge into a more efficient model or will the specialization and consolidation of the FSCs continue and ultimately create a new scenario?

This discussion should be linked to the conclusions of Berechman and de Wit (1996). They predicted that, in the immediate future after the EU deregulation, national carriers would continue to operate in their national home base for a substantial part of their products, but they would probably take the opportunity of a liberalized market by developing a secondary Euro-hub complementary to their national hub. The cross-border mergers are going to create the multi-hub systems similar to the scenario predicted by Berechman and de Wit. However, this is not created by one carrier developing a new hub in one other country. Therefore, the conclusion of Berechman and de Wit that the carrier that behaves as a profit maximizer in a liberalized market will select a second new EU hub raises the question whether deregulation has effectively created sufficient market liberalization or whether it has been able to diminish the role of hubs as a market entry barrier.

Finally, an open question from Part II is whether or not carriers have learned from past events and crises. We think that it is possible as, from our research, we observe that carriers have been more consistent in managing the Asian crisis than the North American crisis. Further, some more evidence comes from the behaviour of British Airways. In fact, it seems that British Airways modified its strategy by changing from a situation where it only cared about long-term variables towards a more balanced situation, closer to the Lufthansa/KLM strategy. After the September 11 terrorist attack and the SARS epidemic, several other smaller but still important events shocked the world and the aviation industries. We refer to the Bali (2002), Madrid (2004) and Sham el Sheikh (2005) terrorist attacks or the South-East Asia earthquake tsunami in 2004. In this context, a critical question for the aviation industry would be: Is the crisis management unit necessary for all carriers to survive? We believe that all the above questions deserve further investigation.

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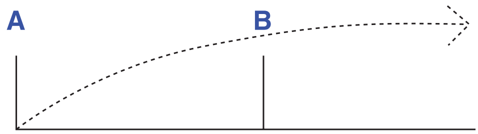
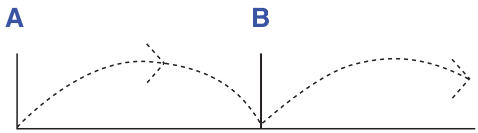
Appendix I – Freedoms of the Air

The first six were defined in the International Air Services Transit Agreement of 1944, and are still used today. Currently there are generally considered to be nine freedoms of the air. Although these operations are called “freedoms”, they are not necessarily available to an airline. Most nations of the world exchange first and second freedoms through the International Air Services Transit Agreement. The other freedoms, to the extent that they are available, are usually exchanged between countries in bilateral or multilateral air services agreements. The eighth and ninth freedoms (cabotage) have been exchanged only in limited instances. (U.S. law currently prohibits cabotage operations.)

First Freedom
The right to fly across the territory of a foreign country. without landing (e.g. United Airlines flies from the United States (A) over Ireland (B) en route to Germany.)

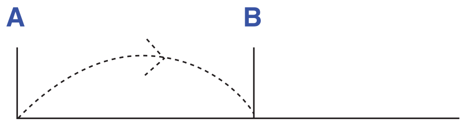


Second Freedom
The right to land in a foreign country for technical or non-traffic purposes, such as for re-fueling or maintenance. (e.g. American Airlines flies from the United States (A) and lands to refuel in Ireland (B) enroute to Germany.)



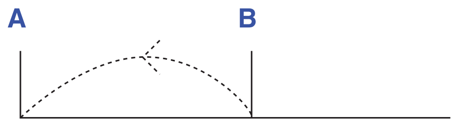
Third Freedom

The right to deplane traffic in a foreign country that was enplaned in the home country of the carrier. (e.g. United Airlines carries passengers from the United States (A) to France (B).)



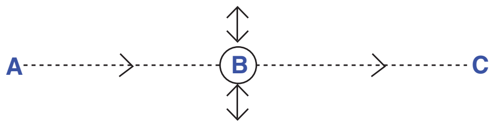
Fourth Freedom

The right to enplane traffic in the foreign country that is bound for the home country of the carrier. (e.g. American Airlines carries passengers from the United Kingdom (B) to the United States (A).)



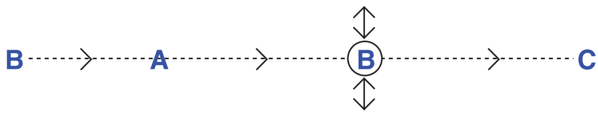
Fifth Freedom

The right to *enplane traffic at one foreign point and deplane it in another foreign point as part of continuous operation also serving the airline's homeland* (e.g. Northwest Airlines has "fifth freedom" rights to carry traffic between Tokyo (B) and Hong Kong (C), on services which stop at Tokyo (B) en route between Los Angeles (A) and Hong Kong (C).



Sixth Freedom

This term is applied to Fifth Freedom *traffic carried from a point of origin in one foreign country to a point of destination in another foreign country via the home country of the airline*. (e.g. KLM, carries sixth-freedom traffic between New York (A) and Cairo (C), carrying passengers traveling from New York (A) to Amsterdam (B) and on to Cairo (C).)

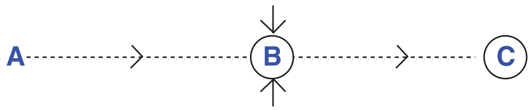


Seventh Freedom

This term is applied to an airline's operating turn around service and *carrying traffic between points in two foreign countries* without serving its home country (e.g., Lufthansa operates between New York (A) and Mexico City (C) without serving Germany (B)).

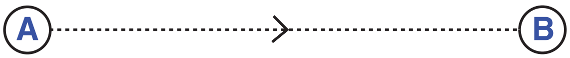
Eighth Freedom

This term is used to refer to "consecutive or fill-up" cabotage in which an airline *picks up traffic at one point in a foreign country and deplanes it at another point in that same foreign country* as part of a service from the home country of the airline (e.g., Singapore Airlines enplanes traffic at Wellington (A) and deplanes it in Aukland (B) as part of its service between New Zealand and Singapore (C)).



Ninth Freedom

This term is used to refer to "pure" cabotage in which an *airline of one country operates flights and carries traffic solely between two points in a foreign country* (e.g., Air France operates flights between Berlin (A) and Frankfurt (B)).



Appendix II – Low-Cost Carriers in Europe

Airline name	Country	In-Date	Code	LCC flights
AIR BERLIN	DE	2002/09	BER	All flights
AIR SOUTHWEST	GB	2003/10	WOW	All flights
ATLAS BLUE	MA	2005/01	BMM	All flights
BLU EXPRESS	IT	2006/01	BPA	Specific routes
BLUE 1	FI	2006/01	BLF	All flights
BLUE AIR	RO	2005/01	JOR	All flights
BMI BABY	GB	2002/03	BMA	All flights
BRUSSELS AIRLINES (NEW)	BE	2007/03	DAT	All flights
BUDGET AIR	IE	2003/10	FUA	Specific routes
CENTRAL WINGS	PL	2005/01	CLW	All flights
CLICKAIR (NEW)	ES	2007/01	CLI	All flights
CORENDON	DE	2003/10	CAI	All flights
DEUTSCHE BA	DE	2002/04	BAG	All flights
EASY JET	GB	2002/01	EZS	All flights
EASY JET SWITZERLAND	CH	2002/01	EZY	All flights
FARE4U	MT	2004/01	AMC	Specific routes
FLY BABOO	CH	2003/10	BBO	All flights
FLY BE	GB	2002/07	BEE	All flights
FLY GLOBESPAN	GB	2003/01	GSM	All flights
FLY ME (bankruptcy March 07)	SE	2004/01	FLY	All flights
FLY NIKI	AT	2005/01	NLY	All flights
FLY NORDIC	SE	2005/01	NDC	All flights
GEXX	DE	2002/01	GMI	All flights
GERMAN WINGS	DE	2002/01	GWI	All flights
GOTLANDSFLYG	SE	2004/01	GAO	Specific routes
HAPAG LLOYD EXPRESS (merged into TUIFly)	DE	2003/06	HLX	All flights
HELVETIC AIRWYAS	CH	2003/10	OAW	All flights
ICELAND EXPRESS	IS	2003/02	JXX	Specific routes
INTERSKY	AT	2002/01	ISK	All flights
JET2	GB	2002/03	EXS	All flights
KULLAFLYG	SE	2004/01	GAO	Specific routes
MONARCH SCHEDULED	GB	2003/10	MON	Specific routes

(*continued*)

(*continued*)

Airline name	Country	In-Date	Code	LCC flights
MY AIR	IT	2005/01	MYW	All flights
NORWEGIAN	NO	2002/01	NAX	All flights
ONUR AIR	TR	2005/01	OHY	All flights
RYANAIR	IE	2002/01	RYR	All flights
SKY EUROPE	SK	2002/01	ESK	All flights
SKY EUROPE HUNGARY	HU	2002/01	HSK	All flights
SMARTWINGS	CZ	2004/01	TVS	Specific routes
STERLING AIRLINES	DK	2002/01	SNB	All flights
SUNDSVALLSFLYG	SE	2005/01	GAO	Specific routes
SUN EXPRESS	TR	2006/01	SXS	All flights
THOMSON FLY	GB	2004/01	TOM	All flights
TRANSAVIA.COM	NL	2005/01	TRA	All flights
VIRGIN EXPRESS (integrated in Brussels Airlines)	BE	2002/01	VEX	All flights
VUELING	ES	2005/01	VLG	All flights
WINDJET	IT	2003/10	JET	All flights
WIZZ AIR	HU	2004/05	WZZ	All flights

Source: EUROCONTROL (2007). Doc. Ref. EUROCONTROL/STATFOR/Doc258 (Date 12/09/2007)

Appendix III – List of Abbreviations

AEA	Association of European Airlines
ASK	Available seat kilometers
ATO	Airport ticket office
CTO	City ticket office
CRS	Computer reservations system
EU	European Union
FFP	Frequent flyer programme
FSC	Full-service carrier
GDS	Global distribution system
HHI	Hirschmann-Herfindahl index
HS	Hub-and-Spoke network configuration
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
LCC	Low-cost carrier
M&A	Mergers and acquisitions
PP	Point-to-Point network configuration
RPK	Revenue passenger kilometers
SARS	Severe acute respiratory syndrome
UK	United Kingdom
US	United States

Full Service Carriers

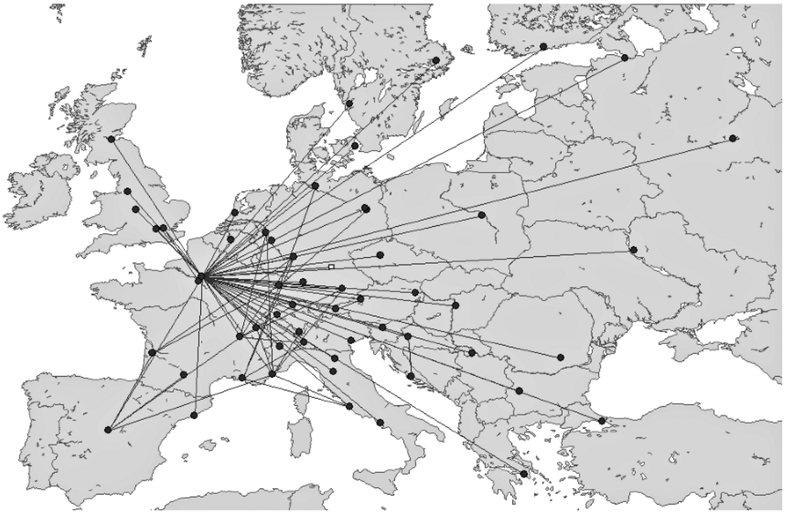
AB	Air Berlin
AF	Air France
BA	British Airways
FR	Ryanair
IB	Iberia
KL	KLM Royal Dutch Airlines
LH	Lufthansa
TV	Virgin Express
U2	Easyjet

Airports

ABZ	Aberdeen
AGP	Malaga
ALC	Alicante
AMS	Amsterdam-Schiphol
ATH	Athens
BCN	Barcelona
BHX	Birmingham
BIA	Poretta
BIO	Bilbao
BLQ	Bologna-Guglielmo Marconi
BMA	StockholmBromma
BOD	Bordeaux
BRE	Bremen
BRU	Brussels
BVA	Paris-Beauvais Tille
CAG	Elmas-Elmas
CDG	Paris-Charles De Gaulle
CGN	Cologne
CIA	Rome-Ciampino
CRL	Brussels-Charleroi South
CWL	Wales
DUB	Dublin
DUS	Dusseldorf
EDI	Edinburgh
FAO	Faro
FCO	Rome-Fiumicino
FMO	Muenster
FRA	Frankfurt-Frankfurt
FUE	Fuerteventura
GLA	Glasgow
GOT	Gothenburg
GRZ	Thalerhof
GVA	Geneva
HAJ	Hanover
HAM	Hamburg
HHN	Frankfurt-Hahn
IBZ	Ibiza
INN	Kranebitten
KZN	Kazan
LBC	Hamburg-Blankensee
LEH	Octeville
LGW	London-Gatwick
LHR	London-Heathrow
LIN	Milan-Linate
LIS	Lisbon
LJU	Brnik
LPL	Liverpool-John Lennon
LTN	London-Luton
LYS	Lyon-Lyon
MAD	Madrid
MAN	Manchester
MJT	Mytilene
MME	Durham Tees Valley
MRS	Marseille-Marseille
MUC	Munich-Munich
NCE	Nice-Cote D'Azur
NOC	Ireland West-Ireland West
ORY	Paris-Orly Field
PEE	Perm
PGF	Llabanere
PIK	Glasgow-Prestwick
PMI	Palma Mallorca
RMI	Miramare
STN	London-Stansted
STR	Stuttgart
SVQ	Sevilla
SXB	Strasbourg
SXF	Berlin-Schoenefeld
TLS	Toulouse
TSF	Venice-Treviso
TXL	Berlin-Tegel
UFA	Ufa
URO	Boos
VIE	Vienna
VLC	Valencia
VLL	Valladolid
ZRH	Zurich

Appendix IV – Network Maps

Air France
1996



Source: OAG June 1996

2004

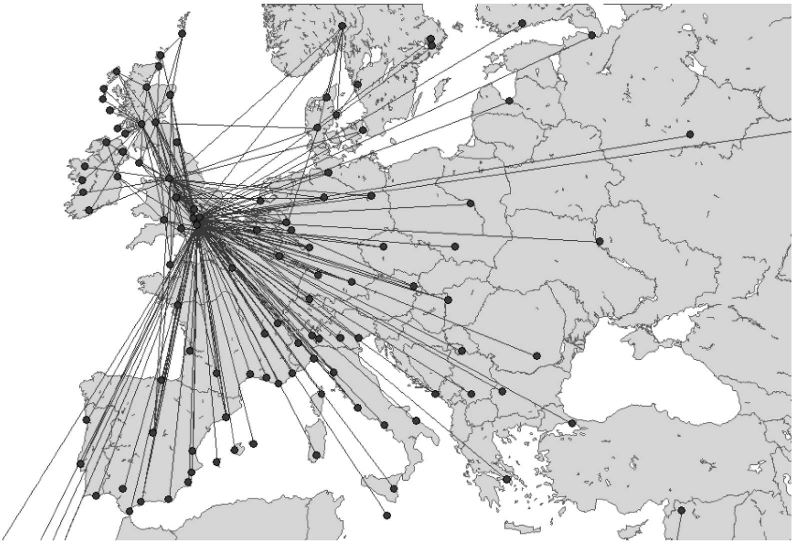
Source: OAG June 2004

British Airways

1996

Source: OAG June 1996

2004



Source: OAG June 2004

Iberia

1996

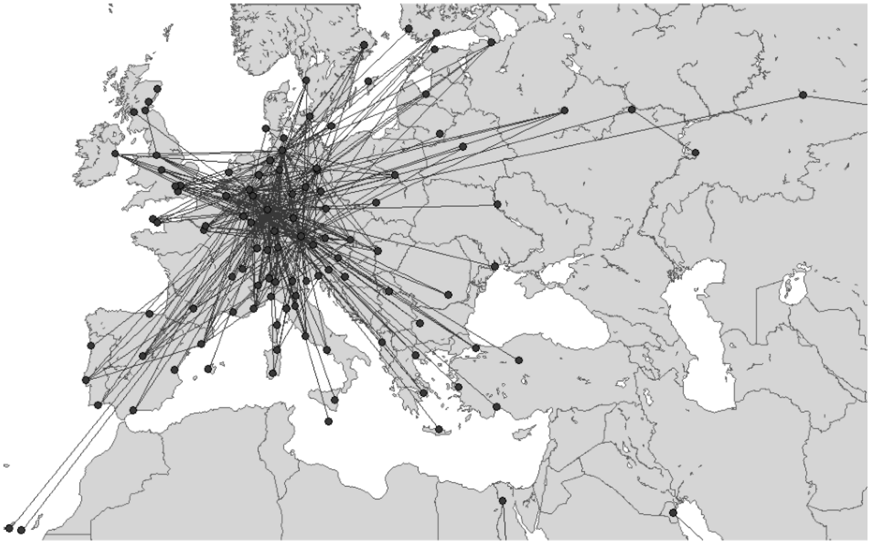
Source: OAG June 1996

2004

Source: OAG June 2004

Lufthansa

1996



Source: OAG June 1996

2004

Source: OAG June 2004

Ryanair

1996

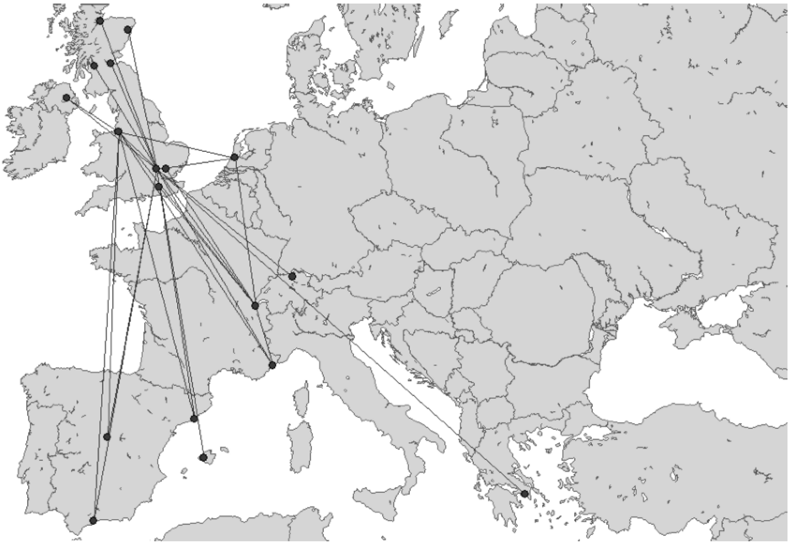
Source: OAG June 1996

2000

Source: OAG June 2000

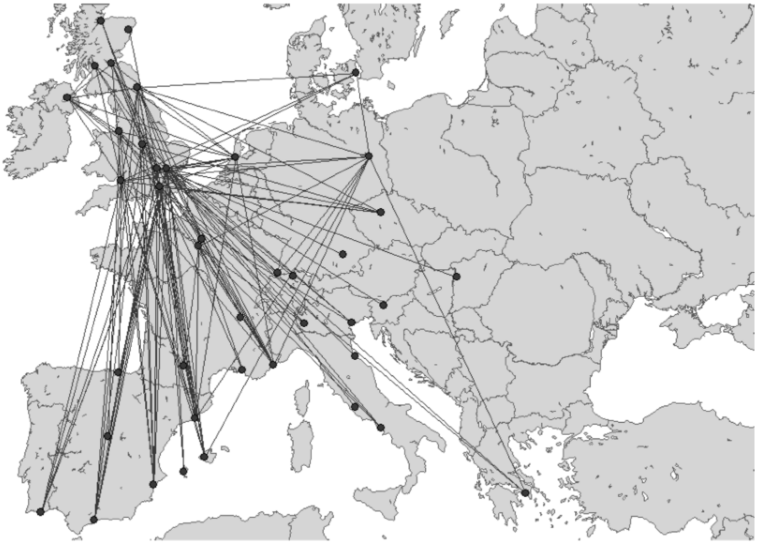
EasyJet

2000



Source: OAG June 2000

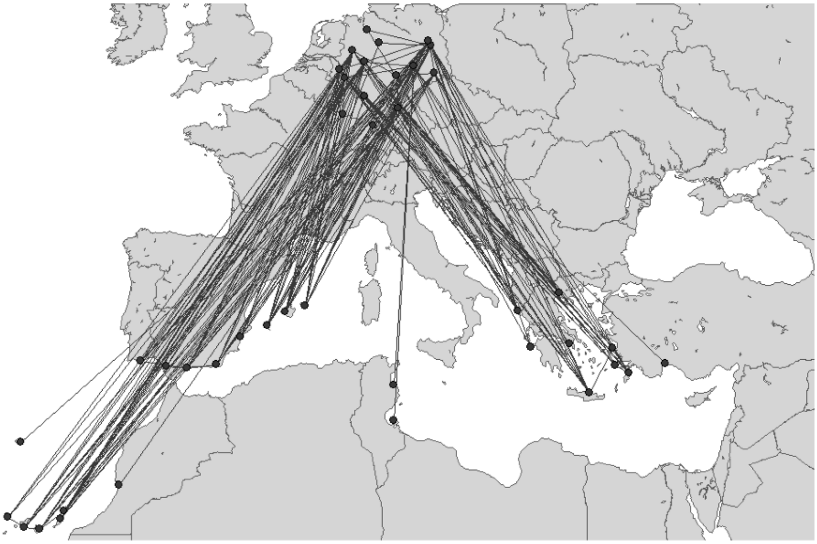
2004



Source: OAG June 2004

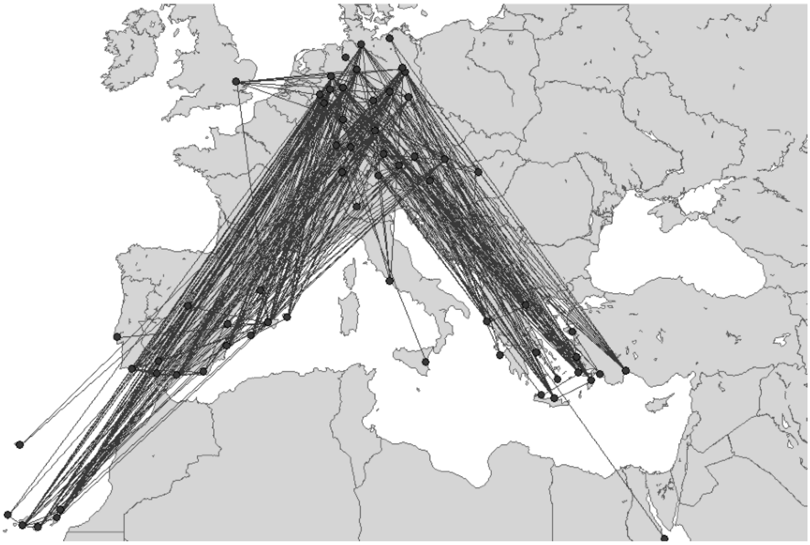
Air Berlin

2000



Source: OAG June 2000

2004



Source: OAG June 2004

Virgin Express

2000

Source: OAG June 2000

2004

Source: OAG June 2004

Appendix V – Bonacich Centrality Results

Factor analysis output of UCINET 6 for Windows: Software for social network analysis, Analytic technologies, Harvard, MA.

Air France
Bonacich centrality

Eigenvalues 1996					Eigenvalues 2000					Eigenvalues 2004				
Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio
1	190.5	61.7	61.7	8.57	1	390.3	46.4	46.4	1.75	1	346.1	42.3	42.3	1.62
2	22.2	7.2	68.9	1.07	2	222.8	26.5	72.8	3.89	2	213.9	26.1	68.4	3.52
3	20.8	6.7	75.6	1.21	3	57.3	6.8	79.6	1.44	3	60.7	7.4	75.8	1.44
4	17.2	5.6	81.2	1.04	4	39.9	4.7	84.4	1.16	4	42.2	5.2	81.0	1.53
5	16.5	5.3	86.5	1.11	5	34.3	4.1	88.4	1.31	5	27.7	3.4	84.3	1.17
6	14.9	4.8	91.3	1.61	6	26.1	3.1	91.5	1.30	6	23.7	2.9	87.2	1.26
7	9.3	3	94.3	1.12	7	20	2.4	93.9	1.12	7	18.8	2.3	89.5	1.03
8	8.3	2.7	97.0	1.38	8	17.8	2.1	96.0	1.43	8	18.3	2.2	91.8	1.11
9	6	1.9	98.9	2.52	9	12.4	1.5	97.5	1.60	9	16.4	2	93.8	1.40
10	2.4	0.8	99.7	2.38	10	7.8	0.9	98.4	1.30	10	11.8	1.4	95.2	1.02
					…						…			
16	0	0	100	1.57	29	0	0	100	1.12	32	0	0	100	1.03
	308.9	100				842	100				818.8	100		

Air France
Bonacich centrality

Bonacich eigenvector centralities 1996				Bonacich eigenvector centralities 2000				Bonacich eigenvector centralities 2004			
		1 Eigenvec	2 nEigenvec			1 Eigenvec	2 nEigenvec			1 Eigenvec	2 nEigenvec
1	CDG	0.694	98.196	1	ORY	0.49	69.289	1	CDG	0.508	71.902
2	NCE	0.224	31.654	2	CDG	0.435	61.474	2	ORY	0.408	57.726
3	LHR	0.211	29.9	3	MRS	0.3	42.358	3	NCE	0.297	41.953
4	LIN	0.179	25.297	4	TLS	0.296	41.834	4	TLS	0.247	34.887
5	GVA	0.174	24.626	5	LYS	0.256	36.165	5	LYS	0.234	33.071
6	FRA	0.173	24.459	6	NCE	0.25	35.422	6	MRS	0.222	31.358
7	LYS	0.169	23.937	7	SXB	0.213	30.103	7	BOD	0.195	27.594
8	FCO	0.167	23.554	8	BOD	0.198	27.948	8	SXB	0.169	23.902
9	MAD	0.161	22.753	9	LHR	0.133	18.816	9	LHR	0.143	20.193
10	AMS	0.153	21.652	10	MAD	0.106	15.059	10	MAD	0.132	18.625
	...				...				...		
54	ORY	0.006	0.872	95	KBP	0.006	0.788	93	VLL	0.008	1.168
55	TLS	0.006	0.836	96	SOF	0.004	0.63	94	SVQ	0.008	1.168
56	SZG	0.004	0.63	97	LEH	0.003	0.472	95	URO	0.004	0.594
57	THF	0.001	0.102	98	FMO	0	0	96	LEH	0.004	0.594
58	SPU	0	0.014	99	DTM	0	0	97	GLA	0.003	0.389

Air France
Bonacich centrality

Descriptive statistics					Descriptive statistics					Descriptive statistics	
		1	2			1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	Mean	0.084	11.899	1	Mean	0.057	8.072	1	Mean	0.064	9.024
2	Std Dev	0.101	14.256	2	Std Dev	0.083	11.699	2	Std Dev	0.079	11.169
3	Sum	4.88	690.14	3	Sum	5.651	799.11	3	Sum	6.19	875.35
4	Variance	0.01	203.24	4	Variance	0.007	136.87	4	Variance	0.006	124.75
5	SSQ	1	20000	5	SSQ	1	20000	5	SSQ	1	20000
6	MCSSQ	0.589	11788	6	MCSSQ	0.677	13550	6	MCSSQ	0.605	12101
7	Euc Norm	1	141.42	7	Euc Norm	1	141.42	7	Euc Norm	1	141.42
8	Minimum	0	0.014	8	Minimum	0	0	8	Minimum	0.003	0.389
9	Maximum	0.694	98.196	9	Maximum	0.49	69.289	9	Maximum	0.508	71.902
10	N of Obs	58	58	10	N of Obs	99	99	10	N of Obs	97	97

Lufthansa
Bonacich centrality

Eigenvalues 1996					Eigenvalues 2000					Eigenvalues 2004				
Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio
1	452.8	58	58	7.212	1	481.4	56.4	56.4	5.65	1	501.3	63	63	6.547
2	62.8	8	66	1.293	2	85.2	10	66.4	1.635	2	76.6	9.6	72.7	1.443
3	48.6	6.2	72.2	1.283	3	52.1	6.1	72.5	1.256	3	53.1	6.7	79.3	1.455
4	37.9	4.8	77.1	1.48	4	41.5	4.9	77.3	1.06	4	36.5	4.6	83.9	1.081
5	25.6	3.3	80.4	1.128	5	39.1	4.6	81.9	1.242	5	33.7	4.2	88.2	1.295
6	22.7	2.9	83.3	1.068	6	31.5	3.7	85.6	1.476	6	26	3.3	91.4	1.134
7	21.2	2.7	86	1.241	7	21.3	2.5	88.1	1.091	7	23	2.9	94.3	1.477
8	17.1	2.2	88.2	1.119	8	19.6	2.3	90.4	1.317	8	15.6	2	96.3	1.752
9	15.3	2	90.1	1.064	9	14.9	1.7	92.1	1.056	9	8.9	1.1	97.4	1.411
10	14.4	1.8	92	1.052	10	14.1	1.6	93.8	1.217	10	6.3	0.8	98.2	1.263
...					...					...				
40	0	0	100	1.186	38	0	0	100	1.302	35	0	0	100	1.215
	781	100				853.8	100				795.2			
											100.0			

Lufthansa
Bonacich centrality

Bonacich Eigenvector Centralities				Bonacich Eigenvector Centralities				Bonacich Eigenvector centralities			
		1	2			1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	FRA	0.448	63.315	1	FRA	0.485	68.656	1	MUC	0.485	68.657
2	MUC	0.398	52.573	2	MUC	0.403	57.063	2	FRA	0.467	66.045
3	TXL	0.362	51.258	3	HAM	0.32	45.321	3	TXL	0.292	41.262
4	HAM	0.339	47.978	4	TXL	0.299	42.306	4	HAM	0.275	38.875
5	DUS	0.302	42.776	5	DUS	0.289	40.873	5	DUS	0.273	38.674
6	CGN	0.224	31.73	6	CGN	0.209	29.524	6	STR	0.184	26.082
7	STR	0.185	26.111	7	STR	0.206	29.141	7	CGN	0.154	21.763
8	VIE	0.156	22.081	8	CDG	0.159	22.445	8	CDG	0.151	21.35
9	LHR	0.136	19.271	9	HAJ	0.146	20.692	9	LHR	0.148	20.963
10	CDG	0.125	17.671	10	LHR	0.135	19.146	10	BRU	0.125	17.651
	...					...					...
107	LUX	0	0.067	100	BIA	0.001	0.119	102	IBZ	0.001	0.208
108	DND	0	0.004	101	OLB	0.001	0.119	103	CAG	0.001	0.172
109	KUF	0	0.001	102	THF	0	0.042	104	KZN	0	0.007
110	OVB	0	0.001	103	KZN	0	0.002	105	UFA	0	0.006
111	ABZ	0	0	104	PEE	0	0.002	106	PEE	0	0.002

Lufthansa
Bonacich centrality

Descriptive statistics				Descriptive statistics				Descriptive statistics			
		1	2			1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	Mean	0.046	6.558	1	Mean	0.053	7.545	1	Mean	0.054	7.686
2	Std Dev	0.083	11.712	2	Std Dev	0.082	11.635	2	Std Dev	0.08	11.384
3	Sum	5.147	727.961	3	Sum	5.549	784.709	3	Sum	5.761	814.763
4	Variance	0.007	137.17	4	Variance	0.007	135.376	4	Variance	0.006	129.598
5	SSQ	1	19999.998	5	SSQ	1	20000.002	5	SSQ	1	20000
6	MCSSQ	0.761	15225.885	6	MCSSQ	0.704	14079.153	6	MCSSQ	0.687	13737.369
7	Euc Norm	1	141.421	7	Euc Norm	1	141.421	7	Euc Norm	1	141.421
8	Minimum	0	0	8	Minimum	0	0.002	8	Minimum	0	0.002
9	Maximum	0.448	63.315	9	Maximum	0.485	68.656	9	Maximum	0.485	68.657
10	N of Obs	111	111	10	N of Obs	104	104	10	N of Obs	106	106

Iberia
Bonacich centrality

Eigenvalues 1996					Eigenvalues 2000					Eigenvalues 2004				
Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio
1	301.6	87.3	87.3	22.408	1	447.3	73.8	73.8	5.637	1	415.9	68.4	68.4	5.812
2	13.5	3.9	91.2	1.283	2	79.4	13.1	86.9	2.872	2	71.6	11.8	80.2	1.605
3	10.5	3	94.3	1.314	3	27.6	4.6	91.4	2.693	3	44.6	7.3	87.5	1.751
4	8	2.3	96.6	1.564	4	10.3	1.7	93.1	1.052	4	25.5	4.2	91.7	1.399
5	5.1	1.5	98.1	1.346	5	9.8	1.6	94.7	1.273	5	18.2	3	94.7	1.914
6	3.8	1.1	99.2	1.855	6	7.7	1.3	96	1.123	6	9.5	1.6	96.2	1.537
7	2	0.6	99.7	4.58	7	6.8	1.1	97.1	1.271	7	6.2	1	97.3	1.078
8	0.4	0.1	99.9	1.015	8	5.4	0.9	98	1.265	8	5.7	0.9	98.2	1.494
9	0.4	0.1	100		9	4.2	0.7	98.7	1.081	9	3.8	0.6	98.8	1.315
10	0	0	100	3.675	10	3.9	0.6	99.4	1.485	10	2.9	0.5	99.3	1.385
...					...					...				
					20	0	0	100	1.44	22	0	0	100	1.157
	345.4	100				606.2	100				608.1	100		

Iberia
Bonacich centrality

Bonacich eigenvector centralities				Bonacich eigenvector centralities				Bonacich eigenvector centralities			
		1	2			1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	MAD	0.637	90.065	1	MAD	0.62	87.683	1	MAD	0.59	83.411
2	BCN	0.605	85.518	2	BCN	0.566	80.095	2	BCN	0.516	73.009
3	PMI	0.205	29.034	3	PMI	0.208	29.396	3	PMI	0.223	31.484
4	AGP	0.156	21.992	4	VLC	0.198	28.008	4	VLC	0.2	28.261
5	VLC	0.147	20.844	5	BIO	0.141	19.981	5	AGP	0.165	23.295
6	BIO	0.146	20.681	6	AGP	0.136	19.178	6	ORY	0.162	22.872
7	ORY	0.14	19.736	7	SVQ	0.125	17.714	7	SVQ	0.15	21.245
8	SVQ	0.138	19.466	8	IBZ	0.12	16.946	8	IBZ	0.148	20.99
9	LHR	0.132	18.697	9	ORY	0.115	16.226	9	ALC	0.137	19.333
10	SCQ	0.129	18.266	10	ALC	0.112	15.825	10	BIO	0.135	19.106
	...				...				...		
42	ALC	0.006	0.807	67	LGW	0.002	0.324	76	LGW	0.001	0.103

Iberia
Bonacich centrality

Descriptive statistics				Descriptive statistics				Descriptive statistics			
		1	2			1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	Mean	0.081	11.447	1	Mean	0.066	9.395	1	Mean	0.066	9.367
2	Std Dev	0.131	18.578	2	Std Dev	0.103	14.5	2	Std Dev	0.094	13.245
3	Sum	3.4	480.776	3	Sum	4.451	629.453	3	Sum	5.034	711.886
4	Variance	0.017	345.156	4	Variance	0.011	210.245	4	Variance	0.009	175.419
5	SSQ	1	20000.002	5	SSQ	1	19999.998	5	SSQ	1	20000.002
6	MCSSQ	0.725	14496.535	6	MCSSQ	0.704	14086.407	6	MCSSQ	0.667	13331.828
7	Euc Norm	1	141.421	7	Euc Norm	1	141.421	7	Euc Norm	1	141.421
8	Minimum	0.006	0.807	8	Minimum	0.002	0.324	8	Minimum	0.001	0.103
9	Maximum	0.637	90.065	9	Maximum	0.62	87.683	9	Maximum	0.59	83.411
10	N of Obs	42	42	10	N of Obs	67	67	10	N of Obs	76	76

Air Berlin
Bonacich centrality

Eigenvalues 2000					Eigenvalues 2004				
Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio
1	34.567	54.1	54.1	4.939	1	86.891	40.4	40.4	2.723
2	6.999	11	65.1	1.537	2	31.906	14.8	55.2	1.648
3	4.554	7.1	72.2	1.314	3	19.363	9	64.2	1.339
4	3.466	5.4	77.6	1.264	4	14.464	6.7	70.9	1.413
5	2.742	4.3	81.9	1.089	5	10.238	4.8	75.7	1.088
6	2.518	3.9	85.8	1.232	6	9.406	4.4	80.1	1.431
7	2.043	3.2	89	1.125	7	6.574	3.1	83.1	1.058
8	1.817	2.8	91.9	1.198	8	6.212	2.9	86	1.313
9	1.517	2.4	94.3	1.254	9	4.732	2.2	88.2	1.127
10	1.21	1.9	96.2	1.258	10	4.199	2	90.2	1.162
...					...				
15	0.197	0.3	100		26	0	0	100	2.128
	63.892	100				215.17	100		

Bonacich eigenvector centralities				Bonacich eigenvector centralities			
		1 Eigenvec	2 nEigenvec			1 Eigenvec	2 nEigenvec
1	PMI	0.617	87.21	1	PMI	0.52	73.568
2	PAD	0.334	47.301	2	DUS	0.368	51.975
3	TXL	0.323	45.687	3	TXL	0.322	45.515
4	FMO	0.288	40.704	4	VIE	0.311	44.016
5	CGN	0.286	40.495	5	STN	0.235	33.296
6	DUS	0.218	30.898	6	ZRH	0.227	32.135
7	NUE	0.168	23.735	7	HAM	0.197	27.873
8	IBZ	0.144	20.31	8	FMO	0.182	25.728
9	FRA	0.128	18.17	9	HAJ	0.17	23.978
10	HER	0.125	17.619	10	MUC	0.164	23.221
	...				...		
34	FNC	0.005	0.687	55	MJT	0.004	0.507
35	SMI	0.005	0.687	56	ATH	0.003	0.354
36	ZTH	0.005	0.687	57	INN	0.001	0.152
37	HAJ	0.004	0.588	58	GRZ	0.001	0.152
38	BRE	0.004	0.51	59	BRE	0.001	0.127

Air Berlin
Bonacich centrality

Descriptive statistics 2000				Descriptive statistics 2004			
		1 Eigenvec	2 nEigenvec			1 Eigenvec	2 nEigenvec
1	Mean	0.106	14.966	1	Mean	0.079	11.198
2	Std Dev	0.123	17.388	2	Std Dev	0.103	14.614
3	Sum	4.021	568.69	3	Sum	4.672	660.693
4	Variance	0.015	302.349	4	Variance	0.011	213.584
5	SSQ	1	19999.998	5	SSQ	1	20000
6	MCSSQ	0.574	11489.243	6	MCSSQ	0.63	12601.43
7	Euc Norm	1	141.421	7	Euc Norm	1	141.421
8	Minimum	0.004	0.51	8	Minimum	0.001	0.127
9	Maximum	0.617	87.21	9	Maximum	0.52	73.568
10	N of Obs	38	38	10	N of Obs	59	59

Ryanair
Bonacich centrality

Eigenvalues 1996					Eigenvalues 2000				
Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio
1	99.2	86.9	86.9	6.621	1	149.5	70.6	70.6	3.77
2	15	13.1	100		2	39.6	18.7	89.3	2.533
3	0	0	100		3	15.7	7.4	96.7	2.257
4	0	0	100		4	6.9	3.3	100	
					5	0	0	100	
	114.1	100			6	0	0	100	
					7	0	0	100	
						211.7	100		

Bonacich eigenvector centralities 1996				Bonacich eigenvector centralities 2000			
		1 Eigenvec	2 nEigenvec			1 Eigenvec	2 nEigenvec
1	DUB	0.672	95.028	1	STN	0.582	82.337
2	STN	0.573	80.978	2	DUB	0.566	80.036
3	PIK	0.264	37.384	3	PIK	0.271	38.34
4	MAN	0.21	29.71	4	LBC	0.266	37.62
5	BHX	0.19	26.834	5	TSF	0.171	24.142
6	LGW	0.183	25.876	6	CRL	0.17	24.061
7	LTN	0.129	18.209	7	LTN	0.125	17.673
8	LPL	0.115	16.292	8	MAN	0.125	17.673
9	ORK	0.075	10.617	9	BVA	0.116	16.377
10	NOC	0.04	5.717	10	LGW	0.106	14.995
					. . .		
				33	NOC	0.027	3.857
				34	PGF	0.027	3.857
				35	RMI	0.027	3.857
				36	CWL	0.027	3.749
				37	MME	0.027	3.749

Ryanair
Bonacich centrality

Descriptive statistics 1996				Descriptive statistics 2000			
		1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	Mean	0.245	34.664	1	Mean	0.104	14.75
2	Std Dev	0.2	28.256	2	Std Dev	0.127	17.972
3	Sum	2.451	346.645	3	Sum	3.859	545.735
4	Variance	0.04	798.374	4	Variance	0.016	322.99
5	SSQ	1	19999.998	5	SSQ	1	20000
6	MCSSQ	0.399	7983.737	6	MCSSQ	0.598	11950.63
7	Euc Norm	1	141.421	7	Euc Norm	1	141.421
8	Minimum	0.04	5.717	8	Minimum	0.027	3.749
9	Maximum	0.672	95.028	9	Maximum	0.582	82.337
10	N of Obs	10	10	10	N of Obs	37	37

Virgin Express
Bonacich centrality

Eigenvalues 2000					Eigenvalues 2004				
Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio
1	89.894	100	100		1	56.95	86	86	6.118
					2	9.308	14	100.0	
	89.894	100.0							
						66.259	100		

Bonacich eigenvector centralities 2000				Bonacich eigenvector centralities 2004			
		1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	BRU	0.707	100	14	BRU	0.706	99.82
2	LHR	0.464	65.633	13	NCE	0.31	43.819
3	BCN	0.362	51.171	12	BCN	0.26	36.808
4	FCO	0.354	50.059	11	ATH	0.26	36.808
5	LGW	0.149	21.136	10	AGP	0.26	36.808
6	CPH	0.055	7.787	9	FCO	0.253	35.792
7	LIN	0.055	7.787	8	MAD	0.248	35.055
				7	LIS	0.186	26.291
				6	GVA	0.124	17.528
				5	LIN	0.092	13.006
				4	FAO	0.087	12.269
				3	PMI	0.074	10.517
				2	BOD	0.062	8.764
				1	AMS	0.042	5.998

Virgin Express
Bonacich centrality

Descriptive statistics 2000				Descriptive statistics 2004			
		1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	Mean	0.307	43.367	1	Mean	0.212	29.949
2	Std Dev	0.221	31.247	2	Std Dev	0.163	23.057
3	Sum	2.147	303.572	3	Sum	2.965	419.282
4	Variance	0.049	976.406	4	Variance	0.027	531.646
5	SSQ	1	20000	5	SSQ	1	20000
6	MCSSQ	0.342	6834.84	6	MCSSQ	0.372	7443.04
7	Euc Norm	1	141.421	7	Euc Norm	1	141.421
8	Minimum	0.055	7.787	8	Minimum	0.042	5.998
9	Maximum	0.707	100	9	Maximum	0.706	99.82
10	N of Obs	7	7	10	N of Obs	14	14

easyJet
Bonacich centrality

Eigenvalues 2000					Eigenvalues 2004				
Factor	Value	Percent	Cum %	Ratio	Factor	Value	Percent	Cum %	Ratio
1	63.632	100	100		1	131.8	38.5	38.5	2.505
					2	52.6	15.4	53.9	1.226
	63.632	100			3	42.9	12.5	66.4	1.629
					4	26.3	7.7	74.1	1.3
					5	20.3	5.9	80	1.122
					6	18.1	5.3	85.3	1.303
					7	13.9	4	89.3	1.181
					8	11.7	3.4	92.8	1.414
					9	8.3	2.4	95.2	1.124
					10	7.4	2.2	97.3	1.251
					20	0	0	100	3.124
						342.3	100		

easyJet
Bonacich centrality

Bonacich eigenvector centralities 2000				Bonaich eigenvector centralities 2004			
		1	2			1	
		Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	STN	0.707	100	1	LTN	0.423	59.884
2	CPH	0.278	39.289	2	AMS	0.313	44.291
3	MXP	0.278	39.289	3	STN	0.31	43.8
4	AGP	0.244	34.574	4	NCE	0.276	39.014
5	CIA	0.233	33.002	5	LGW	0.266	37.598
6	MAD	0.211	29.859	6	LPL	0.245	34.626
7	BCN	0.167	23.573	7	BCN	0.244	34.511
8	FAO	0.167	23.573	8	AGP	0.233	32.902
9	VCE	0.167	23.573	9	SXF	0.211	29.847
10	LIS	0.156	22.002	10	CIA	0.211	29.847
	...				...		
15	IBZ	0.078	11.001	37	MRS	0.028	3.995
16	NAP	0.078	11.001	38	TLS	0.028	3.995
17	PMI	0.078	11.001	39	BLQ	0.016	2.327
18	RKV	0.044	6.286	40	LJU	0.016	2.327
19	LYS	0.011	1.572	41	LYS	0.016	2.327

Descriptive statistics 2000				Descriptive statistics 2004			
		1	2			1	2
		Eigenvec	nEigenvec			Eigenvec	nEigenvec
1	Mean	0.177	25.032	1	Mean	0.119	16.785
2	Std Dev	0.146	20.641	2	Std Dev	0.102	14.355
3	Sum	3.363	475.599	3	Sum	4.866	688.177
4	Variance	0.021	426.055	4	Variance	0.01	206.075
5	SSQ	1	19999.996	5	SSQ	1	19999.994
6	MCSSQ	0.405	8095.048	6	MCSSQ	0.422	8449.076
7	Euc Norm	1	141.421	7	Euc Norm	1	141.421
8	Minimum	0.011	1.572	8	Minimum	0.016	2.296
9	Maximum	0.707	100	9	Maximum	0.423	59.884
10	N of Obs	19	19	10	N of Obs	41	41

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