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DISSERTATION

European Hub Airports – Assessment of Constraints for Market Power in the Local Catchment and on the Transfer Market

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Abstract

Airports have long been considered as an industry in which firms are able to exert significant market power. Nowadays, there is controversial discussion whether airports face a degree of competition which is sufficient to constrain potentially abusive behaviour resulting from this market power. The level of competition encountered by European airports has hence been evaluated by analysing the switching potential of both airlines and passengers between different airports, for example. The research within this thesis contributes to the field of airport competition by analysing the degree of potential competition 36 European hub airports face on their origin-destination market in their local catchments as well as on the transfer market within the period from 2000 to 2016. For this purpose, a two-step approach is applied for each market, with first analysing the degree of market concentration, using the Herfindahl Hirschman Index as a measure, for each destination offered at the hub airports and the respective development over time. In the second step, the effect of market concentration on the seat capacities at the hub airports is estimated.

This analysis shows that the majority of European hub airports has a dominant position on both the origin-destination and transfer market. However, it can be observed that the level of market concentration has been decreasing over time, thus implying a higher overlap between destinations offered at hub airports and their competitive counterparts. Passengers thus have more alternatives available when travelling between two points, this increasing switching ability therefore imposes potential constraints on airport market power. In the second step of the analysis, the above approach is complemented by empirically estimating the impact of an increase in market concentration, and additional factors such as the presence of low cost carriers at competing airports, on the seat capacities offered on a particular destination. Using panel data for the considered time period, the statistically significant results show that an increase in market concentration leads to a decrease in the amount of seats as well the flight frequencies offered to a destination. These findings are coherent for both the origin-destination and transfer market. Considering the decrease in market concentration across the majority of European hub airports, it can in turn be inferred that more seats and frequencies are supplied on the respective routes, resulting in an increase in consumer welfare.

This approach and the respective findings in this thesis serve as further guidance to policy makers deciding on the extent of economic regulation feasible for individual hub airports in Europe. From an airport and airline standpoint these results can, of course, also be applied to gain insight as to which airports are their main competitors, and which routes face a high overlap with other airports and airlines, thus designing their network structure accordingly.

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Abbreviations

AA	American Airlines
AB	Air Berlin
AC	Average cost
ACH	St. Gallen-Altenrhein Airport
ACI	Airports Council International
ADB	Izmir-Adnan Menderes Airport
AER	Sochi Airport
AF	Air France
AGB	Augsburg Airport
AGH	Ängelholm–Helsingborg Airport
AGP	Malaga Airport
AMS	Amsterdam-Schiphol Airport
ANR	Antwerp Airport
ARN	Stockholm-Arlanda Airport
AS	Asia
ATH	Athens Airport
AUH	Abu Dhabi Airport
AY	Finnair
AYT	Antalya Airport
AZ	Alitalia
BA	British Airways
BAA	British Airport Authority
BCN	Barcelona Airport
BFS	Belfast Airport
BGO	Bergen Airport
BGY	Orio al Serio Airport
BHD	Belfast City Airport
BHX	Birmingham Airport
BLK	Blackpool Airport
BMA	Stockholm-Bromma Airport
BOH	Bournemouth Airport
BOS	Boston-Logan Airport
BRN	Bern Airport
BRS	Bristol Airport
BRU	Brussels Airport
BSL	Basel Mulhouse Freiburg Airport
BTS	Bratislava Airport
BUD	Budapest Airport
BVA	Paris-Beauvais Airport

CAG	Cagliari Airport
CDG	Paris-Charles de Gaulle Airport
CFE	Clermont-Ferrand Auvergne Airport
CGN	Cologne Bonn Airport
CHQ	Chania Airport
CIA	Rome-Ciampino Airport
CLA	Critical loss analysis
CNU	Connectivity units
CPH	Copenhagen Airport
CRL	Brussels-South Charleroi Airport
CTA	Catania Airport
CVP	Countervailing power
CVP	Countervailing power
DKR	Dakar Airport
DLA	Douala Airport
DME	Moscow-Domodedovo Airport
DOH	Doha Airport
DRS	Dresden Airport
DSA	Doncaster Sheffield Airport
DTM	Dortmund Airport
DUB	Dublin Airport
DUS	Dusseldorf Airport
DXB	Dubai Airport
EDI	Edinburgh Airport
EI	Aer Lingus
EIN	Eindhoven Airport
EMA	East Midlands Airport
ESB	Ankara-Esenboga Airport
EU	Europe
EWR	Newark Airport
FC	Fully connected
FCO	Rom-Fiumicino Airport
FDH	Friedrichshafen Airport
FERM	Full equilibrium relevant market test
FI	Icelandair
FKB	Karlsruhe-Baden-Baden Airport
FMM	Munich-Memmingen Airport
FMO	Münster-Osnabrück Airport
FNC	Madeira Airport
FRA	Frankfurt Airport
FSC	Full Service Carrier
GDN	Gdansk Airport

GDP	Gross Domestic Product
GLA	Glasgow Airport
GLO	Helsinki-Vantaa Airport
GLS	Generalised least squares
GNB	Grenoble Airport
GOA	Goa Airport
GRO	Girona-Costa Brava Airport
GRQ	Groningen Airport
GRZ	Graz Airport
GVA	Geneva Airport
HAD	Halmstad Airport
HAM	Hamburg Airport
HEL	Helsinki Airport
HEM	Helsinki-Malmi Airport
HER	Heraklion Airport
HHI	Herfindahl Hirschman Index
HHN	Frankfurt-Hahn Airport
HS	Hub-and-spoke
HUY	Humberside Airport
IAG	International Airline Group
IATA	International Air Transport Association
IB	Iberia
ILD	Lleida-Alguaire Airport
INN	Innsbruck Airport
ISE	Isparta Airport
ISO	International Organization for Standardization
IST	Istanbul-Ataturk Airport
JFK	New York John F. Kennedy Airport
JNB	Johannesburg Airport
KCO	Izmit Topel Airport
KEF	Keflavik Airport
KGS	Kos Airport
KID	Kristianstad Airport
KL	KLM
KLM	Koninklijke Luchtvaart Maatschappij
KLV	Karlovy Vary Airport
KRK	Krakow Airport
KSC	Kosice Airport
LA	Latin America
LBA	Leeds Bradford Airport
LCC	Low cost carrier
LCJ	Lodz Airport

LCY	London City Airport
LED	Pulkovo Airport
LEJ	Leipzig Halle Airport
LGW	London-Gatwick Airport
LH	Lufthansa
LHG	Lufthansa Group
LHR	London Heathrow Airport
LIL	Lille Airport
LIN	Linate Airport
LIS	Lisbon Airport
LNZ	Linz Airport
LO	LOT
LON	London Metropolitan Area
LPL	Liverpool Airport
LTN	London-Luton Airport
LUG	Lugano Airport
LUX	Luxembourg Airport
LX	Swiss
LYN	Lyon-Bron Airport
LYS	Lyon-Saint-Exupéry Airport
MAD	Madrid-Bajaras Airport
MAN	Manchester Airport
MC	Marginal cost
ME	Middle East
MHG	Mannheim Airport
MJT	Mytilene Airport
MME	Durham Airport
MMX	Malmö Airport
MR	Marginal revenue
MRS	Marseille Airport
MST	Maastricht Aachen Airport
MUC	Munich Airport
MXP	Milan-Malpensa Airport
NA	North America
NCE	Nice Airport
NEIO	New Empirical Industrial Organisation
NRK	Norrköping Airport
NRN	Weeze Airport
NUE	Nuremberg Airport
NUTS	Nomenclature of Territorial Units for Statistics (French: Nomenclature des Unités Territoriales Statistiques)
NWI	Norwich Airport
NYO	Stockholm-Skavsta Airport

O&D	Origin and destination
OA	Olympic Air
OAG	Official Airline Guide
OK	Czech Airlines
OLS	Ordinary least squares
OPO	Porto Airport
ORB	Örebro Airport
ORD	Chicago O'Hare Airport
ORK	Cork Airport
ORY	Paris-Orly Airport
OS	Austrian
OSL	Oslo Airport
OST	Ostend-Bruges International
OUL	Oulu Airport
OVB	Tolmachevo Airport
PAD	Paderborn Lippstadt Airport
PGF	Perpignan-Rivesaltes Airport
PMF	Parma Airport
PMI	Palma de Mallorca Airport
PMO	Falcone Airport
PRG	Prague Airport
QPL	Quickest path length
R&D	Research and development
REK	Reykjavík Airport
REU	Reus Airport
RGS	Burgos Airport
RLG	Rostock Airport
RTM	Rotterdam Airport
RYG	Moss Airport
S7	S7 Airlines
SAW	Istanbul-Sabiha Gokcen Airport
SCN	Saarbrücken Airport
SCP	Structure-Conduct-Perfomance
SER	Standard error of the regression
SIN	Singapore Airport
SIP	Simferopol Airport
SIP	Simferopol Airport
SK	SAS
SKG	Thessaloniki Airport
SLM	Salamanca Airport
SN	Brussels
SOU	Southampton Airport

SPL	Shortest path length
SSNIP	Small but significant non-transitory increase in price
STN	Stansted Airport
STR	Stuttgart Airport
SU	Aeroflot
SVG	Stavanger Airport
SVO	Moscow-Sheremetyevo Airport
SXB	Strasbourg Airport
SXF	Berlin-Schönefeld Airport
SZG	Salzburg Airport
SZZ	Szczecin-Goleniów Airport
TK	Turkish Airlines
TKU	Turku Airport
TLS	Toulouse Airport
TOJ	Madrid-Torrejón Airport
TP	TAP
TRF	Sandefjord Airport
TRN	Turin Airport
TXL	Berlin-Tegel Airport
U.S.	United States
UK	United Kingdom
VBS	Brescia Airport
VIE	Vienna Airport
VIF	Variance inflation factors
VKO	Moscow-Vnukovo Airport
VRN	Verona-Villafranca Airport
WAT	Waterford Airport
WAW	Warsaw-Chopin Airport
WMI	Warsaw-Modlin Airport
WRO	Wroclaw Airport
XCR	Châlons Vatry Airport
ZQW	Zweibrücken Airport
ZRH	Zurich Airport

Nomenclature

AC	Average cost curve
C	Cost of production
CVP	Countervailing power
D	Market demand
HHI	Herfindahl Hirschman Index
L	Lerner index
M	Minimum cost
MC	Marginal cost
MR	Marginal revenue
MS	Market share
N	Number of firms (airports)
P	Price
Q	Output
R^2	Goodness-of-fit in regression analysis
SER	Standard error of regression
s	Market share
sc	Sunk cost
w_d	Distance-weighting factor
β	Coefficient
γ	Intercept representing time effect
ε	Price elasticity of demand
u	Error term
π	Firms' profit
σ^2	Variance

1 Introduction

"… a major hub airport can exploit its significant market power over airlines that, due to the markets they serve and their investment in a route network, are captive customers for the airport." (Smyth & Pearce, 2007:p.9)

This particular argument has been one of many adding to the discussion on airport market power and the need to restrain this industry from abusive price setting behaviour. The notion of airports being natural monopolies due to their cost structure and locational specifics, and the resulting limited constraints of market power have dominated the discussion in academia and industry. As a result, airport charging structures have long been subject to various forms of ex-ante, and in some limited cases ex-post economic regulation, such as cost-based or incentive regulation, since it is assumed that the inherent market structure of this industry leads to allocative, productive and dynamic inefficiency (Starkie, 2004; Smyth & Pearce, 2007; Niemeier, 2009).

However, discussion on the costs of economic regulation potentially arising due to setting wrong incentives for the airport in question, and the changing European airport landscape have been fostering the debate on a re-thinking of the current regulatory practice in the airport sector (Reinhold *et al.*, 2010; Niemeier, 2009; Frontier Economics, 2009; Burghouwt & Hakfoort, 2001; Dobruszkes, Givoni & Vowles, 2017; Dobruszkes, 2013). The focus of this thesis is placed on the analysis of competitive constraints, i.e. the constraints imposed on market power, arising from, for example, the deregulation of the European airline market from the 1990s onwards, and the resulting increasing presence of multiple (low cost) airlines. The impact of these various developments in the air transport sector and the resulting effects on the degree of airport market power are controversially discussed (Thelle *et al.*, 2012; Smyth & Pearce, 2007; Müller *et al.*, 2010). A comprehensive analysis of the effects requires the consideration of those market segments at the airport which constitute the monopolistic bottleneck, and are thus currently subject to economic regulation at most European airports. Figure 1 provides an overview of these different market segments, which are divided into airport services and airport infrastructure according to Müller *et al.* (2010); a similar discussion of airport market segments can also be found in Frontier Economics (2009) or Polk & Bilotkach (2013).

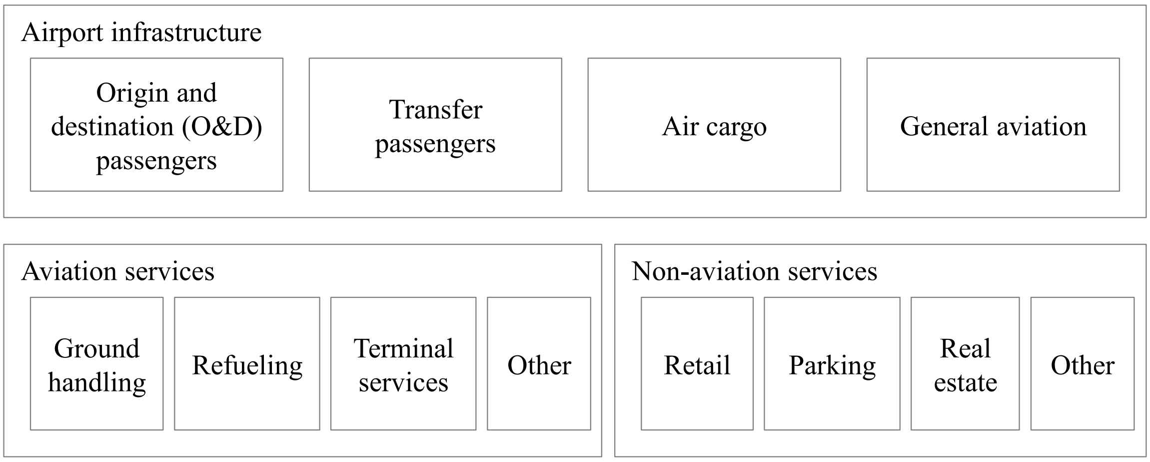

Figure 1: Airport market segments

Source: own depiction based on Müller *et al.* (2010)

Based on these definitions, research has been focusing on the assessment of market power either across all relevant segments, or on particular markets and the degree of competition prevalent in these. Competition authorities have established frameworks to investigate the overall level of competition for individual airports and to implement tailored economic regulation accordingly (e.g. Competition Commission, 2009b; Civil Aviation Authority, 2016). A range of studies has been assessing different factors that impose competition for airports, such as the potential of airlines to switch their operations between airports and the associated costs (Thelle *et al.*, 2012; Maertens, 2012; Polk & Bilotkach, 2013; Müller *et al.*, 2010). Another aspect concerns the substitution potential passengers have, and which factors determine their choice in selecting a particular airport, both for point-to-point and transfer flights (Starkie, 2010; Redondi, Malighetti & Paleari, 2011; Wiltshire, 2013; Burghouwt & Redondi, 2013; Malina, 2010; Mandel, 1998). An important issue in this regard has been the emergence of low cost carriers on the European aviation market, contributing to the growth of secondary or regional airports, which has been argued to put increasing competitive constraints on hub airports (Burghouwt, Mendes de Leon & De Wit, 2015; Dobruszkes, 2013; Thelle *et al.*, 2012).

Looking at the interaction between aviation and non-aviation services has been the focus of studies by Bracaglia, D'Alfonso & Nastasi (2014); Gillen (2009); Gillen & Mantin (2013), who highlight that airports have the incentive to set their charges at a level to incentivise airlines to increase their passenger base by either offering more frequent services or increasing the capacities per flight. This development may be an effective restraint to the airport's exertion of market power. Furthermore, welfare implications of increased competition have been assessed by Allroggen & Malina (2010); Lin (2006); Brueckner & Spiller (1991). The findings of these studies differ in terms of the degree of competition faced by (European) airports. Müller *et al.* (2010) and Wiltshire (2013), for example, highlight the limited extent of competition the airports in their analyses are exposed to, and postulate that some form of economic regulation is still required. Thelle *et al.* (2012), on the other hand, conclude from their analysis of the competitive environment faced by different European airports that constraints on market power have been increasing, and that regulatory frameworks should therefore be amended or even rendered obsolete.

Building on this current research landscape in the field of airport competition, this thesis focuses on the assessment of potential competitive constraints imposed on European hub airports. For this purpose, those airports within Europe with the highest passenger volume in 2016 as well as those which represent the node of a network carrier operating a hub-and-spoke network are considered (Airports Council International Europe, 2016b, 2016a). This sample size represents an extension of the current research on competition for hub airports, which focuses on various subsets of the dataset considered here. For all these airports, both the origin and destination (O&D) and the transfer market are analysed in terms of their development over time, the overlap of offered destinations with other airports and carriers, and the comparison across these airports. The complementary assessment of these two markets is essential in the case of hub airports since these engage in a close vertical relationship with their network carriers. These operate a hub-and-spoke network at the airport node and thus enable transfer passengers to connect between two feasible flights. Hence, passengers are fed into the node from different origins and bundled to travel to a single destination, which enables the carrier to realise economies of density, for example. The size of these two markets and the degree of interaction between the hub airport and the network carrier, however, differ across the sample of European airports. Therefore, it is necessary to first consider both markets individually, and secondly assess the potential competitive constraints of both markets together to obtain a comprehensive picture for each airport.

The degree of potential competition European hub airports face, both in terms of the origin-destination market in their local catchments as well as on the transfer market, is the main focus of the research in the following chapters. Both markets are analysed according to the same structure and research methodologies, starting with the assessment of the level of market concentration each European hub airport faces in its local catchment and on the transfer market, and the respective development over time. Employing data for the years 2000, 2004, 2008, 2012, and 2016 exceeds the observed time periods within most other studies on airport competition, and therefore provides an extension to existing research by considering this long-term development.

In order to get a detailed insight into the hub airports' position in their respective markets, market concentration is assessed on the individual destination level. Using the Herfindahl Hirschman Index as a proxy for this, yields information on how much each route at a hub airport is concentrated in terms of airline seats offered. Considering the local catchment of an airport, for example, a rather even distribution of seats to a particular destination across all catchment airports suggests that passengers have the potential to substitute between different airports. This availability of substitutes therefore may impose constraints on a hub airport's market power. This first part of the assessment delivers a detailed insight into each hub airport's position in both the origin-destination and the transfer market. However, since airport market power cannot be directly inferred from a high degree of market concentration, the second strand of research in this thesis provides an extension to the methodologies currently applied in airport competition assessment. Here, the effects of market concentration, and other factors potentially constraining market power, on airport output are empirically estimated using panel data for the observed period.

It is assumed that in case there is little substitution potential on a particular destination, i.e. this route exhibits high market concentration, the amount of seats offered is restricted, compared to routes with a higher overlap across different airports. As stated by the Productivity Commission (2011), "… a monopolist will maximise its profits by reducing the total output of goods or services it supplies to the market, in order to increase the price charged" (p.71). Furthermore, as highlighted above, the rise of low cost carriers and the associated growth of additional competitors in the European airport landscape is assumed to put competitive pressure on hub airports. This development currently mainly refers to the origin-destination market, the implications of low cost carrier presence are therefore only assessed in regard to the local catchment of hub airports, and not in terms of the transfer market. The same applies to the availability of rail services, which may act as substitutes or complements for air services offered at hub airports. Estimating these effects is also included in the analysis of competition in the local catchment.

In the analysis of competition in the local catchment of hub airports, the assessment focuses on these hub airports and their secondary counterparts, and how the increased offer of flights and seats at the latter impacts the traffic development at European hub airports. Within the first step of this assessment the degree of market concentration in the local catchment is analysed, followed by an empirical estimation of the respective effects on the output supplied at the hub airport. The impact low cost carriers as well as rail services have on air services at hub airports provides a further extension to this analysis. The following research questions are hence being investigated:

(1) How concentrated is the origin-destination market in the local catchment of European hub airports, and has there been a development to a less concentrated one in between 2000 and 2016?
(2) What is the impact of market concentration on the output decisions, in terms of seats offered to a particular destination, at European hub airports? As a measure for market concentration, the Herfindahl Hirschman Index is employed as explanatory variable in the regression analysis.
(3) As discussed earlier, low cost carriers are presumed to have an impact on the rising constraints on hub airports' market power, since these particular airlines are often believed to locate their operations at smaller airports with spare capacity, i.e. those secondary airports within a hub airport's catchment, see, for example, Dobruszkes, Givoni & Vowles (2017). The third research question therefore assesses the impact of low cost carrier presence on the output provided at hub airports.

(4) Furthermore, potential competition from other modes of transport, such as (high-speed) rail, might constrain the market power of hub airports. The fourth research question therefore focuses on the evaluation of the effect of (high-speed) rail services on the seats offered at European hub airports.

A similar structure can also be found for the analysis of competition on the transfer market. This market in particular is characterised by a close interlinkage between a hub airport and its respective network carrier. The latter are those airlines offering transfer connections for passengers via the hub airport. When assessing market concentration on the transfer market, the connections offered by network carriers and their alliance partner are thus taken into consideration. Based on this assumption, the analysis of this market starts with a detailed analysis of the degree of market concentration, and the respective development over time, for the European hub airports in the dataset. Following this, the effects of a high degree of market concentration on the transfer connections offered via the hubs are assessed empirically, yielding the following research questions:

(5) How concentrated is the transfer market, in relation to the number of transfer connections and the capacities offered via each European hub airport, and has there been a development to a less concentrated market in between 2000 and 2016?
(6) What is the impact of market concentration on the output decisions, in terms of seats offered on a transfer connection, at European hub airports? A transfer connection is a route offered from origin A to destination B via a hub airport H, which is comprised of the European hub airports considered in this thesis. As a measure for market concentration, the Herfindahl Hirschman Index for each available transfer connection is employed as explanatory variable in the regression analysis.

In order to evaluate and discuss these research questions, the thesis is structured into four main parts, focusing on (1) the theoretical background necessary for the assessment of market power in an industry (Chapter 2), with particular emphasis on the discussion of approaches currently applied in competition policy to assess the degree of market power in an industry, thus building the basis for the second part of the thesis. This provides (2) a discussion of the market structure of the airport industry (Chapter 3), placing a focus on the specific vertical relationship between airports and airlines, and putting the research questions addressed within this thesis into the context of the current airport competition research landscape. Applying the findings and assumptions discussed in the first two parts of the thesis, the remaining parts assess (3) competition in the local catchment of European hub airports (Chapter 4), focusing on research questions (1) to (4), followed by the analysis of the transfer market at these airports (Chapter 5), addressing research questions (5) and (6). Complementing these four main parts of the thesis is Chapter 6 which discusses the findings of the thesis in relation to the initial research questions posed, and outlines implications to the potential competition European hub airports face both in their local catchment and on the transfer market.

2 Theoretical Foundations for the Assessment of Market Power

Airports have long been considered as an industry in which firms are able to exert significant market power and hence often became subject to economic regulation. The economic theory underlying the sources of firms' market power including natural monopolies, potential entry barriers as well as assessment approaches of market power are therefore discussed in detail in this chapter to provide the foundation for the discussion of airport market power. In the case of monopoly power a firm might only be able to raise its prices incrementally above the marginal cost, and not be able to earn competitive profits, though (Landes & Posner, 1981). The Lerner index, which measures the difference between prices and marginal cost as a fraction of price, is therefore applied in determining a firm's market power, for example. The degree of this strongly depends on the elasticity of demand in the market, and it thus influences the ability of the firm to exert market power.

In line with this, Chapter 2.1 starts with a detailed outline of the theory of natural monopolies and potential entry barriers that might restrain competition. Following that, the different approaches taken to assess the degree of market power is subject of Chapter 2.2, with a particular focus on methodologies applied to define the relevant market and to measure market concentration. Controversy has arisen as to which approaches and respective underlying economic theory provide the most feasible methodology, especially considering its application in past and current competition policy. Understanding the different sides supporting distinct ways of assessing monopolistic or oligopolistic industries hence yields a comprehensive overview of each approach's drawbacks as well as data requirements[1].

2.1 Market power and rationale for economic regulation

Providing the underlying concepts for the discussion of market power in the airport industry, Chapter 2.1 focuses on the economic theory of (natural) monopolies and related aspects.

[1] Part of this chapter has been published in: Paul, A. (2015) *Theoretical Foundations Relevant for the Analysis of Hub Airport Competition*, in: Zeitschrift für Verkehrswissenschaft, 86. Jahrgang, 2015, Heft 1, pp. 47-64.

Building on this, Chapter 2.1.2 discusses potential barriers to entry of new competitors to a market, highlighting the different views as to the feasibility of the diverse barriers

2.1.1 The economic theory of natural monopolies

A monopoly exists if a particular good is supplied by only one firm in the market and if this firm either raises the price (P_m) of the good above marginal cost (*MC*) in order to maximise profits or by selecting the profit-maximising output (Q_m), as depicted in Figure 2 (Mas-Colell, Whinston & Green, 1995:p.384; Carlton & Perloff, 2005:p.89), assuming a simple setting to illustrate the negative impacts of a monopoly.

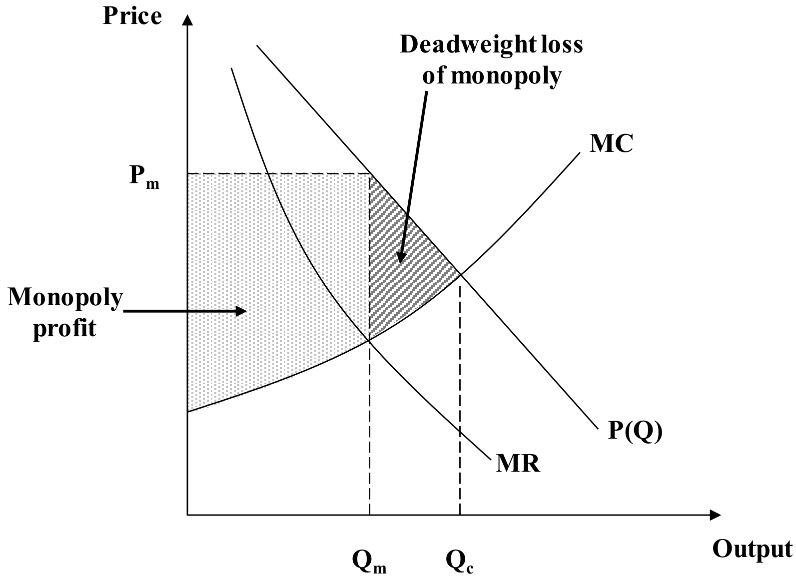

Figure 2: Monopoly profit maximisation
Source: Mas-Colell, Whinston & Green (1995:p.386)

Instead of setting the output where prices are equal to marginal costs as in a perfectly competitive market (Q_c), the monopolist chooses its optimal output level where marginal revenue (*MR*) equals marginal cost. This monopoly output, however, deviates from the socially optimal output level and is hence considered as a distortion resulting in welfare losses ("deadweight loss of monopoly") and thus a cost to society due to foregone consumer surplus (Church & Ware, 2000:p.34). The dark shaded area in Figure 2 shows this deadweight loss which is also considered as allocative inefficiency since output remains below the social optimum.

In addition to this adverse welfare effect of monopoly behaviour, other disadvantages of a monopoly are assumed in the form of x-inefficiencies and rent-seeking behaviour. The former concept has first been highlighted by Leibenstein (1966) in saying that monopoly firms lack incentives to minimise costs, describing different industry examples to support his argument. These might stem from "managerial slack" (Church & Ware, 2000:p.145) or as Leibenstein (1978) puts it that "[it] results from incomplete contracts, effort discretion, and non-maximizing behaviour, rather than lack of information or errors" (p. 203). The introduction of competition to the market thus leads to cost minimisation efforts by the monopolist since previously it had been lacking incentives to increase both productive and dynamic efficiency, in addition to the allocative inefficiency discussed above. Productive inefficiency means that a firm does not choose the optimal technology, which might result in a further deviation from the socially optimal output level (Motta, 2009:p.45). Dynamic inefficiency addresses a firm's incentive to invest in new technologies and innovation. The argument in this case is that monopolistic firms do not see the necessity to do so unless they can increase their overall profit. In a competitive environment, however, dynamic efficiency is said to play a much greater role since it enables a firm to gain a competitive advantage of their rivals in the market (Motta, 2009:p.56).

There have been a range of empirical studies supporting these arguments across different industries[2]. However, critics of this reasoning argue that a monopolist's profit maximising strategy is inherent with efforts to minimise costs and that incentives for product as well as dynamic efficiency are also apparent in a monopolistic market environment (Carlton & Perloff, 2005:p.94). Stigler (1976) states that the observation of firms' inefficiencies by Leibenstein (1966) can be ascribed to allocative inefficiency along the lines of classical price theory. And that x-inefficiencies are due to firms operating on different production frontiers, meaning they have a different "entrepreneurial capacity" (p. 215), and not to the fact that a monopolist foregoes the aim of profit maximisation. Further, Button & Weyman-Jones

[2] See Viscusi, Harrington & Vernon (2005:p.171) for an overview of empirical studies supporting the x-inefficiency argument in terms of a firm's monopoly behaviour.

(1992) point out that the methodological approach taken and the underlying assumptions of a model used to determine the level of x-inefficiency in a firm can be biased and thus strongly influence the outcome of an empirical investigation.

Motta (2009:p.56) and Perelman (2011) highlight that the x-inefficiency debate emphasises the principal-agent problem and its importance in identifying managerial and organisational misconduct which can lead to welfare losses. Frantz (1992) also points out that the theory of x-inefficiencies hints at irrational behaviour of individuals which is not assumed in classical economy theory and therefore caused a controversial debate on how this should be treated in the theory of the firm. In addition to allocative inefficiency and x-inefficiencies, Posner (1975), inter alia, brought forward the notion that a monopolist spends his profits in order to maintain its position and hence “the cost of obtaining a monopoly is exactly equal to the expected profit of being a monopolist” (p.809). This rent-seeking hypothesis implies that the social costs of monopoly are even higher than the initially assumed deadweight loss (Tirole, 1989:p.76; Church & Ware, 2000:p.147; Carlton & Perloff, 2005:p.96; Motta, 2009:p.45).

The existence of a natural monopoly in an industry is one of the rationales for economic regulation. Baumol, Panzar & Willig (1988:p.17) state that “an industry is said to be a natural monopoly if, over the entire range of outputs, the firm’s cost function is subadditive” which allows only one firm to produce the socially-optimal output in a cost-minimising way. Therefore, economic regulation addresses the arising trade-off between productive efficiency and allocative inefficiency in the single-firm case: Consumers benefit from a single firm producing in the least-cost way but have to bear the cost associated with a single producer setting monopoly prices (Viscusi, Harrington & Vernon, 2005:p.401).

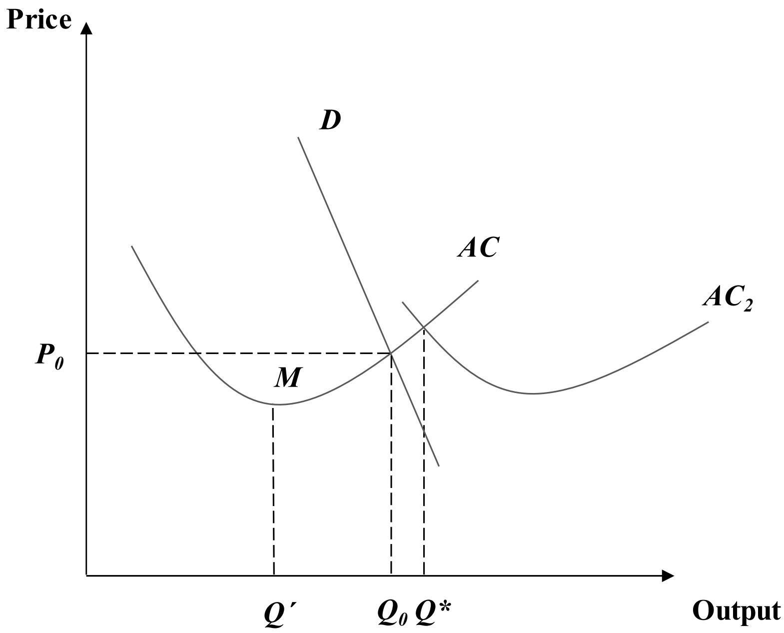

Figure 3: Natural monopoly in the single-product case

Source: Viscusi, Harrington & Vernon (2005:p.407)

To illustrate the concept of a natural monopoly in more detail, Figure 3 shows the single-product natural monopoly case. Up to the output level *Q'* a firm's production is characterized by economies of scale and it exhibits a declining average cost curve (*AC*) with increasing output. For the output range up to *Q'* a single firm can therefore produce the output in the least-cost manner (*M*). However, although economies of scale are sufficient in the single-product case, they are not a necessary condition for the existence of a natural monopoly, which can also prevail in the case of diseconomies of scale, i.e. in the example for output larger than *Q'*. Considering the case of two firms in the market and their respective average cost curve (AC_2) shows that the range of subadditivity exists up to the output level Q^* at which a single firm can produce at least cost. At the point where market demand *D* intersects the average cost curve *AC*, the cost function is subadditive and hence leads to a natural monopoly with output Q_0 and price P_0. (Viscusi, Harrington & Vernon, 2005:p.405; Braeutigam, 1989; Baumol, Panzar & Willig, 1988:p.108)

In reality, however, the single-product case often does not apply since firms are offering multiple products to its customers, e.g. such as an airline offering direct and connecting flights. In the multi-product case economies of scale are neither necessary nor sufficient but a natural monopoly exists if the cost function is subadditive. In this regard, the concept of economies of scope is of importance which says that "… it is cheaper to produce the two output levels [in a two-product case] together in one plant than to produce similar amounts of each good in single-product plants." (Church & Ware, 2000:p.58). For the two-product case, economies of scope exist if the following inequality holds:

$$C(Q_1, Q_2) < C(Q_1, 0) + C(0, Q_2) \tag{1}$$

With C being the cost of production and Q_1 representing the output of commodity 1 and Q_2 the output of commodity 2. A single firm can produce the combination of these multiple products in the least cost manner if the cost function is subadditive (Viscusi, Harrington & Vernon, 2005:p.405). Therefore, it is important to distinguish between economies of scope and the notion of cost subadditivity, which is defined in the following way:

$$C(\boldsymbol{Q}) < \sum_{i=1}^{k} C(\boldsymbol{Q}^i) \tag{2}$$

In which k denotes the amount of different firms i in the market ($i = 1, \ldots, k$) and n is the number of products b in the market, with $b = 1, \ldots, n$. The amount of output of product b being produced by firm i is thus denoted Q_b^i and the vector $\boldsymbol{Q}^i$ in (2) is the vector of outputs of firm i $(Q_1^i, Q_2^i, \ldots, Q_n^i)$[3] (Braeutigam, 1989). Considering this definition, according to (Baumol, Panzar & Willig, 1988:p.17) a "… cost function $C(\boldsymbol{Q})$ is *strictly subadditive* at $\boldsymbol{Q}$ if for any and all quantities of outputs $\boldsymbol{Q}^1, \ldots, \boldsymbol{Q}^k, \boldsymbol{Q}^i \neq \boldsymbol{Q}, i = 1, \ldots, k, such\ that\ \sum_{i=1}^{k} \boldsymbol{Q}^i = \boldsymbol{Q}$" and thus yielding (2). If the combined production of multiple products within a firm is cheaper than the production of each commodity in separate firms economies of scope are present, whereas in the presence of cost subadditivity at industry output level, both in the case of single and multiple products, a single firm ensures the least-cost production.

A natural monopoly is said to be sustainable if it can deter entry by potential competitors, or if it is too costly for potential competitors to enter the market. However, in the example depicted in Figure 3 the firm faces diseconomies of scale in producing the industry output

[3] The equation also holds for the single-product case in which n is equal to 1 and (2) reduces to $C(Q) < \sum_{i=1}^{k} C(Q^i)$.

level and thus serving the entire market. Assuming that an entrant has the same technology as the incumbent firm, perceives no entry barriers such as sunk costs and that it expects the incumbent to keep its price unchanged for some time after the entry, this competitor would charge a price which is below P_0 and produce output below the industry output level of Q_0, leaving the incumbent with the supply of the remaining output (Viscusi, Harrington & Vernon, 2005:p.408; Braeutigam, 1989), this represents the case of a weak monopoly of the incumbent firm.

2.1.2 Potential barriers to entry

Market power of a firm hence does not necessarily imply that it may exploit this since other firms may be able to enter the market (Braeutigam, 1989). Barriers to entry are an important criterion when considering the number of firms in a market as well as those of potential entrants. Regarding the definition and subsequent identification of entry barriers, much controversy has arisen among economists. The different views on entry barriers in an industry are exemplary represented by their main contributors in this chapter. One line of argument, supported by Stigler (1968) and stated by Baumol, Panzar & Willig (1988:p.282) in the way that "[an] entry barrier is anything that requires an expenditure by a new entrant into an industry, but imposes no equivalent cost upon an incumbent", defines an entry barrier as leading to higher long-run average costs for the new entrant compared to the market incumbent. Bain (1968), on the contrary, postulates "the extent to which, in the long run, established firms can elevate their selling prices above the minimal average costs of production and distribution ... without inducing potential entrants to enter the industry" (p. 252). In this view, the disadvantage of a new entrant towards an incumbent firm is enabled by economies of scale, as well as product differentiation and absolute cost advantages (Church & Ware, 2000:p.513). For the purpose of the discussion of entry barriers, it is distinguished between (1) structural entry barriers (or structural advantages of incumbent firms as depicted in Figure 4[4]), those ascribed to the (2) strategic behaviour of firms in order to prevent rivals from entering the market, and (3) barriers resulting from governments giving

[4] Due to the scope of research addressed within this thesis, not all potential advantages of incumbent firms are discussed in detail but those are highlighted which are often discussed in more detail in the economic literature in regard to entry barriers or entry deterrence.

only one or few firms access to the market (Church & Ware, 2000:p.116). Furthermore, Viscusi, Harrington & Vernon (2005:p.165) propose several indicators which are relevant for the assessment of entry conditions including the number of potential competitors, the length and costs of entry, the quality of access to the same technologies and information as the incumbent, and the exit costs associated with leaving the industry.

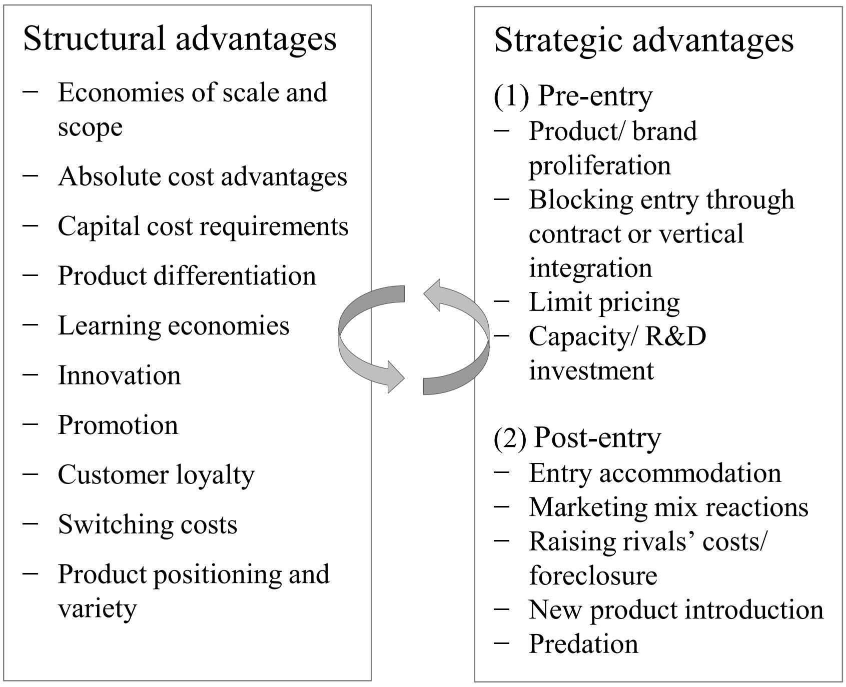

Figure 4: Overview of potential advantages for incumbent firms
Source: Hüschelrath (2009:p.225)

Structural barriers refer to economies of scale, sunk expenditures of the entrant, absolute cost advantage of the incumbent as well as product differentiation intended to create loyalty for an incumbent's brand. Especially in regard to economies of scale as an entry barrier opinions diverge widely. In the presence of these, the line of reasoning following Bain (1968) argues that a new entrant would incur losses because production will take place at a scale at which it is disadvantaged due to producing at higher average costs than the incumbent[5]. Stigler (1968) opposes that market entry is profitable if the competitor charges a price lower than

[5] In Figure 3 this means that an entrant would produce an output level less than *Q'* at which the price is higher than that of the incumbent at output level *Q'*. Charging the same price as the incumbent would lead to losses by the entrant and therefore make entry unprofitable (Church & Ware, 2000:p.119).

the incumbent and is thus able to redirect all market demand to its products. In this regard, according to the definition of entry barriers by Baumol, Panzar & Willig (1988:p.289), highlighted above, fixed costs do not represent a barrier to entry since they have to be borne by entrants and incumbents alike. The reason why an incumbent has an advantage over a new entrant might rather be that consumers are unwilling to switch to a new entrant's products due to the brand loyalty they have with the incumbent's products (Viscusi, Harrington & Vernon, 2005:p.171). This is not due to economies of scale but to the incumbent's attempt to differentiate its products from its competitors'. Product differentiation refers to a firm attaching unique characteristics to its products to prevent them from being perfect substitutes with other firms' products (Carlton & Perloff, 2005:p.79). Customers therefore incur switching costs when attempting to substitute products, thus being a potential barrier to entry for new entrants[6] (Tirole, 1989:p.277).

Absolute cost advantages of the incumbent may arise due to having access to cheaper production technologies or capital required for entry. However, Posner (1979) argues that capital requirements in itself are not a barrier to entry giving the example that the amount required by a new entrant to build the smallest efficient plant size is spread over the lifetime of the plant. These annual costs are also incurred by the incumbent assuming that it plans to replace their plants as well (p. 929). An entrant might be disadvantaged, though, since it bears a higher level of uncertainty or risk regarding its investment compared to the player already operating in the market (Viscusi, Harrington & Vernon, 2005:p.170). Based on this overview of structural entry barriers it can be seen that there is no coherent definition which serves as a strict guideline how to investigate the sustainability of monopolistic behaviour[7].

The second category of entry barriers, or potential entry deterrence, discussed in the economic literature can be accrued to the strategic behaviour of incumbents before or after the entry of new firms (Figure 4). Strategic behaviour of firms to keep their rivals from

[6] An example of product differentiation also exists in the form of network benefits for users as in the case of mobile messaging services WhatsApp or Facebook Messenger and its competitors. In January 2017, both WhatsApp and Facebook Messenger had 1 billion active monthly users compared to less than 900 million for mobile messaging services ranking in third and fourth place (Statista, 2017). For a user, having more friends using the same mobile messaging service therefore increases the attractiveness of this particular platform.

[7] This issue will be further discussed in Chapter 2.2, highlighting again some differences between the different schools of thought, Harvard and Chicago, by discussing the different perspectives and assumptions in regard to the assessment of market power.

entering the market or inducing them to exit it may take on different forms, some exemplary ones will be outlined in more detail. Respective strategies address the raising of rivals' costs or a reduction of their respective revenues. The latter strategy often becomes apparent in the form of predatory or limit pricing in an industry.

Predatory pricing means that a firms lowers its price once new competitors enter the market in order to make it unprofitable for these to participate in production efforts. In the case of new competitors entering the market, economic theory says that in equilibrium prices are falling due to each firm maximizing its profits given the other firm's price (Viscusi, Harrington & Vernon, 2005:p.307), an expected outcome of competition therefore is lower prices. However, in conducting predatory pricing incumbent firms have the intent to lower prices to a level so as to drive out new entrants and thus being able to earn future profits. Once these potential competitors have either left the market or restrained from entering in the first place, the incumbent raises its prices again, i.e. "… there is a temporary sacrifice of net revenues in the expectation of future gains" (Areeda & Turner, 1975:p.698). The threat by the incumbent to lower prices upon entry has to be perceived as credible by potential entrants otherwise this game would be repeated once the incumbent raises its prices in order to recoup its short-run losses (Church & Ware, 2000:p.646). This credibility is heightened if the incumbent has greater financial means compared to its potential competitors and if the outlook to gain future profits is substantial. In case competitors have similar financial means, the game may take place repeatedly, thus decreasing the incentives of the incumbent to engage in such pricing strategies. However, finding empirical evidence on predatory pricing has been the subject of diverse lawsuits, with economic theory evolving alongside and providing the theoretical assessment framework, recently in the form of game theoretic models, for the identification of such behaviour (Viscusi, Harrington & Vernon, 2005:p.321; Church & Ware, 2000:p.661; Motta, 2009:p.416).

One issue related to predatory pricing is the definition and identification of the appropriate cost against which prices are benchmarked. Areeda & Turner (1975) propose to apply average variable costs as cost measure, "… despite the possibility that average variable cost will differ from marginal cost, it is a useful surrogate for predatory pricing analysis" (p.718). However, this measure has been discussed as being incorrect and new approaches have been put forward such as average total cost or average incremental costs (Motta, 2009:p.448). In antitrust law, a comprehensive assessment is thus conducted on a case-by-case basis analysing the underlying market structure, evidence supporting pricing strategies and possible recoupment by firms as well as other relevant factors[8] (Viscusi, Harrington & Vernon, 2005:p.322). Predatory pricing is seen as an attempt of incumbent firms to induce competitors to exit the market.

The strategy of limit pricing, on the other hand, is intended to deter competitors from entering the market in the first place. In this strategy, the incumbent basically sets its output so as to reduce the residual demand for a potential entrant to a level at which the potential earnings are unprofitable for the competitor, and it thus decides not to enter the market (Viscusi, Harrington & Vernon, 2005:p.186; Church & Ware, 2000:p.478). Here, it is required that the entrant credibly believes that the incumbent will maintain this particular pre-entry output level and thus render it unprofitable for new competitors to enter the market, which is known as the Bain-Sylos postulate. Critics of this approach, however, argue that the entrant's decision to enter the market is independent of the incumbent's previous output level. This is reasoned by the assumption that all competitors engage in Cournot competition once in the market and thus simultaneously determine their respective output level.

If limit pricing is to work, pre-entry output has to have an effect on the post-entry equilibrium in the market, which can be justified by the presence of adjustment costs in production of the incumbent firm, for example[9]. This implies that an incumbent may not be able to adjust its output quickly from one production period to the next due to these costs and thus its pre-entry output may have a deterring effect on potential entrants. (Church & Ware, 2000:p.478; Viscusi, Harrington & Vernon, 2005:p.186) Discussing the derivation of these linkages and the impact on firms' behaviour, i.e. the use of limit pricing and potential benefits resulting

[8] Demsetz (1982) highlights different criteria which are often applied to determine the presence of predatory pricing and which can assist in identifying the difference between competitive and predatory prices: (1) firms' prospect of obtaining higher prices in the future by selling at a price below marginal cost today, (2) in case incumbent firms expand their output level upon the entry of new firms, this hints to the existence of predation, and market incumbents should be prohibited to do so for a predetermined period after entry, and (3) the motivation behind a firm's price decrease which is more of a legal criterion than an economic one.

[9] Adjustment costs are those costs that arise if a firm has to adjust its level of production from one period to another; these costs include, for example, inventories, the accumulation of capital, or lay-off payments for workers which are no longer required in case of a reduced production level (Carlton & Perloff, 2005:p.280).

for the incumbent, are not within the scope of this thesis. The intention here is to provide an overview of different mechanisms which can be employed by incumbent firms to deter entry or induce rivals to exit the market.

Further strategies employed by incumbent firms are outlined by Salop & Scheffman (1983) as attempts to raise rivals' costs, a strategy to deter entry in the first place. This may incur at only little cost for the incumbent since, "[for] example, a mandatory product standard may exclude rivals while being virtually costless to the predator" (p.267), other examples include increasing advertising expenditures, or the implementation of industry-wide wage contracts. Ibid. and Salop & Scheffman (1983) outline that this particular strategy might be more appealing to incumbent firms than reducing their rivals' revenues since it does not necessarily require the commitment of financial resources by the incumbent as is the case with predatory or limit pricing. A sufficient condition for the incumbent to profitably engage in this strategy therefore "[…] is that it increases the marginal cost of the (fringe) rival firms more than it increases the average costs of the dominant firm" (Church & Ware, 2000:p.628).

In addition to those strategies previously highlighted, vertical foreclosure can represent an attempt to exclude rivals from the market. A simple example of vertical integration between an upstream firm (U1) and a downstream firm (D1) where both the upstream and the downstream market are oligopolistic is depicted in Figure 5[10]. In the case of competition on the upstream market, prices are equal to marginal cost in equilibrium. Assuming vertical integration between U1 and D1, as depicted in the right-hand part of Figure 5, it is presumed that the now integrated firm supplies input at the same price as before the integration. Further supposing that the now integrated firm U1 does not provide inputs to downstream firm 2 (D2) anymore, the latter faces a monopoly on the upstream market and is thus likely to face a higher input price and raise its prices accordingly to compensate for these. This induces a higher price by the now integrated downstream firm 1 (D1) as well, enabling it to increase its profits, and thus representing an anticompetitive effect of the vertical integration. (Viscusi, Harrington & Vernon, 2005:p.251)

[10] In this setting it is assumed that the two upstream firms supply homogeneous goods to the downstream firms and engage in Bertrand competition, the downstream firms produce differentiated products using the same technology and can thus either use inputs from upstream firm 1 (U1) or upstream firm 2 (U2) (Church & Ware, 2000:p.632).

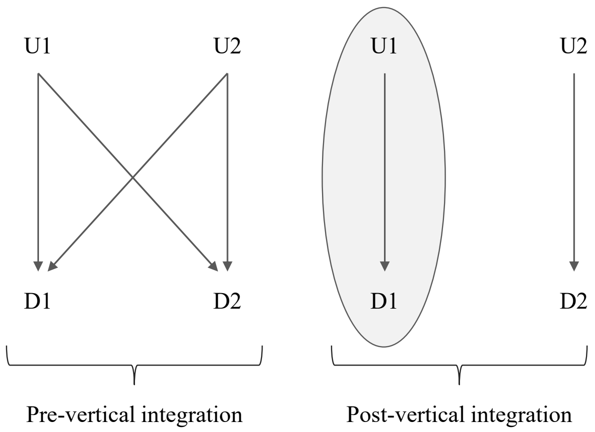

Figure 5: Vertical foreclosure

Source: Viscusi, Harrington & Vernon (2005:p.249)

However, the overall output of a vertical integration may be different in case the upstream firms' products are differentiated and therefore no perfect substitutes, or if these firms engage in Cournot instead of Bertrand competition. This may lead to the upstream firms not pricing at marginal cost, representing the case of double marginalization and vertical integration will reduce this effect and will be welfare-enhancing. Other aspects to be considered in the setting outlined in Figure 5 are the commitment of upstream firm 1 (U1) not to sell to downstream firm 2 (D2) and the case in which the remaining unintegrated firms (U2, D2) may also pursue vertical integration (Church & Ware, 2000:p.633).

In regard to vertical or horizontal foreclosure within an industry, Rey & Tirole (2007) define the concept of foreclosure and provide a good review as well as extension to the existing foreclosure literature. They establish a theoretical framework with which to assess the benefits and costs of market foreclosure. This occurs if the owner of a bottleneck, e.g. airport infrastructure, restricts access to its facilities for competitive firms on the downstream market, e.g. airlines, in order to increase its profits. Another option can be to engage in exclusive deals with specific downstream firms. Comanor & Frech (1985) investigate exclusive dealing and the resulting anticompetitive effects in an industry. This model assumes that the incumbent on the upstream market may engage in some form of exclusive dealing in order to deter the entry of a new manufacturer. The analysis of low-pricing and high-pricing strategies shows that the incumbent profits regardless of the selected strategy. The decision of the downstream player depends on the consumers brand preference for the incumbent's product. If this preference is strong, the downstream producer engages in exclusive dealing only if the incumbent opts for the high-price strategy. However, the low-price strategy is more likely to occur since more consumers will buy the incumbent's product. In this case, no exclusive dealing occurs. Ibid. highlight that the credible threat of the incumbent to engage in vertical integration may already deter an entrant's strategy.

Salinger (1988) analyses the effects of a vertical merger in the case of oligopolistic market structures on both the upstream and downstream market. The results imply that vertical mergers have both positive and negative welfare effects by removing the double marginalization effect and increasing the price of the intermediate good, respectively. Diverging from this is the model by Ordover, Saloner & Salop (1990). Here, successive duopolies with two firms in both the upstream and the downstream market are assumed and there are no market imperfections such as double marginalization. The model focuses on whether vertical foreclosure can be applied by a firm in order to increase its market share towards its rival. Ibid. analyse how measures such as counterstrategies of the non-integrated firms or a bidding process for the merger influence the incentives for vertical foreclosure. In the analytical model, the firms engage in Bertrand competition and they offer homogeneous input on the upstream market, have differentiated products downstream and equal market shares on their respective market. The authors find that for vertical foreclosure to be successful the gain acquired by the unintegrated upstream firm has to be larger than the loss incurred by the unintegrated downstream firm. Furthermore, social welfare decreases since there are no efficiency gains to be accrued by the merger due to the lack of previous double marginalization.

A similar analytical approach is taken by Chen (2001). Here, prices are also considered as strategic complements and hence competitors on the downstream market engage in Bertrand competition. Ibid. finds that there is a collusive effect and an efficiency effect going along with vertical integration. The former denotes the case of market foreclosure and the latter the gain in social welfare to be achieved by vertical integration. The analysis shows that the collusive effect prevails if the downstream firms are close substitutes.

Another area of potential entry barriers for new competitors are restrictions imposed by government due to various reasons. One is the granting of intellectual property rights, in the form of patents, or copyrights which are intended to protect a firm's innovations, and enable it to gain a temporary monopoly and thus to reap the benefits from its investment in research and development (R&D) activities (Tirole, 1989:p.390; Carlton & Perloff, 2005:p.102; Motta, 2009:p.65). Further, Demsetz (1982) outlines that government intervention can aim at ensuring the benefits of productive efficiency of a natural monopoly by restricting the production to a single firm. This firm then often becomes subject to economic regulation in order to minimize the allocative inefficiency associated with a monopolisation of the market (see Chapter 2.1.1). Another barrier to enter a particular market can be the requirement of a licence which is granted by a public authority only and which restricts the market to licence holders (ibid.).

It is possible that, in the theory of contestability, the mere threat of potential entry by a competitor restrains the existing firm from abusing its market power (Baumol, Panzar & Willig, 1988). Baumol (1982) states that for markets to be perfectly contestable there has to be "… no cost discrimination against entrants [and] that any firm … in the process of departure can recoup any costs incurred in the entry process" (p. 4). Based on this, for the threat of entry to be credible several conditions have be fulfilled: (1) All producers, either being new to the market or existing ones, have access to the same production technology, including input prices and information about demand, (2) the absence of sunk costs, meaning that a new entrant can fully recover its costs upon exit[11], and (3) the time it takes a firm to start production in the market (entry lag) is shorter than the time it takes the incumbent to adjust its prices (Viscusi, Harrington & Vernon, 2005:p.172; Church & Ware, 2000:p.507; Tirole, 1989:p.308; Motta, 2009:p.73). Resulting from these conditions is a hit-and-run entry by potential competitors which enter in case they detect an opportunity to earn positive profits. Therefore, the welfare implications of a perfectly contestable market are that economic profits in a contestable market have to be zero, there are no inefficiencies in the long-run equilibrium, and prices must at least equal marginal costs (Baumol, 1982). In this regard, ibid. emphasises that the contestable market theory objects that an industry, fulfilling

[11] Sunk costs are described by Baumol, Panzar and Willig (1988) in the way that "[the] need to sink money into a new enterprise, whether into physical capital, advertising, or anything else, imposes a difference between the incremental cost and the incremental risk that are faced by an entrant and an incumbent" (p. 290). Ibid. therefore state that sunk costs can be a barrier to entry.

the above conditions, with no entry and high concentration is prone to abuse its market power and that antitrust policy thus has to consider the implications of potential competition more carefully.

Another conclusion drawn from the theory of contestable markets is the divergence from the theory that industry structure is determined exogenously in stating that it is determined simultaneously with prices and outputs (ibid.). In regard to the promotion of the theory of contestable markets, a controversial debate as to the underlying assumptions and resulting implications for market structure and performance arose. Weitzman (1983) states that "… you cannot have a range of decreasing average cost without sunk costs" (p. 486), but that in the absence of sunk costs the technology is rather characterised by constant returns to scale (Church & Ware, 2000:p.509). Regarding the conditions that have to be fulfilled for a market to be (perfectly) contestable, Schwartz and Reynolds (1983) argue that the results change significantly in case these conditions are slightly altered or relaxed[12]. Despite the criticism it received, contestability theory has contributed to the development of antitrust policy in regard to the assessment of market power as it "… shifts attention away from structural measures of market power … and from the nature of oligopoly interactions towards variables that affect the ease of entry and exit" (Schwartz, 1986:p.37)[13].

2.2 Approaches towards the assessment of market power

Building on the theoretical background on natural monopolies and potential entry barriers in Chapter 2.1, Chapter 2.2 focuses on the discussion of different approaches that have been applied to assess the degree of market power a firm possesses, with a particular discussion on current applications in competition policy both in the European Union and the United States (Chapter 2.2.1). Sine potential antitrust cases are often investigated by defining the

[12] For example, in case a potential competitor cannot enter instantaneously, thus facing an entry lag, and at the same time the incumbent faces no price-adjustment lag, the entrant will base its entry on the oligopolistic game the firms engage in after entry. The incumbent will therefore set its prices at monopoly level before entry and market power is hence not constrained by contestability (Schwartz & Reynolds, 1983). Baumol, Panzar & Willig (1983) provide a detailed reply to the issues raised in relation to contestability theory. These will not be elaborated in further detail here, though, since this particular theory is not in the focus of this thesis.

[13] Taking the airline industry as an example, which is often considered as being (im)perfectly contestable, both Borenstein (1992) and Peteraf (1995) outline that the application of contestability theory in the airline industry may not be robust, suggesting that there are sunk costs apparent in this industry.

relevant market for consideration and subsequently assessing the degree of market power as well as entry barriers, respective approaches are discussed in more detail in Chapter 2.2.2.

2.2.1 Developments regarding the assessment of market power

Following the line of argument in Chapter 2.1 on the existence of a natural monopoly and the outline of the controversial discussion on structural as well as strategic entry barriers, the different approaches determining the degree of market power a firm faces have been equally debated in the past. Within this chapter the focus is placed on two different approaches taken to determine the degree of market power (Figure 6), the direct and indirect assessment. Discussing the development as well as the economic reasoning of these different approaches yields a more detailed insight into their respective feasibility for the economic analysis of antitrust cases.

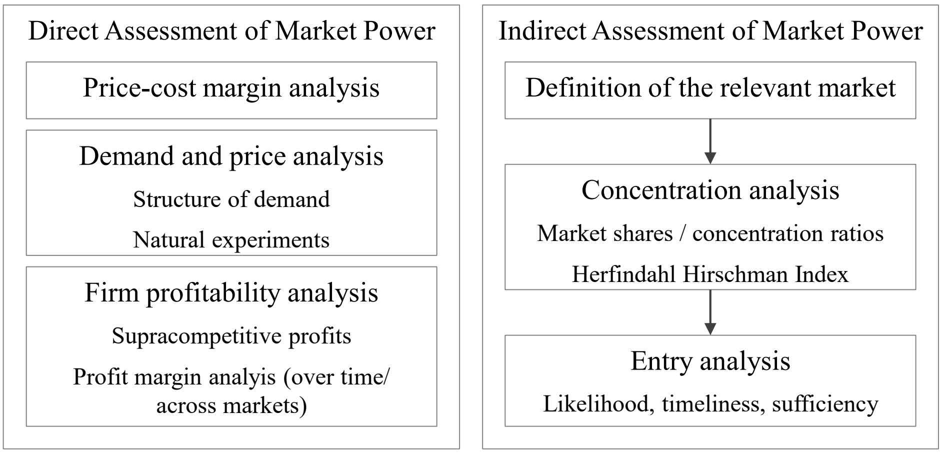

Figure 6: Assessment of market power
Source: Hüschelrath (2009:p.172)

The indirect assessment of market power is based on the Structure-Conduct-Performance (SCP) paradigm which was first introduced in the 1930s and 1940s in the field of industrial organisation as a means to analyse and explain industry performance. It is an approach which assesses the market power of a firm indirectly since "… market power is inferred from the presence of high concentration figures and significant entry barriers" (Hüschelrath, 2009:p.172). Two of the main early contributors to the SCP approach have been Mason (1937, 1939) and Bain (1951, 1954, 1956) who are linked to the so called Harvard School of thought. In the SCP approach, a causal relationship between the different parameters characterising an industry – structure, conduct, and performance – is assumed (see Figure 7). In order to understand an industry's performance, i.e. its efficiency level and degree of technical progress, it is essential to analyse the conduct of the market participants in terms of decisions concerning pricing, advertising, or investment in research and development (R&D) (Church & Ware, 2000:p.426). Since measuring the conduct of firms in an industry proved to be difficult, traditional approaches in this field focused on determining market structure and inferring to market performance, assuming a linear and stable relationship between these parameters, i.e. "… to explain, through an examination of the structure of markets and the organisation of firms, differences in competitive practices including price, production, and investment policies" (Mason, 1939:p.66).

In this theory of structuralism, market structure is determined by, inter alia, analysing the number of buyers and sellers in the market, i.e. the respective level of concentration, since "[moderate] concentration should tend to give rise to quasi-competitive market behaviour … whereas high concentration should provide an environment conducive to effective collusion or its equivalent" (Bain, 1950:p.44).

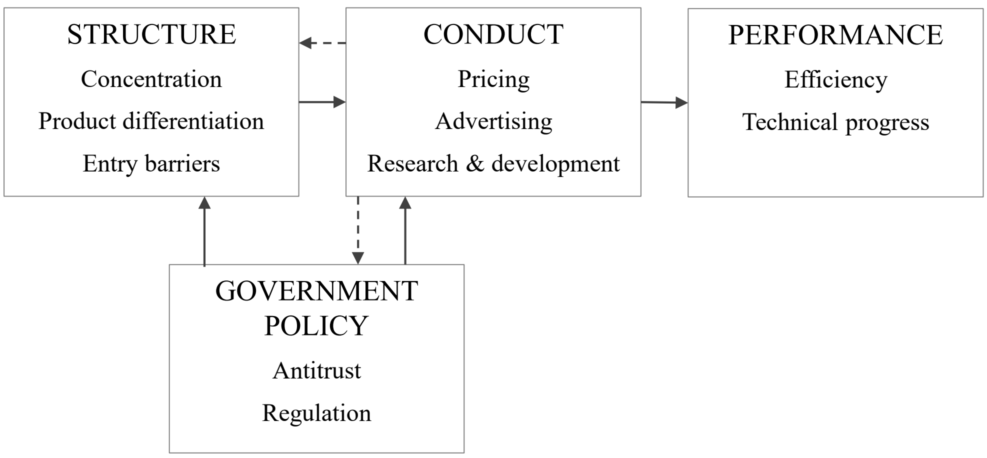

Figure 7: The Structure-Conduct-Performance paradigm in Industrial Organisation
Source: Viscusi, Harrington & Vernon (2005:p.63)

As stated by Bain (1950) and discussed in Chapter 2.1.2, market structure includes multi dimensions and hence, in addition to firm concentration, entry conditions are an important criterion to analyse the competitiveness of a market as is the degree of product differentiation firms engage in. One argument of this approach states that "… both high concentration and high barriers to entry were necessary to produce excess profits in long-run equilibrium" (Schmalensee, 1989:p.969), which is why the causal effect of these on firms' profitability levels, as a measure for the performance in an industry, have been tested in various studies. As highlighted before, economic profits are assumed to reflect the degree of market power of a firm. Measures of market performance hence include the rate of return, the price-cost margin, or Tobin's q, and usually accounting data has been used as a proxy to calculate the respective values. Therefore, in the SCP approach measures of profitability are applied to reflect this relationship. However, one of the main drawbacks here are the potential measurement errors and data availability inherent in the calculation of rates of return, price-cost margins and Tobin's q (see Table 1).

Table 1: Profitability measures

Profitability measure	Definition	Drawbacks[14]
Rates of return	Measuring how much is earned per one dollar investment, used as a proxy for economic profits	Clear distinction between economic and accounting profits; measurement errors of e.g. capital cost
Price-cost margin	Lerner index defines the difference between price and marginal cost as a fraction of price	Unavailability of marginal cost data, average cost as a proxy might cause bias
Tobin's q	Ratio of the market value of the firm to its assets' replacement cost	Using a proxy for economic profit may lead to biased results

Source: own depiction based on Carlton & Perloff (2005); Church & Ware (2000)

Along these lines, Bain (1951) conducted an empirical analysis to test the relationship between market structure and performance using data for the American manufacturing industry, i.e. conducting an inter-industry study, between 1936 and 1940, with the hypothesis "… that the average profit rate of firms in oligopolistic industries of a high concentration will tend to be significantly larger than that of firms in less concentrated oligopolies or in industries of atomistic structure" (p. 294). One aspect ibid. highlights as a crucial first step in this approach is the definition of the relevant market which is to be analysed. As outlined in Figure 6, this represents the initial step in the indirect approach to assess the market power

[14] See also Schmalensee (1989) for potential measurement errors associated with determining profitability and how these can be addressed.

of firms in an industry[15]. The results suggest a positive correlation between profit rates and industry concentration and a critical concentration ratio of 70 per cent (using the 8-firm concentration ratio) above which the correlation was more pronounced.

Comanor & Wilson (1967) advance the previous analysis by empirically testing for the effect of advertising, here applied as a proxy for the degree of product differentiation in an industry, on profit rates, also applying an inter-industry data set. In the model, profit rates observed in the considered industries serve as dependent variable, and seller concentration, the rate of growth demand, economies of scale in production in relation to the size of the market, absolute capital requirements for a plant, and advertising represent proxies for the different structural parameters of a market and are hence included as independent variables. Ibid. finds that "[industries] with high advertising outlays earn, on average, at a profit rate which exceeds that of other industries by nearly four percentage points" (p. 437)[16]. Leonard Weiss has also been a contributor to this field in following the structural approach to detect market power and potential abuse in an industry. Weiss (1979), inter alia, focused on analysing the relationship between concentration and price instead of profits and empirical evidence from different industry studies yields a positive effect of concentration on prices. This relation has been confirmed by various other studies, as outlined in Schmalensee (1989), and appeared to be statistically more robust than the relation between concentration and profit margins[17]. Following the assumptions of the SCP approach, antitrust analysis has thus been deducing an industry's or firm's performance from the level of concentration, which is often known as the per se rule, i.e. assuming that high concentration will likely end in anticompetitive behaviour (Piraino, 2007).

However, criticism in regard to these empirical studies highlighted the problems of causality and potential endogeneity in the structural models as well as the use of inter-industry data to derive implications for the treatment of mergers in an industry or monopolised markets. In

[15] The specific elements and respective tests of this particular approach will be further discussed in Chapter 2.2.2.

[16] Ibid. also test for the impact of concentration, scale economies and capital requirements; due to high collinearity between these factors the joint impact of these is considered and the results show a significant impact on the profit rates across industries.

[17] Ibid. outlines a large range of studies which have been investigating the relation between concentration and profitability and comes to the conclusion, after careful examination of the different results, that the relation between concentration and profits is weak statistically.

regard to causality, the relationship between market structure, conduct and performance is not necessarily unidirectional, but conduct can have an influence on the market structure, as illustrated by the dashed arrow in Figure 7. Examples of this reverse relationship include the investment in research and development of a firm to gain a competitive advantage over other firms in the market, further fostered by firm protection in the form of intellectual property rights by the government which might leave a firm with a larger market share due to its exclusive rights for a particular good (Viscusi, Harrington & Vernon, 2005:p.62). These causal loops apparent in the SCP model may lead to the problem of endogeneity in estimating structural models, i.e. determining independent variables which are exogenous in the long-run proves to be a difficult task (Schmalensee, 1989).

Furthermore, since the focus of early SCP studies has been on inter-industry studies, symmetry in explanatory variables across industries was assumed. However, since the inherent structure of different industries is determined by a large variety of factors, including historic developments for example, the structure is rather asymmetric and therefore conclusions drawn from cross-industry studies can lead to biased results (Carlton & Perloff, 2005:p.265; Church & Ware, 2000:p.439). Schmalensee (1989) points out that cross-industry studies aiming at analysing market performance and the factors shaping it can rather contribute to the field of industrial organisation by providing valuable descriptive analysis on different industries. Further biases arising from measurement errors are due to the inappropriate definition of the relevant antitrust market. The definition has to account for product heterogeneity and potential close substitutes, for example (Church & Ware, 2000:p.604). Deducing potential market power or competitive constraints applying a too wide or too narrow market definition can lead to false conclusions and hence misguided policy incentives. This particular aspect will be elaborated in more detail in Chapter 2.2.2.

The SCP approach hence became widely criticised, for one due to its rigidity of assumptions and the resulting implications for antitrust cases, i.e. postulating that a highly concentrated market results in anticompetitive behaviour. Representatives of the Chicago School argued that "… deconcentration may have the total effect of promoting inefficiency even though it also may reduce some monopoly-caused inefficiencies" (Demsetz, 1973:p.4) since a high level of concentration in an industry may imply that large firms are more efficient. The empirical evidence in ibid. supports the assumption that high concentration in an industry may result from superior efficiency of the large firm. Breaking up this industry into smaller firms may thus result in higher costs and ultimately in losses in regard to consumer welfare. This approach led to antitrust policy being more focused on the implications for consumer welfare as a whole, as postulated by Bork (1966) "… to distinguish between agreements or activities that increase wealth through efficiency and those that decrease it through restriction of output" (p. 7). Representatives of this distinct approach focused on price theory to analyse and interpret market structure and firm behaviour and accordingly criticising the early postulations of the Harvard School as not following economic theory, especially with regard to rational profit maximisation (Posner, 1979).

The diverging assumptions of the two schools of thought, Harvard and Chicago, especially in the 1960s, thus also became apparent in regard to the entry barriers new competitors face in an industry, as outlined in Chapter 2.1.2. In this regard, the notion of advertising as a barrier to entry has been opposed since it is rather considered as reduction of search costs for consumers than product differentiation which creates a lock-in effect with customers (ibid.). In the 1960s and 1970s, these assumptions, pursued by Chicago School economists, led to the proposal that only very specific cases required antitrust investigation, namely "… explicit price fixing and larger horizontal mergers (mergers to monopoly)" (Posner, 1979:p.933), which became known as the rule of reason (Piraino, 2007; Baker, 1999)[18].

As a response to the criticism regarding the SCP approach – deriving generalised statements about market structure and implications for performance from inter-industry studies, potential measurement errors arising from the use of accounting data, and the assumption that performance can be directly inferred from structure – a new and enhanced empirical approach of determining market power was developed (Bresnahan, 1989). This "new empirical industrial organization (NEIO)" or direct assessment (Figure 6) focuses on the estimation of market power in a single industry instead of cross-sectional analyses and relies on structural models to directly determine firms' conduct in a particular industry (Church & Ware, 2000:p.440). Basically, this approach models the perceived outcome in an industry,

[18] However, Stiglitz (2017) states that the Chicago School approach to competition policy, i.e. restricting antitrust intervention only to few cases, has not been followed through with in European Union competition law.

which is assumed to exert market power, by applying theoretical models from oligopoly theory and by using econometric techniques to test these formal theories (Carlton & Perloff, 2005:p.275; Motta, 2009:p.126). By this, the estimation of conduct parameters reveals whether firms' reactions to changes in price comply with competitive, competing oligopoly, or collusive models (Davis & Garcés, 2010:p.343)[19].

One methodology applied in this field is the estimation of the residual demand elasticity, which constitutes an empirical test to define the geographical scope of an antitrust market or the extent of market power of a firm (Scheffman & Spiller, 1987; Landes & Posner, 1981). Whereas ibid. concentrate on a homogenous product market, Baker and Bresnahan (1988) analyse an industry with differentiated products. The residual demand is the function which denotes a firm's relationship between price and quantity, considering the supply decisions of the other firms in the market. This approach relies on the model of the dominant firm and its fringe firms. The former is thus assumed to have market power in case the fringe firms have a relatively inelastic supply (Davis & Garcés, 2010:p.222). Pakes (2017) provides an overview on both static and dynamic models currently applied in competition analysis, stating that in selecting appropriate methodologies it has to be considered that available information can be used and that these approaches comply with the resources available for policy makers.

However, the differences apparent between the two schools of economic thought, Harvard and Chicago, and their perception of antitrust analysis have been disappearing over time, or as Posner (1979) formulates it, "… it is no longer worth talking about different schools of academic antitrust analysis" (p. 925). Weiss (1979), for example, after investigating the relationship between concentration and capacity decisions, alleviates his view that mergers and concentration per se should be considered illegal but instead states that there are potential gains to be incurred from large firms operating in an industry. As a result "… many of the horizontal merger cases that reached the Supreme Court in the 1960's were decided too strictly" (Weiss, 1979:p.1119). Views have also been converging in regard to the treatment of vertical integration between firms. Initially considered by Harvard economists as harming

[19] Without the availability of a structural model, non-parametric approaches have also been applied of which examples can be found in Ashenfelter and Sullivan (1987) and Panzar and Rosse (1987).

the positive effects of competition and therefore in need of antitrust intervention, work in the 1970s and onwards has revised this proposition towards one that highlights the benefits of such mergers (Posner, 1979). However, ibid. also emphasises that at that time discrepancies remained in regard to the meaning and treatment of concentration within an industry, though representatives of both schools moved away from their positions of either per se illegality or per se legality of a concentrated industry and towards a more detailed assessment of specific cases.

The overall goal of antitrust policy, especially in regard to mergers, has become consumer welfare, i.e. guaranteeing product quality and variety as well as ensuring that firms do not set too high prices or reduce output, and thus to "… protect competition, not competitors" (Hovenkamp & Shapiro, 2017:p.10). Along the advancement of economic theory, competition policy in the U.S. thus shifted from a strict derivation of market performance from market structure to an approach in which potential anticompetitive behaviour is assumed and firms are put in the position to refute this assumption, i.e. produce evidence that e.g. a horizontal merger is welfare enhancing (ibid.). In detecting the degree of concentration in an industry and thus potential anticompetitive behaviour of firms, the role of market shares and market concentration in antitrust analysis has changed over time, but these parameters are still applied as a supplement in the analysis of, inter alia, horizontal mergers or significant market power of a firm (U.S. Department of Justice and Federal Trade Commission, 2010; European Commission, 2002)[20]:

> "Nonetheless, economic theory and subsequent empirical evidence do not suggest ignoring market shares and concentration in merger analysis. First, various theories of oligopoly conduct - both static and dynamic models of firm interaction - are consistent with the view that competition with fewer significant firms on average is associated with higher prices. In general, the smaller the number of firms, the more likely the firms will be able to reach a mutually satisfactory outcome at a higher-than-competitive price. Unilateral price increases or output restraints also are more likely to be profitable when the merged firms have higher market shares, ceteris paribus. Accordingly, a horizontal merger reducing the number of rivals from four to

[20] The U.S. Department of Justice and Federal Trade Commission (2010) states that values of the Herfindahl Hirschman Index, as a measure of concentration, between 0.15 and 0.25 depict an industry which is moderately concentrated and that values above 0.25 represent a highly concentrated industry. The European Commission (2004) considers post-merger cases and defines HHI values below 0.1 and between 0.1 and 0.2 to be rather non-critical; furthermore assuming a delta below 0.025 compared to pre-merger HHI values. The European Commission highlights that the nature of the merging firms has to be considered, e.g. if the firms are both important innovators in the industry. Usually, other factors apart from the HHI are included and decisions regarding mergers are made on a case by case basis.

> three, or three to two, would be more likely to raise competitive concerns than one reducing the number from ten to nine, ceteris paribus".
>
> (Salop, 2015:p.276)

Stiglitz (2017) makes the case for the broadening of current competition policy, i.e. moving away from the focus on only specific cases as under the rule of reason, and not merely relying on the "natural forces of competition" (p. 12). In this regard, ibid. states that imperfections in information or even small deviations from the situation of a perfectly competitive market can cause abusive behaviour of the dominant firm which should be taken into account by current competition policy. Looking at developments in the U.S., Hovenkamp and Shapiro (2017) and Shapiro (2017) also support stronger antitrust enforcement policies to be put in place. Competition policy in the European Union pursues an indirect approach of market assessment as illustrated in Figure 6, essentially following the different steps of relevant market definition, concentration and entry analysis. It thus provides guidelines according to which national regulatory authorities are recommended to assess cases of assumed market power to "… ensure that they can fully justify any form of early, ex-ante intervention in an emerging market" (European Commission, 2002:p.10). Table 2 highlights this approach, respective guidelines and criteria which are to be considered in the assessment of significant market power.

According to these guidelines it can be tested whether a firm is experiencing significant market power. The definition of the relevant market for antitrust analysis, i.e. the products and services which are included in this market as well as the geographical scope of it, is the crucial first step within the proposed guidelines. One approach often applied is the hypothetical monopoly test which assesses the effects of a "[…] small but significant, lasting increase of a product or service, assuming that the prices of all other products or services remain constant", on other firms' or consumers' behaviour (European Commission, 2002).

Table 2: Approach of the European Commission in assessing market power

Steps	Approach and criteria
(1) Definition of the relevant market	– Description of products/ services making up the market; assessment of geographical scope – Consideration of competitive constraints: (a) demand side substitution, (b) supply side substitution, (c) potential competition – Potential application of hypothetical monopoly test ("only with regard to products or services, the price of which is freely determined and not subject to regulation" – p. 11) – Relevant market clustered by products/ services serving the same end use by consumers – Definition of geographic market: analysis of consumer preferences and geographic purchase behaviour
(2) Assessing significant market power (dominance)	– Significant market power exists if "[a firm] enjoys a position equivalent to dominance, that is to say a position of economic strength affording it the power to behave to an appreciable extent independently of competitors, customers and ultimately consumers" (p. 15) – A dominant position does not equal anticompetitive behaviour – Ability to increase price/ restrict output without incurring losses – Initial assessment of market shares (considering volume and value of sales)
(3) Other criteria to be considered in the analysis of potential market power (potential entry barriers)	– Overall size of considered firm – Control of infrastructure not easily duplicated – Absence of or low countervailing power – Product/service diversification – Economies of scale/scope – Vertical integration – Absence of potential competition – Barriers of expansion

Source: Based on European Commission (2002)

Having defined the relevant market, within the second step, market shares are applied to assess whether a firm has a dominant position in the market. Since this does not necessarily mean that a firm is abusing its market power by restricting output or increasing price, the third step proposed within the guidelines focuses on the assessment of potential entry barriers, which have been discussed already in Chapter 2.1.2. Those aspects related to the definition of the relevant market and market concentration are discussed in more detail in the following Chapter 2.2.2 since the economic theory and the associated guidelines proposed by the European Commission (2002) and the U.S. Department of Justice and Federal Trade

Commission (2010) will be used as the baseline for the assessment of market power of European hub airports.

2.2.2 Definition of the relevant market and concentration analysis

The definition of the relevant market in competition or antitrust analysis is the crucial and essential first step in defining the boundaries within which a firm's market power is to be assessed. In this context, antitrust studies refer to the concept of an antitrust market as opposed to an economic market (Church & Ware, 2000:p.601). Both definitions comprise a product and a geographic dimension. The economic market determines the market place for particular products, the respective buyers and sellers and the interaction between these that determine price setting behaviour. Products in the economic market are considered close substitutes if there are high cross-price elasticities of demand and supply. Demand side substitutability means that customers can either switch to a substitute product if the price of other options increases or they can buy their products from a different location. Supply side substitutability refers to the producer being able to switch to the production of other products, i.e. those which can be rather easily produced with the available input factors (Davis & Garcés, 2010:p.163). The antitrust market in comparison focuses on a particular firm and whether this firm exerts market power in its particular market, i.e. "[in] antitrust analysis, a market is collection of products and geographic locations, delineated as part of an inquiry aimed at making inferences about market power and anticompetitive effects" (Baker, 2007:p.130). This market thus comprises the relevant products of a firm and the geographic scale or market containing potential competitors.

Table 3: Approaches to defining relevant (antitrust) markets

Approach	Definition	Required data
Qualitative assessment	Outline of product characteristics and identification of relevant demand and supply side substitutes	Product characteristics
Price level differences and price correlations	Observation of movement of prices of selected products, i.e. perfect substitutes only differ in regard to transportation costs	Cost and demand data of included products
Natural experiments	Analysis of reaction of one product's price to effect of exogenous shock on price of another good	Exogenous shock, price information
Estimation of substitution effect	Consumer choice modelling in regard to different available alternatives	Consumer-level data on available choices (revealed vs. stated preferences data)
Shipment data	Analysis of level of imports vs. exports in a market	Import and export data, firm purchasing data
Critical loss analysis (CLA)	Analysis of the loss in sales a firms incurs after a price increase,	Marginal cost data, product own-price elasticity of demand
Hypothetical monopoly test (pricing constraints)	Analysing the profitability of a price increase of the considered firm: − SSNIP test − FERM	Marginal cost data, product own-price elasticity of demand

Source: own depiction, based on Davis & Garcés (2010)

There are different approaches which are used to define the relevant antitrust market including price level differences and price correlations, natural experiments (e.g. exogenous shocks), shipment data (transportation costs) to determine the geographic market, or the measurement of pricing constraints (see Table 3). Baker (2007) discusses some of these approaches and points out potential deficiencies which may lead to biased results, especially considering the use of price correlations, shipment data, and critical loss analysis. Using the correlation between prices across different firms' products to define a relevant market can be misleading, since this can be induced by a shift in demand, thus not necessarily implying that products are (perfect) substitutes. Ibid. also criticises that the use of shipment data may lead to a biased definition of the relevant market, since it applies the flow rates of imports and exports at current prices. Considering that a price increase may induce a distant firm to offer its products on the defined market is thus not taken into account.

Another way to analyse the effects of a price increase and thus determine the relevant antitrust market is the critical loss analysis (CLA) in which the question "how much do sales need to drop in order to render an x [per cent] price increase unprofitable" (Davis & Garcés, 2010:p.211) defines the relevant market by giving an indication to the pricing constraints imposed by other firms. In this particular application case, Baker (2007) points out that inferring demand elasticities from price-cost margins is not a reliable approach, since the amount of critical loss incurred from a price increase depends on the height of price-cost margins before a merger. In case a firm already faces a high mark-up above marginal cost this results in a smaller critical loss. Relying on this approach therefore does not provide a reliable indicator to the expected level of buyer substitution.

Considering this criticism, a common methodology often recommended in antitrust guidelines in the European Union and the United States is the hypothetical monopoly test (European Commission, 2002; U.S. Department of Justice and Federal Trade Commission, 2010). Here, the relevant antitrust market is defined by assessing the effect of a small price increase on buyers' substitution behaviour, accordingly a firm would not find it profitable to increase the price for its products if buyers move to the products from other suppliers or locations. In this case the relevant market is too small and a broader definition has to be selected (Baker, 2007). If the prices are constrained and cannot be increased profitably, further products representing close substitutes have to be included in the market until the firm under investigation can increase its prices without losing customers. The first step in regard to the hypothetical monopoly test is the definition of the narrowest product or geographic market, i.e. the smallest set of products which allows the hypothetical monopolist to raise prices. Following that, it is investigated whether the firm can increase the price to a profitable level.

One measure for this is the small but significant non-transitory increase in price (SSNIP) test, which represents a price-based implementation of the hypothetical monopoly test (Church & Ware, 2000:p.602; Motta, 2009:p.102; Davis & Garcés, 2010:p.201). The SSNIP test, being mostly applied in antitrust analysis, has the underlying assumption that a price increase above the current level by the hypothetical monopolist, e.g. a five to ten per cent increase within a year, within the predefined market leads to either a substitution of demand by consumers to other firms' products or to increasing profits for the firm under consideration. If the firm is able to raise prices without incurring losses, this market then constitutes the antitrust market. However, this specific approach is not free of criticism either. Baker (2007) points out that difficulties exist in defining the starting point of the market definition exercise, i.e. which products and locations to include, that the rate of the price increase is only an "arbitrary benchmark" (p. 146), and it has to be considered that a market may not only consist of one set of products and locations. Another aspect that potentially constrains the reliability of this test is the assumption of current prices when investigating a price increase and resulting profitability for the firm ("cellophane fallacy", Motta, 2009:p.105). If the firm is already a monopolist, current prices do not reflect the competitive level but already exceed this. A price increase might therefore not yield any additional profits for the firm, and the SSNIP test implies a market definition which is too large[21].

Other approaches investigating the potential pricing constraint a firm faces are the full equilibrium relevant market test (FERM), or the residual demand function approach, which has shortly been addressed in Chapter 2.2.1 (see Table 3). The FERM test addresses some of the criticism that has been raised in regard to the SSNIP test by also allowing firms which are outside the relevant market to respond to price increases by the hypothetical monopolist (Ivaldi & Lorinz, 2005). By this, the FERM test also includes supply side substitution in its assessment of the relevant market. Ibid. also highlight another difference between the SSNIP and the FERM tests, namely that the former compares "the observed industry equilibrium to a hypothetical out-of-equilibrium situation [whereas] the FERM test compares the same observed equilibrium to another, hypothetical equilibrium" (p. 3). Identifying the relevant market is essential for the next steps of assessing a firm's level of market power. Using wrong or misleading assumptions in the market definition exercise may lead to biased results with respect to the consecutive steps.

Having defined the relevant market, antitrust analysis focuses on determining the degree of a firm's market power. In competition policy, as outlined in Chapter 2.2.1, the market

[21] In the case of airports, for example, a high share of these is subject to economic regulation such as rate-of-return or price-cap regulation. In this case, economic regulation has an influence on an airport's price setting behaviour. The use of airport charges as an indicator to assess the level of competition can hence lead to biased results.

structure is analysed using market shares or indices to measure industry concentration. Since market shares are more easily obtainable than a firm's cost function or the demand for certain products, these often provide a first good complementary step in the analysis of antitrust markets, as does the analysis of industry concentration. To assess the level of industry concentration, concentration ratios (e.g. four-firm or n-firm concentration indices), or the Herfindahl Hirschman Index (HHI) are applied and as outlined in the previous chapter, volume or value of sales provide appropriate measures to be applied here (Church & Ware, 2000:p.429; Davis & Garcés, 2010:p.287; Motta, 2009:p.124; Carlton & Perloff, 2005:p.225; Tirole, 1989:p.221).

Since the Herfindahl Hirschman Index will be used in the analyses in Chapters 1 and 1, the properties, application as well as implications of this indicator are discussed in more detail. First, it measures industry concentration by summing up all firms' squared market shares and hence a single aggregated value is obtained:

$$HHI = \sum_{i=1}^{N} s_i^2 \tag{3}$$

The market share of firm *i (i = 1,..., N)* is denoted by *s*, with $s_i = Q_i/Q$ and Q representing output, and *N* is the number of firms in the considered market (Church & Ware, 2000:p.429). The HHI can take values between 0 and 1 with the latter representing the monopoly case. An increasing HHI value therefore is an indicator for increasing industry concentration. Furthermore, if the *N* firms in the market are of the same size, then HHI = 1/*N*. This shows that the HHI can depend both on the distribution of supply across firms in the market as well as the absolute number of firms in the market:

$$HHI = \frac{1}{N} + N\sigma^2 \tag{4}$$

with σ^2 representing the variance of firm size in the market (Bikker & Haaf, 2002); the larger the variance the higher the HHI will be, e.g. implying that there might be a dominant firm in the market. Considering the number of firms in the market, thus correctly defining the relevant market, and firms' size are therefore important criteria when assessing the HHI results.

Another important property of the Herfindahl Hirschman Index is the direct link to the mark-up of price over marginal cost, i.e. the Lerner index which "… measures the proportional deviation of price at the firm's profit-maximising output from the firm's marginal cost of that output" (Landes & Posner, 1981:p.239). The link between the Lerner index and the Herfindahl Hirschman Index is established here by following Cowling & Waterson (1976) as well as Church & Ware (2000:p.36). For the derivation of the Lerner index, an oligopolistic Cournot market with *N* firms (*i*) is assumed (*i = 1,…N*) in which each firm maximises its profits depending on the output decisions of the rival firms. Profits of firm *i* (π_i) are hence defined as revenue minus cost:

$$\pi_i = P(Q)Q_i - C_i(Q_i) \tag{5}$$

With P representing the price, Q_i is the output of the individual firm *i* and $C_i(Q_i)$ its cost function. From the first order condition of the revenue function, the marginal revenue (*MR*) is derived, yielding:

$$MR(Q_i) = P(Q) + \frac{dP(Q_i)}{dQ_i} Q_i \tag{6}$$

The profit-maximising output is determined by setting marginal revenues equal to marginal cost

$$P(Q) + \frac{dP(Q_i)}{dQ_i} Q_i = MC_i(Q_i) \tag{7}$$

By following Church & Ware (2000:p.238) (7) is rewritten as

$$P(Q) - MC_i(Q_i) = -\frac{dP(Q)}{dQ} Q_i \tag{8}$$

Subsequently, both sides of (8) are divided by the market price *P*, i.e. the Cournot equilibrium price, and the bottom and top terms on the right hand side are each multiplied with industry output *Q*.

$$\frac{P(Q) - MC_i(Q_i)}{P(Q)} = -\frac{dP(Q)}{dQ} \frac{Q_i}{P} \frac{Q}{Q} \tag{9}$$

Rearranging (9) and substituting the price elasticity of demand, defined as $\varepsilon = -\frac{\%\Delta Q}{\%\Delta P} = -\frac{dQ}{Q} / \frac{dP}{P} = -\frac{dQ}{dP}\frac{P}{Q}$, yields:

$$L_i = \frac{P(Q) - MC_i(Q_i)}{P(Q)} = \frac{1}{\varepsilon}\frac{Q_i}{Q} \tag{10}$$

in which $Q_i/Q$is the market share s_i of firm i in the market. Now multiplying both sides by s_i and summing over all firms in the market yields

$$\sum_{i=1}^{N} s_i \left(\frac{P - MC(Q_i)}{P}\right) = \sum_{i=1}^{N} \frac{s_i^2}{\varepsilon} \tag{11}$$

This equation shows that the Lerner index is directly linked to the Herfindahl Hirschman Index in a market (see (3)) and that the price elasticity of demand ε is inversely related to the mark-up of price over marginal cost (see also Cowling & Waterson (1976)). Equation (11) shows that a higher HHI, holding the price elasticity of demand constant, leads to a higher Lerner index. Hence, in the Cournot model depicting the interaction between firms in the market the HHI as well as the price elasticity of demand may give an insight into the conduct of a specific market (Church & Ware, 2000:p.240).

Several studies point to potential inconsistencies in the calculation of this index and propose different amendments how these can be properly addressed. Hannan (1997), for example, analyses whether the inequality in market shares and the number of competitors in the market is adequately reflected. Decomposing the HHI as in (4) and applying it to bank pricing behaviour, the results imply that the number of firms in the market should obtain a higher weight. Furthermore, if products with different characteristics are included in the definition of the relevant market, this may lead to biased results of the assessment of market concentration since these products are not perfect substitutes. Lijesen (2004) accounts for this potential bias by introducing a weight for product quality to the traditional Herfindahl Hirschman Index and thus accounting for close substitutes. In the approach, ibid. analyses a market with two firms subject to Cournot competition and exogenously differentiated products. For this purpose, a utility function is defined which includes a parameter accounting for the quality of products. It is assumed that the utility consumers derive from a product increases with a product's quality, and that consumers are less price sensitive with regard to products of higher quality. An important assumption here is that industry output is constant, and thus "…industry profits in markets with close substitutes depend on the sum of squared market shares" (Lijesen, 2004:p.127). Adjusting the Herfindahl Hirschman Index for product quality therefore results in the squared market shares of each firm being multiplied by a weight for quality. Higher quality products are multiplied by a higher weight. In the empirical analysis testing the effects of the introduction of a quality indicator, ibid. applies the weighted Herfindahl Hirschman Index to the airline industry. Considering different city pairs offered by airlines the relative travel time on each serves as an indicator for quality, i.e. the relative time is "[…] the ratio of travel time to the shortest travel time on the [origin-destination]-pair considered" (p. 131). In order to compare the weighted and unweighted results, ibid. assumes that the number of flights per city pair is constant. However, since airlines are likely to adjust their supply over time and thus change the level of output, this particular assumption may not apply in the medium-run to long-run. The empirical analysis of eight European airlines suggests that accounting for the difference in quality provides more accurate results and therefore a weighting should be introduced.

The analysis of market concentration, and the respective application of the Herfindahl Hirschman Index to measure this, requires the definition of the relevant market as a crucial first step. As outlined, methodologies applied in this field may be prone to measurement error and therefore lead to biased results. These potential biases have to be kept in mind when calculating the degree of market concentration in an industry to infer to the degree of market power in this. First, showing that there is a formal link between the Lerner index as a measure of market power and the Herfindahl Hirschman Index has been providing the rationale for the application of this index in competition policy. However, different studies have pointed out potential inconsistencies which require an adjustment of this concentration measure by e.g. a weighting indicator in order for results to be more reliable. Furthermore, the assumption of specific thresholds with which to define market power is often critical. Therefore, observing changes in the degree of industry concentration might provide a more useful tool in assessing the degree of a firm's market power.

Summarising, Chapter 2 started with the discussion on natural monopolies and potential entry barriers, emphasising the different lines of arguments that developed historically in this context, before outlining a range of approaches used to determine the existence and degree of market power in an industry. These discussions provide the theoretical foundations to assess the prevalence and level of market power in the airport industry, especially (1) to analyse airport market structure in terms of exhibiting characteristics of a (natural) monopoly, (2) to understand the specifics of the vertical relationship between airports and airlines, and (3) to discuss those factors that constrain potential market power, which is the focus of the following Chapter 3.

3 Market Structure of the Airport Industry

Airports are often assumed to exhibit characteristics of a natural monopoly, due to the inherent sunk cost associated with their required infrastructure, which cannot be used for alternative purposes in the long-term, and thus represents costs that the operator cannot recoup (Reinhold *et al.*, 2010; Müller-Rostin *et al.*, 2010; Pels, Nijkamp & Rietveld, 2003b; Lechmann & Niemeier, 2013; Lewisch, 2010; Smyth & Pearce, 2007). This also stems from the indivisibilities of airport infrastructure investment such as runways whose capacity cannot be increased marginally (Bruinsma, Rietveld & Brons, 2000).

The existence of a natural monopoly infers that only one firm can produce market output in a cost efficient way (see Chapter 2.1.1). Therefore, there has been ongoing controversial debate whether several airports are sustainable within a particular region, or whether only one airport can produce the required output in an efficient way. Regarding the existence of economies of scale in the airport sector, empirical studies have shown that existing airports are even operating under diseconomies of scale, suggesting that the former are not the source of airport market power (Pels, Nijkamp & Rietveld, 2003b; Müller-Rostin *et al.*, 2010). Pels, Nijkamp & Rietveld (2003b) consider both air passenger movements and air transport movements as airport output, when assessing airport efficiency in Europe. The findings show that the average European airport in their dataset operates under constant returns to scale in regard to movements, and under increasing returns to scale in terms of passenger output. Contrary to this, Martín & Voltes-Dorta (2011) show that the minimum efficient scale of an airport goes beyond 116 million passengers, based on the analysis of 161 airports worldwide, thus stating that increasing returns to scale are currently not exhausted. Lechmann & Niemeier (2013) confirm these contrary findings in their review of several studies investigating the minimum efficient scale at airports, with this ranging from three million to more than 100 million passengers. However, as discussed in Chapter 2.1.2, economies of scale itself may not pose a barrier to entry for new competitors. For example, assuming a setting with two airports in a region, with the first one offering flights and the second one being an old military base not used for commercial traffic. Since the infrastructure is already available at the second airport, airlines can start operations here and provide a potential substitute for the first airport. By pricing below the airlines at the first airport, airlines at the second airport can redirect some demand to their services.

In terms of economies of scope, Lechmann & Niemeier (2013) highlight that there are only few studies in regard to economies of scope in the airport sector. These are assumed to exist between the aviation and non-aviation business at an airport, such as the provision of terminals for passenger processing, and the establishment of retail services. Furthermore, economies of scope may exist between the different traffic segments such as domestic and international, or origin-destination and transfer traffic (Martín & Voltes-Dorta, 2011). The facilities and infrastructure required for passenger processing may differ slightly, such as the degree of border controls, but some of these can be used for all passenger segments. Bracaglia, D'Alfonso & Nastasi (2014) discuss the impact on competition in case airports are multiproduct companies, particularly in regard to the combined sale of tickets and non-aviation services such as parking. If competing airports both engage in the complementary sale of these products, a negative effect on aviation charges can be observed.

Airport market power may also stem from a geographic monopoly, i.e. building a new airport in a nearby geographical location is often constrained by land scarcity or political restrictions (Forsyth, 2010; Niemeier, 2009; Productivity Commission, 2011). This circumstance, in combination with the high sunk investment required to set up new airport facilities, therefore often prohibits the construction of new airports in the vicinity of existing ones. Furthermore, the vertical relationship between the airport operator and its airlines may provide a barrier to entry (or exit) since large scale airline investment at the node, as in the case of hub-and-spoke operations, prevents these carriers from easily switching to or duplicating their operations at other airports.

As highlighted, these different sources of airport market power are controversially discussed in both academia and industry. One view supports the argument that nowadays airports are facing increasing constraints for market power, thus rendering economic regulation obsolete. Contrasting that is the opinion that airports still possess a significant degree of market power, which would result in abusive price setting behaviour in regard to airport charges, for example. Since the focus of this thesis is on the analysis of European hub airports and the competitive constraints these face, emphasis is first placed on discussing the specific characteristics inherent to these airports, especially in regard to the interaction with their dominant airline, the network carrier. Chapter 3.1 hence dicusses the vertical relationship between an airport and an airline, with a focus on the benefits and drawbacks of network carriers operating a node at hub airports. Focusing on the question who actually engages in competition, the airport or the airline, factors affecting the choice for an airport by these two stakeholder groups are outlined. Taking up this discussion, Chapter 3.2 highlights current approaches to the assessment of market power in the airport industry, and, based on this, discusses the approach and research questions within this thesis as well as its contribution to the current research landscape[22].

3.1 Airport market structure

The relationship between hub airports and network carriers has distinct characteristics which are discussed within in this chapter in order to get an understanding of the factors potentially influencing an airport's competitive position. Chapter 3.1.1 therefore starts out with a discussion of the specifics of the vertical relationship between an airport and its airline(s). The interlinkage between these two can be even stronger, if the airline operates a hub-and-spoke network via the airport, its node. Relating aspects are discussed in Chapter 3.1.2. The discussion on airport competition often evolves around who is actually competing, the airport or the airlines. Chapter 3.1.3 thus focuses on factors that drive passengers' or airlines' choice for a particular airport. The discussion in this chapter builds the basis to discuss the approach taken in this thesis in assessing the degree of competition faced by European hub airports.

3.1.1 Vertical relationship between airports and airlines

There is a strong dependency between network carriers and their respective hub airports, both due to the large share in movements this particular carrier has at its node, and the sunk investment of the carriers at the airport. Network carriers' switching potential to other

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airports is hence limited due to financial and organisational investment made in the hub airport. However, it is not only the network carrier being dependent on the continuation of operations at the same node but also the hub airport relying on the network airline and its share of movements in the overall airport traffic, thus creating strong mutual lock-in effects between these two parties (Polk & Bilotkach, 2013). Elliot (2016) argues that airline countervailing power exists if the airline has a large stake in an airport's overall traffic, and can thus engage in negotiations regarding service levels and charges. An airline with only a small share in traffic may not exert this kind of buyer power, since the loss in traffic due to this airline switching operations can potentially be compensated by an increase in other airlines' traffic. This chapter therefore focuses on the specifics of and the different forms the relationship between airports and airlines can take.

Table 4 gives an overview of the diverse types of relationship an airport and an airline might engage in, with a discussion of each form provided afterwards.

Table 4: Different forms of vertical relationship between airports and airlines

Form of relationship	Explanation
Signatory status	Airline and airport engage in contractual agreement, according to which airlines guarantee the provision of flight services, and in return gain some influence in terms of airport planning and operations.
Long-term use contracts	Airlines and airports engage in contractual agreement, in which airports lease out facilities to airlines over long-period, e.g. ten years or more. Airlines can sublease these facilities to other carriers.
Airline ownership of airport facilities	Airline holds shares or owns facilities directly, mutual planning of investment and operations as well as profit sharing between airport and airline.
Concession revenue sharing	Often related to the signatory status of an airline, long-term contracts or airline ownership. For example, airlines receive a share of revenues if these exceed a certain threshold, thus incentivising them to increase passenger throughput at an airport.

Source: adapted from Fu, Homsombat & Oum (2011)

First, airlines may obtain a so called signatory status, as outlined by Oum & Fu (2008). The airline commits to using the airport to a certain degree and to provide part of the financing of operations. In return, it obtains a share of control over certain areas at the airport such as relevant infrastructure projects, slot allocation, or facility usage. Long-term usage contracts depict another option which can often be found between airports and their respective low cost carriers. Furthermore, in some cases airlines acquire direct control over certain airport facilities or services by investing financially and earning respective revenues from airport functions. Resulting from this type of cooperation, both the airline and the airport derive benefits such as risk sharing, ensuring investments and generating (additional) revenues. The positive demand externalities of the airline-airport relationship are hence intended to be internalised (ibid.).

Fu & Zhang (2010) examine the effects on consumer surplus as well as social welfare, if the airport and one or multiple airlines engage in concession revenue sharing. The model considers three different airline market structures, namely a monopoly airline as well as a symmetric and an asymmetric airline oligopoly. The airport is non-congested and acts as an input monopoly. Within this setting, the airport operator offers the involved airlines to participate in the sharing of concession revenues, which the airlines can accept or reject (stage one of the game). In the second step, airlines engage in Cournot competition, resulting in the subgame perfect Nash equilibrium. The findings of the model show that there may be an increase in social welfare due to the internalisation of demand complementarities on the concession revenue side and the elimination of double marginalisation. In the monopoly case, both airline and airport profits increase as do consumer surplus and social welfare. If the airport engages in revenue sharing with symmetric airlines in an oligopoly, the airport's profit as well as social welfare increases. On the contrary, if the airport has an exclusive deal with only one airline, the latter increases its output at the expense of its competitors (ibid.). The analysis also reveals that the airport operator has an incentive to exert influence on the downstream airline market, i.e. it can thus attain additional surplus apart from aviation service charges in the form of fixed payments by the airline. An asymmetric airline duopoly sets incentives for the dominant carrier and the airport to commit to revenue sharing. In this particular case, the position of the dominant airline is further strengthened, which has negative effects on competition. Overall, positive effects of revenue sharing include an increase in consumer surplus and social welfare, whereas on the negative side increased airline market power and an airport's incentive to raise aeronautical charges have to be noted.

A development which can be observed at some airports is a closer cooperation between the hub airport and the network carrier regarding the provision of aviation and non-aviation services, i.e. some form of vertical cooperation. The agreement of long-term contracts, or even shared ownership between an airport and an airline often ensure exclusive usage of facilities for the respective airline, granting it with the possibility to design its designated terminal for the airline's specific purposes, and also create a value of brand recognition (Fu, Homsombat & Oum, 2011).

A prominent example of a joint venture between a hub airport and a network carrier is the partnership between Munich Airport and Lufthansa regarding terminal infrastructure development and terminal operations, thus representing the case in which an airline owns airport facilities. Within this joint venture, both companies have a stake in the financing, construction and operation of Terminal 2, Lufthansa 40 per cent and Munich Airport 60 per cent. The intention behind this kind of partnership was the alignment of the terminal layout, the various facilities and services with the requirements of a transfer terminal. Achieving a minimum connecting time of 30 minutes for transfer passengers and hence providing a hassle-free and seamless travel for these by ensuring short waiting and processing times within the terminal was one of the main goals (Munich Airport, 2004). Another example of mutual ownership of airport facilities is the carrier JetBlue and New York John F. Kennedy (JFK) Airport. The airline invested 80 million U.S. dollars in the construction of a new terminal and agreed to a 30-year lease of this terminal (The Port Authority of New York & New Jersey, 2005).

Apart from the positive effects of such a cooperation, the market power of airlines can increase in this case and it may be subject to more favourable pricing conditions at the airport than other airlines (Fu & Zhang, 2010; Barbot, 2009; Barbot, 2001). As will be outlined in Chapter 3.1.2, airlines dominating at an airport, in terms of their share in movements or seats being offered, are prone to charging a hub premium. Due to this high share of operations at an airport, and the potential investment as well as commitment made, though, a carrier cannot easily relocate operations to a different airport in the proximity. Especially hub airports and their respective network carrier foster the cooperation in order to strengthen their competitive position towards other airports and airlines.

As discussed in Chapter 2.1.2, different forms of cooperation, or vertical integration, between upstream and downstream firms, in this case the airport and the airline, may lead to vertical foreclosure, and have negative effects on the competition on a specific market. Potential areas affected in the case of vertical integration between airports and airlines may be ticket prices, or service quality offered. Basso (2007) and Basso & Zhang (2007) develop a model illustrating the vertical structure and competition of congestible facilities and the resulting effects on prices and capacities, with an application to the airport sector. Within Basso (2007) it is assumed that airports are input providers whose demand is a function of airport charges, capacities, and airline market structure. To determine optimal prices and capacity decisions it is therefore not only necessary to have information on the airport's cost and demand function but also on the respective airline market. Considering different airport objective functions, i.e. welfare and profit maximisation, shows that prices are higher and traffic levels are lower in a profit-maximising setting. Other cases considered in this paper are the joint profit maximisation of an airport and an airline as well as the case of two independent profit-maximising airports. The first case may help to avoid so called vertical double marginalisation, whereas the second one addresses horizontal double marginalisation, which occurs when airports' outputs are considered as complements.

Basso & Zhang (2007) also employ a model which incorporates two rival congestible facilities (airports in a multi-airport region) which are input providers for the downstream market (airline operators) and hence the final consumers (passengers). The competing airports choose prices and capacities for the input they provide for the downstream market. Subsequently, the airports' respective carriers compete and the final consumers select one of the facilities. The results from competition in terms of welfare are compared with the single airport case. The facilities' decisions and the resulting service levels for users depend on the nature of the game. In a closed loop game (decisions on prices and capacities are made sequentially), as also in De Borger & Van Dender (2006), the duopolists offer a lower service quality than the monopolist. In a situation where capacity and pricing decisions are made at the same time, the service level under a duopolist regime is the same as in a monopolist setting (Basso & Zhang, 2007).

Barbot (2009) analyses the incentives for vertical collusion between an airline and an airport by considering a three-stage game. The airlines engage in Bertrand competition in a spatial setting, which leads to the airport's derived demand function. According to that, the airports set the level of aeronautical fares, and in turn both parties decide whether they engage in collusion. If there are market and quality asymmetries, the applied model shows that there will not be any collusion. However, in the case of market asymmetry and airline vertical differentiation, the conditions are suitable for collusion between the airport and the airline. Integration of a parameter accounting for the airport's concession revenue does not yield any significant changes to the findings. Barbot (2009) therefore concludes that this aspect does not make a difference with respect to the collusion decision.

Barbot (2011) investigates the effects of various types of possible vertical relations. Within the analysis, different types of vertical integration between an airport and an airline are modelled, assuming that there is a monopolist on the upstream market and imperfect competition on the downstream market. The three types of arrangements include joint profit maximisation, airline's operative participation in the upstream market (e.g. terminal provision), and price discrimination in favour of the dominant airline. In the first two cases the author finds anti-competitive behaviour with regard to the downstream market whereas price discrimination does not lead to market foreclosure. If the airport and airline jointly maximise profits or if there is price discrimination, consumer surplus as well as welfare will increase due to the prevention of double marginalisation. The underlying assumption for this is linearity of demand in the downstream market. In case the dominant airline engages in the upstream market, ibid. finds that there will be a decrease in both consumer surplus and welfare which can only be avoided if this interaction leads to an increase in efficiency of the operated facilities. The same findings result if Cournot competition in the downstream market is assumed.

D'Alfonso & Nastasi (2012) take up the three arrangements discussed in Barbot (2011) and add competition in both the upstream and downstream market. The authors analyse the incentives for airlines and airports, and the incentives for social welfare, consumer surplus as well as pro-competitiveness. Assumptions of the model are that airports do not compete for airlines but for passengers via airlines. In terms of airline market structure in the model, D'Alfonso & Nastasi (2012) assume that there is a leader at each facility which engages in Stackelberg competition with its followers. Among themselves, both the leaders and the followers engage in Cournot competition. Further assumptions include a spatial competition model of an infinite linear city with each airport having spare capacity available and no congestion. The findings suggest that vertical collusion and an airline's participation in the upstream market are anti-competitive. However, the incentives for the players to engage in price discrimination are rather small compared to the incentives for collusion. This finding is slightly different to Barbot (2009) since D'Alfonso & Nastasi (2012) assume that the market is not fully covered. They outline that regulatory considerations may address the arising trade-off between airline competitiveness and welfare as well as the fact how incentives have to be designed for the implementation of agreements that maximise social welfare.

This discussion shows that the effects of vertical cooperation or integration between airports and airlines are not clear-cut, and strongly depend on the degree of dominance of the airline at the airport, in terms of market share, and the type of vertical interaction these players engage in. This interaction may hence even lead to an increase in the market power of airlines and also airports (Fu & Zhang, 2010). Since especially network carriers and their respective hub airports are in a co-dependent relationship, with the airlines organising their network in a hub-and-spoke structure, and often engaging in contractual agreements with the hub airport in question, the advantages as well as drawbacks of this relationship are discussed in more detail in the following chapter. Emphasis will be placed on this particular network structure and the resulting benefits and drawbacks for airlines as well as passengers.

3.1.2 Specifics of airline hub-and-spoke networks

Airlines derive benefits by structuring their operations in a hub-and-spoke (HS) network as opposed to a fully connected or point-to-point network. Carriers operating this type of network have the potential to realise economies of scale and scope. Since traffic from multiple spokes is bundled in the node, airlines are able to obtain higher load factors on their aircraft (Kahn, 1993; Dennis, 1994). Instead of operating a high amount of point-to-point connections as is the case in a fully connected network, traffic concentrates on a small number of spokes and in the node (Hansen & Kanafani, 1989). As a result, average costs per flight are declining (Huston & Butler, 1993). Another positive effect of traffic bundling is the possibility to employ larger aircraft on certain routes (Hansen & Kanafani, 1989; Kahn, 1993; Dennis, 1994). In addition to this, Caves, Christensen & Tretheway (1984) examine the concept of economies of density with regard to specific U.S. airline markets where trunk and local carriers operate. The authors find that the level of traffic density within a given network accounts for differences in airlines' cost. Economies of scale and density differ since the former consider an extension of the network whereas economies of density depict unit costs within a given network. Furthermore, Brueckner & Spiller (1991) assume that airlines are multi-product firms with cost complementarities which enable them to obtain economies of scope with HS network operations. This is achieved by being able to offer different products, i.e. types of flights, from a single node (Huston & Butler, 1993). Within the HS network the addition of a new destination increases the number of available city-pairs by a multiple factor.

Other benefits gained from HS network operations are an airline's competitive advantage due to being able to offer high service frequencies, lower ticket prices at high quality and multiple destinations for airline passengers (Dennis, 1994). However, this view is opposed by analytical findings that the fares for O&D (origin and destination) passengers in a HS network are higher than those in a fully connected network (Brueckner & Zhang, 2001). The findings suggest that this is due to the fact that the high flight frequency offered by airlines in a HS network induces departure times being closer to passengers' preferred times and hence airlines are able to levy higher prices. Dennis (1994) also suggests that network carriers benefit from their position in a HS network by gaining more control over available capacities and prices. These carriers can use internal cross-subsidies to maintain non-profitable routes in order to attract more passengers.

Table 5: Hub-and-spoke versus point-to-point networks

Network	Passengers	Airlines
Hub-and-spoke	+ Increasing number of available city pairs + High service frequencies – Potentially longer travel times – Potentially higher fares	+ Economies of scale, scope and density + Spatial and temporal concentration of flights + Traffic bundling, higher load factors + Employment of larger aircraft – Potential of negative network effects
Point-to-point	+ Shorter travel times – Low level of interconnected flights	+ Focus on high volume routes + Incentives for new entrants – Unprofitable flights if insufficient demand

Source: own depiction

Brueckner & Spiller (1991) and Zhang (1996) investigate the so called negative network effect (negative externalities) apparent in HS networks. Basically, competition on a particular route may have positive effects within this city pair but may cause negative effects on other routes within the hub-and-spoke network. Brueckner & Spiller (1991) state that the entry of competitors on a previously monopolistic market results in lower fares for passengers. However, some passengers now switch to the competitor on the affected spokes which leads to reduced traffic volume for the incumbent. Due to economies of density, the incumbent's passengers therefore face higher marginal cost, i.e. higher fares, on these routes which might be offset by the lower fares in the competitive market. The positive effects such as fare reduction do not occur in monopolistic markets within the hub-and-spoke network. These markets do, however, experience the negative effects on the spokes induced by competition in a different market. Zhang (1996) elaborates further that this particular effect occurs when increasing returns to traffic density are strong and that a carrier has to balance its profits, i.e. assess the profits gained from entering a market versus the losses incurred in the network market.

Finding the optimal hub-and-spoke network from an airline point of view is the research focus by Adler & Berechman (2001). The authors' approach includes the generation of a network and consecutively connecting the different hubs via either minimisation of distance or of total legs travelled. For the model development it is assumed that the relevant network configuration for an airline is determined by the profit maximising objective. Mathematical programming is applied in order to determine the optimal hub-and-spoke network. This model is in turn applied to data of the Western European air transport system. In their findings, the authors show that the preferable network for an airline consists of an international hub and an intra-European, secondary hub. Furthermore, they highlight that the airports in question are impacted by the airlines' decisions in regard to their pricing policies or strategic capacity planning. Adler (2005) extends this analysis by considering competition between hub-and-spoke networks and how this influences an airline's optimal network choice. A multinomial logit model is applied to determine airlines' market shares, an operations research based program is used to solve the airlines' objective function of profit maximisation, and a game theoretic approach enables to depict the competitive situation with multiple airlines. These choose their network first and consecutively maximise profits given the other airlines' decisions. In the application of this model to the Western European aviation market, the author finds that a single, monopolistic subgame perfect equilibrium exists with British Airways as the monopolist running a hub-and-spoke network with London Heathrow (LHR) and Zurich Airport (ZRH) as their primary and secondary hubs. Conducting a so called doubled-demand sensitivity analysis shows that there is sufficient demand to support two profitable airline networks within Western Europe.

Flores-Fillol (2009) investigates the airline network structure under competition in an unregulated environment. Welfare implications are assessed by analysing different scenarios in an equilibrium analysis. The author applies a duopoly model of schedule competition and looks at fully connected (FC) and hub-and-spoke (HS) networks and which conditions have to be fulfilled in order for symmetric or asymmetric equilibria to arise. The findings reveal that in the presence of low transport cost airlines opt for a HS network structure and with high transport cost for a FC network. HS networks are characterised by different effects which entail opposing impacts. First, the demand effect occurs, which means that in a HS network higher flight frequencies than in a FC network are offered, Second, the cost-saving effect results from economies of density. And third, the cost-per-passenger effect, which means that passenger costs have to be paid twice by the airline since the airline connect flights via its hub airport, and therefore has to be the associated costs for each flight. Providing a direct flights lets the airline only incur these passenger costs once. Therefore, in case these costs are very high, the airline will incur high costs which can eventually not be offset by the former two effects, and it will hence aim for a FC network. Furthermore, the author states that asymmetries may arise, i.e. there might be airlines establishing FC networks and others relying on HS networks, without previously having introduced asymmetry in the model.

The benefits from an airline operating a hub-and-spoke at an airport may induce passengers to opt for this particular airport, due to higher frequencies available and more destinations to choose from. More insight into this behaviour is given in the following chapter, by outlining factors that influence both passengers' and airlines' choice of an airport.

3.1.3 Airline and passenger choice factors

Airlines and passengers determine an airport's attractiveness by various factors. Hess & Polak (2005) outline three different studies concerned with passengers' airport choice factors. The studies use either revealed or stated preference data and show that originating passengers favour short journey times to their airport of departure. Morrell (2010) states that passengers place high importance on the frequency of transport services as well as the associated cost, as do Matsumoto, Burghouwt & Veldhuis (2009). However, airport choice factors have to be distinguished by passenger type. A long-haul passenger may accept a much higher access time to the airport than a passenger traveling to a short-haul destination.

One way to determine the relevance of different factors is to employ a passenger utility function which includes multiple variables. Harvey (1987) differentiates by business and leisure passengers in the San Francisco Bay Area. Here, the former place high negative utility on airports with no direct flight connections, which is not even offset by superior airport access time. Ibid. also states that passengers also do not derive additional benefits from more than nine flights per day to a specific destination. Matsumoto, Burghouwt & Veldhuis (2009) cite decision making factors such as comfort aspects or airline loyalty. Malina (2010) and Strobach (2010) also highlight a range of variables which cause passengers to favour a particular airport: the quality of airport access, ticket price, flight availability and frequency, or type of aircraft and aircraft size available. A study by Jung & Yoo (2014) investigates passenger choice for air or high-speed rail travel on the short-haul route between Seoul and Gimpo-Busan. The results of the multinomial and nested logit models indicate that ticket price, access as well as overall journey time significantly affect passenger choice and that business passengers are more sensitive to access time changes than leisure travellers.

Pels, Nijkamp & Rietveld (2001) and Pels, Nijkamp & Rietveld (2003a) conduct case studies of airport choice in the San Francisco Bay area with particular regard to passenger preferences. The authors apply (nested) logit models to test for the significance of various passenger decision-making variables. They find that access time to the airport is very important in defining an airport's attractiveness. Suzuki (2007) extends the above model by a two-step approach in assuming that passengers make their airport and airline choice jointly and then consider a choice set instead of all available alternatives. The airport choice depends on the proximity to a passenger’s home and whether the airport has been used before. The airline choice is determined by the level of ticket prices, the frequency of services offered as well as loyalty programs such as frequent flyer programs. Also placing a focus on the metropolitan airport region of San Francisco are Ishii, Jun & Van Dender (2009). However, this study specifically focuses on the San Francisco Los Angeles route and finds that both leisure and business passengers’ choice is affected by available flight frequency, and that business passengers place high importance on punctuality. In addition, the results suggest that the hub premium a network carrier earns at its node airport also results from this carrier offering more frequencies within the region than competing airlines. An overview of different passenger and airline choice factors is given in Table 6.

Table 6: Passenger and airline decision making factors

Passengers	Airlines
Duration and quality of airport access	Customer preferences
Frequency of transport services	Size of relevant market
Ticket price	Nature of local economy
Flight availability	Geographical location
Comfort aspects	Airport infrastructure and facilities
Airline loyalty	Available capacity
Type of aircraft and aircraft size	Airport charging structure

Source: own depiction

Airlines strongly consider customer preferences when making the decision at which airport to locate their operations (Starkie, 2010). In addition to this, Huston & Butler (1991) highlight the size of the relevant market, the nature of the local economy defined by established industries and business centres, as well as demographic aspects such as population prone to travel, or income of relevant groups. The geographical location also plays an important role in terms of proximity to the markets served by the airline (Martin & Roman, 2004). Since network carriers intend to derive the benefits from hub-and-spoke operations, coordination of schedules is a crucial factor. In order to realise this in an efficient way, runway and terminal structures have to be designed accordingly and offer sufficient capacities (Dennis, 1994). Congestion and delays may cause airline services to be less attractive and hence less competitive. Available spare capacity and the possibility to expand existing infrastructure may therefore exhibit a competitive advantage for an airport (Starkie, 2010).

Summarising Chapter 3.1, the discussion on the types of vertical relationships between airports and airlines, the resulting effects for market power as well as the inherent specifics of network carriers and their operation of hub-and-spoke networks, gives an insight into the relationship between hub airports and network carriers. This is characterised by a strong interdependency, driven by the often apparent dominance of the network carrier at the hub airport, which results in a potentially strengthening of these players' market power. The network carrier is able to earn a significant hub premium, for example, and, due to contractual long-term agreements with the airport and mutual investment, has the ability to restrict other carriers' access to essential facilities at the airport, thus possibly imposing barriers to entry for other carriers (D'Alfonso & Nastasi, 2012). But this relationship between network carrier and hub airport may also bear benefits for passengers in terms of higher travel frequencies, and more travel destinations available. Furthermore, since network carriers benefit from offering transfer connections, this leads to competition with other airports also offering these connections. In order to persist in this competitive market, network carriers and hub airports may decide to engage in a closer relationship with each other to strengthen their overall position.

Concerning the question, who is actually competing for which customers in this market, the discussion outlined several decision making factors important for airlines and passengers when selecting a particular airport. Suzuki (2007) assumes that passengers make their decision regarding airport and airline choice jointly, especially when it comes to the local catchment of an airport, i.e. the origin and destination (O&D) traffic. The Productivity

Commission (2011) states that "… airports do not supply services directly to passengers; rather, they supply services to airlines" (p.71). Compared to this, D'Alfonso & Nastasi (2012) assume in their model of vertical interaction between airports and airlines that the latter are locked in with a particular airport, and therefore "…airports do not compete for the airlines but compete through airlines to get passengers" (p.995).

As outlined in Chapter 1, the main focus of this thesis is on the investigation of market power of European hub airports, both in the local catchment and on the transfer market. Regarding the local market, it is presumed that the availability of close substitutes within the catchment imposes constraints on airport market power (Productivity Commission, 2011). In this case, substitutes represent other airline-airport choices apart from the hub airport and its respective airlines. It can therefore be assumed that airports also compete for passengers in their local catchment. In terms of the transfer market at European hub airports, the close linkage between the hub airports and their respective network carrier leads to the inference that competition between network carriers for passengers on transfer connections also implies competition the hub airport is exposed to. Concerning these particular markets which may be subject to competition, the following chapter outlines various approaches how competition in the airport industry is measured, and discusses the added value of the analysis within this thesis to the field of airport competition.

3.2 Market power assessment in the (European) airport industry

Coming back to the discussion in Chapter 2.2, there are different approaches regarding the assessment of market power in the airport industry. With a particular focus on the local catchment and the transfer market, these will be highlighted in Chapter 3.2.1. Following that, the specific research questions addressed within this thesis are placed into the context of current analyses in the field of airport competition (Chapter 3.2.2), both in regard to the added value as well contribution to the field of airport competition.

3.2.1 Current assessment of market power in the airport industry

Airports may compete for traffic shares, certain passenger groups or traffic types (Morrell, 2010; Tretheway & Kincaid, 2010). Airports within the same urban region or those with overlapping catchment areas compete for origin-destination (O&D) traffic. Within these regional markets passengers may be indifferent regarding airport choice. Thelle *et al.* (2012) highlight the increased amount of airports now available for passengers within certain regions. Furthermore, airports may specialise in attracting particular airline business models or passenger groups such as low cost carriers or business passengers (Tretheway & Kincaid, 2010). Hub airports, for example, may compete for transfer traffic (Morrell, 2010). There is also competition for services within an airport, e.g. between terminals or between airport retail and high street retail shops (ibid.). Picking up this discussion, Table 7 highlights the different forms of competition airports may engage in, the different approaches taken to measure these, and selected studies investigating these aspects.

Airport market power can be limited by the power airlines exert in terms of potentially switching operations to other airports that offer better conditions. The degree of this countervailing power depends on the airline's traffic share and position at the airport (Button, 2010). Starkie (2012) and Thelle *et al.* (2012) argue that nowadays there are more airlines which can potentially switch operations in case terms and conditions at the respective airport do not match their expectations. Starkie (2012) discusses airlines' increased buyer power which results from the establishment of the European single aviation market and other developments such as the pervasion of the internet. Airlines operating a point-to-point network such as low-cost carriers (LCC) can relocate their relatively mobile aircraft assets across European airports and reduce lock-in effects with airports accordingly (Starkie, 2002; Button, 2010; Thelle *et al.*, 2012). Carriers operating hub-and-spoke networks, however, cannot switch their operations easily due to the inherent network structure and the associated investment and costs, as discussed in Chapter 3.1.1 and 3.1.2.

The substitution coefficient defined by Malina (2010) calculates the degree to which an airline is willing to switch its operations from a particular base airport to another substitute airport. Assuming that flight availability and frequency as well as ticket price are determined by the airline, feasible German airports are identified according to available infrastructure such as runway length and legal practicality of operations. Then, the study looks at the quality of passenger airport accessibility by applying the substitution coefficient. Feasible airport access times are differentiated by passenger preferences, e.g. leisure travelers, and the share of passengers within a certain catchment area which is willing to travel to the substitute airport is calculated.

Table 7: Different forms of competition between airports

Type of competition	Explanation	Approaches	Selected references
(1) Competition for airline services	– Airlines switching operations between airports	– Analysis of route churn rates, i.e. opening and closing of routes – Contractual agreements between airport and airline, leaving airlines with sunk investment and thus less incentive to switch	Oxera Consulting, 2017; Thelle *et al.*, 2012; Button, 2010; Starkie, 2002; Malina, 2010
(2) Competition for passengers in the local catchment	– Passengers are switching between airports in the local catchment – Availability of substitute transport modes such as rail services	– Definition of the relevant market using SSNIP test – Analysis of number of airports offering the same route – Analysis of market concentration on the route level, applying the Herfindahl Hirschman Index – Analysis of the effect of (high-speed) rail services on the routes offered at an airport	Adler, Nash & Pels, 2008; Adler & Nash, 2004; Thelle *et al.*, 2012; Starkie, 2002; Maertens & Grimme, 2015; Oum & Fu, 2008; Albalate, Bel & Fageda, 2015; Behrens & Pels, 2009; Adler, 2008; Müller *et al.*, 2010; Polk & Bilotkach, 2013; Bilotkach, Fageda & Flores-Fillol, 2013
(3) Competition for passengers on the transfer market	– Passengers are switching between hub airports, which offer the same transfer connections	– Analysis of overlap in transfer connections at hub airports – Assessment of overlap between transfer connections and direct connections – Calculation of market concentration on the transfer market using the Herfindahl Hirschman Index – Analysis of self-hubbing, i.e. transfer flights are not offered by the same airline or within an alliance	Oxera Consulting, 2017; Malighetti, Paleari & Redondi, 2008; Maertens, Pabst & Grimme, 2016; Allroggen & Malina, 2010; Lieshout & Burghouwt, 2013; Fichert & Klophaus, 2016; Redondi & Burghouwt, 2010; Fageda, Suau-Sanchez & Mason, 2015; Burghouwt & Veldhuis, 2006
(4) Airports as two-sided markets	– Complementarity between aviation and non-aviation business to limit monopolistic price-setting	– Theoretical modelling to test assumptions of two-sided platforms in the airport context	Gillen, 2009; Fröhlich, 2010; Gillen & Mantin, 2013; Bracaglia, D'Alfonso & Nastasi, 2014

Source: own depiction

The coefficient can take on values between zero and one, with the latter denoting the case where the substitute airport exhibits the same or a better quality level, and hence imposes competitive pressure on the base airport. Each airport has to be assessed individually. The application to the German market shows that the large hub or international airports such as Frankfurt Airport (FRA), Munich Airport (MUC), or Hamburg Airport (HAM) have a coefficient of zero, and hence it is assumed that airlines have no feasible substitutes available regarding the demand for O&D traffic.

In starting with the assessment of airport market power in the local catchment, the relevant market is often defined using the SSNIP test, which was discussed in detail in Chapter 2.2.2 (Müller *et al.*, 2010; Polk & Bilotkach, 2013; Competition Commission, 2009). Assessing the market power of UK airports, and whether common ownership should be prohibited, the Competition Commission (2009) states that there is "… no advantage in defining rigid geographic markets for airports" (p.36). Relying on passenger surveys for these particular airports, the Commission defines district share thresholds in order to assess how willing or likely passengers are to switch between different airports. First, if the number of passengers from a certain districts exceeds a specific threshold, e.g. 30 per cent of all passengers from that district, this district is considered to be in the catchment of the considered airport. Second, the same is done for all airports which are potential competitors for the airport in question. If these draw their passengers from the same districts as the investigated airport, an overlap is assumed which imposes constraints on market power. This approach relies on detailed passenger data, and is therefore often difficult to reproduce. In its definition of the local catchment area of Amsterdam Schiphol Airport (AMS), Müller *et al.* (2010) focus on an area of 200 kilometres as well as a two-hour drive time around the airport. Relying, inter alia, on the analysis of the substitution potential between AMS and other airports within its catchment, this study finds that AMS has a dominant position in its catchment, thus only facing limited competition on the market for O&D passengers.

A differentiated approach towards overlapping catchment areas is introduced by Wiltshire (2013) and Thelle *et al.* (2012). The latter report finds by means of a passenger choice model that the share of European destinations which have an overlap at different airports within two hours' drive has increased in the period from 2002 to 2011. At Frankfurt Airport (FRA), for example, the share of destinations which are also offered at other airports has increased from 35 per cent to 54 per cent. For airports to exhibit equally ranked substitutes for passengers, the price, availability and frequency of flights has to be incorporated as well. The findings of Wiltshire (2013) suggest that a one per cent increase in distance decreases passengers' likelihood to travel to a particular airport by four per cent. Yet, a one per cent decrease in ticket price would provide the necessary incentive to use the further away airport.

Competition in the local catchment of airports may also be imposed by other transport modes, such as high-speed rail, but is usually constrained to short-haul traffic. The impact of (high-speed) rail services on air transport is investigated in several studies. Albalate, Bel & Fageda (2015), for example, analyse the effect of available rail services on routes offered at airports in four European countries. The findings show that air services on a route are reduced if high-speed rail services are available on this city pair. Behrens & Pels (2009) confirm this result for the market between London and Paris, stating that airlines are observed to retreat from this market by no longer offer this route. This substitution may also be taking place since rail services are acting as a complement for air services by providing feeder services to airports, thus replacing short-haul flights, and enlarging an airport's catchment area (Dobruszkes, Lennert & Hamme, 2011; Polk & Bilotkach, 2013).

The analysis by Allroggen & Malina (2010) looks at the existence and extent of market power with regard to hub airports. The cases of joint and independent profit maximisation of an airport and an airline are considered. Assumptions of the analytical model are duopolistic Bertrand competition for transfer passengers on the downstream market and a monopolistic upstream market. Both airlines and airports are considered to be profit maximisers and both exhibit symmetric cost structures. An airport's non-aeronautical revenues are not considered in the model. Due to the competition on the airline market, the authors find that the market power of hub airports is limited and that there are incentives for joint profit maximisation of the different players. In this particular case, individual profits for both the airport operator and the respective airline are maximised. The theoretical model suggests that independent profit maximisation causes a negative impact on social welfare. Considering the benefits of the strategic vertical relationship, the paper proposes to consider asymmetric regulation for hub airports, i.e. to restrain regulatory measures to areas other than the transfer passenger market.

Apart from theoretical modelling, the transfer market is often investigated by determining the overlap in transfer connections offered at an airport. Since transfer connections are a specific feature of an airline operating a hub-and-spoke network (see Chapter 3.1.2), this type of potential competition is mainly imposed on hub airports. The degree to which transfer connections at hub airports are also offered via other hub airports is calculated using airports' market shares, indices to display the degree of market concentration on a particular route, or by assessing the level of demand on a connection, and thus derive conclusions as to the level of competition (Lieshout & Burghouwt, 2013; Grosche, Klophaus & Seredynski, 2015; Malighetti, Paleari & Redondi, 2008).

The notion of airports as a business with two distinct, but interrelated markets, the one for aviation services and that for non-aviation services, provides a further strand of discussion regarding the constraint of airport market power (Gillen & Mantin, 2013). Since airports generate an increasing share of total revenues from non-aviation businesses such as retail or parking, ensuring the continuity of this source of income is of high importance. In 2015, the share of these business activities accounted for almost 40 per cent of total revenues across European airports (Airports Council International Europe, 2015). Therefore, it is argued that airports have an incentive to attract an increasing customer base using non-aviation facilities and services at the airport, thus passengers are becoming direct customers of the airport. In regard to the different business areas at an airport, Starkie (2002) and Gillen (2009) raise the argument whether the complementarity between aviation and non-aviation revenues incentivise airports to set lower charges on the aeronautical side, since the additional demand attracted by this will generate ancillary revenues on the non-aviation side, e.g. airport parking, shops, restaurants, or real estate. Research on this particular topic is still rather limited, though. Furthermore, this particular aspect will not be subject of the analysis in the following chapters, and therefore not elaborated in more detail here.

This overview of the different types of competition an airport may face helps to put the research focus of the following chapters in context, and highlight this thesis' contribution to the field of assessing airport competition. The following chapter therefore provides an overview of the research questions in regard to competition in the European hub airport market.

3.2.2 Research focus and considered dataset of European hub airports

In line with the above discussion, the research focus in the subsequent Chapters 4 and 5 is placed on the assessment of competition for European hub airports in the period from 2000 to 2016, both in their local catchment and on the transfer market. The methodological approach in both chapters will be the same, and it is partly based on the indirect approach to the assessment of market power, outlined in Figure 6 in Chapter 2.2. Certain elements of this approach are chosen since they provide a useful tool to obtain a detailed overview of the considered firms and their position in the market. In the first step in both Chapter 4 and 5, the degree of market concentration is determined on each market, the one for origin and destination traffic in the local catchment, and the one for transfer traffic passing through the hub airports. For this purpose the Herfindahl Hirschman Index is employed, an index widely used in competition analysis in different industries, and also in the airport sector (e.g. Rodrigues Pacheco, Estrada Braga & Fernandes, 2015; Papatheodorou, 2010; Lieshout & Burghouwt, 2013; Givoni & Rietveld, 2009; Albalate, Bel & Fageda, 2015). This analysis provides an initial overview of the degree of market concentration each European hub faces. Regarding the substitution potential of other airports, in regard to destinations available for passengers, this measure is a first approximation to the overlap in destinations between airports, and thus the choice passengers have when planning their journey.

However, as discussed in detail in Chapter 2.2, airport market power cannot be directly inferred from a high degree of market concentration on either the origin-destination or transfer market. The research in the following chapters therefore provides an extension to the methodologies currently applied in airport competition assessment. In the second step of the analysis of competition for European hub airports, regression analyses are employed to test the effect of market concentration on airport output. As stated by the Productivity Commission (2011), "… a monopolist will maximise its profits by reducing the total output of goods or services it supplies to the market, in order to increase the price charged" (p.71), and depicted in Figure 2.

Output in this thesis is represented by the amount of seats offered by an airport to a particular destination, with seats being scheduled airline seats. For the analysis here, supply side data, instead of actual passenger data or ticket prices, is used for several reasons. First, the analysis in Chapters 4 and 5 focuses on individual destinations and their development over time. Passenger data on this disaggregated level and across the considered time span was not available for this thesis, using supply side data therefore provides an approximation for this. Second, the same reasoning applies to ticket data, with no comprehensive database available for this thesis, which covers all investigated destinations over the considered time period. Third, using supply data for the analysis of airport competition has been part of many studies highlighted in Table 7. Albalate, Bel & Fageda (2015), for example, use the number of seats offered to a particular destination as dependent variable in their empirical estimation of the effects of high-speed rail on air transport services. Also, Burghouwt & Veldhuis (2006) make use of supply side data to analyse airports' competitive position on the aviation market between Europe and the United States. Supply side data is also applied as dependent variable in the empirical analysis by Givoni & Rietveld (2009), investigating the factors influencing the choice of aircraft size. Also relying on this type of data in regard to the analysis of competition on the transfer market are Müller *et al.* (2010).

The main source of data used in regard to supply side data is the OAG database, which provides scheduled airline traffic on a global scale, i.e. those flights are listed in the database which have been planned by airlines in advance. This includes the route (airport pair) flown as well as the available frequencies and number of seats on this route. It does not include actual passenger numbers for each flight or data on ticket prices and airline revenues. However, it gives a good overview of overall traffic volumes and the distribution across airlines and airports. Table 8 outlines the variables in the OAG database which have been used in the subsequent analysis. Due to data availability a period of 16 years, from 2000 to 2016 in intervals of four years, is considered[23].

[23] The OAG data for the year 2008 was provided by the Institute of Aircraft Design at the Technical University of Munich, which has a cooperation with Bauhaus Luftfahrt.

Table 8: Description of variables from OAG database

Variable name	Definition	Code defined by
Carrier1	Carrier code	IATA / OAG (e.g. AA)
Carrier1Name	Carrier1 name	(e.g. American Airlines)
DepAirport	Departure airport code	IATA (e.g. JFK)
ArrAirport	Arrival airport code	IATA (e.g. LHR)
ArrAirportName	Arrival airport name	(e.g. London Heathrow)
ArrCity	Arrival city code	IATA (e.g. LON)
ArrCityName	Arrival city name	(e.g. London)
ArrState	State code - unique by country only	IATA (e.g. NY)
ArrIATACtry	IATA country code	ISO/IATA (e.g. U.S.)
ArrIATACtryName	IATA country name	(e.g. United States)
ArrReg	Arrival region code based on IATA forecasting regions	OAG (e.g. NA1)
Seats	Available seat capacity (total) on departure aircraft	OAG (e.g. 420)
Km	Great Circle Distance in kilometres. The summed distance of individual legs (stopping) flights	OAG (e.g. 1325)
Frequency	The number of flights occurring in a specific time period	OAG

Source: own depiction

For the purpose of obtaining a detailed overview of the development of the European hub airport market and potential competitive constraints, a set of 36 hub airports and their respective secondary airports in the catchment are defined. Secondary airports refer to those airports which are located in the catchment areas of these hub airports (Table 42 in Appendix 8.1). A hub is an airport at which an airline and its potential alliance partners offer connecting flights between different destinations, as highlighted in Chapter 3.1.2.

The identification of European hub airports is based on several sources and assumptions. First, since a hub airport is the node of an airline operating a hub-and-spoke network, all these European airlines are identified and the respective airports included in the database, see Table 47 for an outline of these carriers. Further, the Connectivity Report by the Airports Council International Europe (2016a), which defines different categories of hub airports according to their level of connectivity in 2016, is analysed and respective airports included. In addition to this, a range of different studies investigating airport competition and the connectivity of hub airports have been evaluated to complement the above sample of European hub airports.

Table 9: Passenger volume at European hub airports

Rank	Airport	2000	2004	2008	2012	2016
1	London Heathrow Airport (LHR)	64.28	67.11	67.06	70.04	75.71
2	Paris Charles de Gaulle (CDG)	48.25	50.95	60.87	61.61	65.94
3	Amsterdam Schiphol Airport(AMS)	39.27	42.43	47.43	51.04	63.62
4	Frankfurt Airport (FRA)	48.96	50.70	53.47	57.52	60.79
5	Istanbul Atatürk Airport (IST)	14.7	15.6	28.63	45.12	60.01
6	Madrid Barajas International Airport (MAD)	32.71	38.16	50.82	45.18	50.40
7	Barcelona Airport – El Prat (BCN)	19.44	24.35	30.20	35.13	44.13
8	London Gatwick Airport (LGW)	31.95	31.39	34.21	34.24	43.14
9	Munich Airport (MUC)	22.87	26.60	34.53	38.36	42.26
10	Rome Fiumicino (FCO)	n/a	27.16	35.13	36.98	41.74
11	Moscow Sheremetyevo International Airport (SVO)	n/a	n/a	15.21	26.19	34.03
12	Paris Orly Airport (ORY)	25.40	24.05	26.21	27.23	31.24
13	Istanbul Sabiha Gökcen (SAW)	n/a	0.25	4.36	14.84	29.65
14	Copenhagen Airport (CPH)	18.40	18.89	21.48	23.29	28.99
15	Moscow Domodedovo Airport (DME)	n/a	n/a	20.45	28.25	28.50
16	Dublin Airport (DUB)	13.66	17.03	23.47	19.10	27.92
17	Zurich Airport (ZRH)	22.68	17.72	22.04	24.75	27.62
18	Palma de Mallorca Airport (PMI)	19.26	20.63	22.83	22.67	26.25
19	Manchester Airport (MAN)	18.32	20.97	21.41	19.85	25.70
20	Oslo Airport (OSL)	n/a	13.18	19.34	22.08	25.57
21	Stockholm Arlanda Airport (ARN)	n/a	16.47	18.18	19.66	24.72
22	London Stansted Airport (STN)	11.86	20.91	22.36	17.46	24.29
23	Düsseldorf Airport (DUS)	15.91	15.09	18.15	20.83	23.52
24	Vienna International Airport (VIE)	5.92	14.71	19.75	22.17	23.35
25	Lisbon Airport (LIS)	9.21	10.39	13.60	15.30	22.45
26	Brussels Airport (BRU)	21.60	15.45	18.48	18.94	21.79
27	Berlin Tegel Airport (TXL)	10.24	10.98	14.49	18.16	21.25
28	Athens International Airport (ATH)	13.35	13.66	16.45	12.86	19.99
29	Milan Malpensa Airport (MXP)	n/a	18.42	19.22	18.52	19.41
30	Antalya Airport (AYT)	n/a	n/a	18.85	25.27	18.91
31	Helsinki (HEL)	10.00	10.73	13.43	16.42	17.18
32	Vaclav Havel Airport Prague (PRG)	n/a	9.57	12.59	10.77	13.07
33	Warsaw (WAW)	n/a	n/a	9.46	9.59	12.80
34	Budapest (BUD)	n/a	6.38	8.43	8.43	11.44
35	Lyons Airport (LYS)	5.92	6.12	7.80	8.36	9.50
36	Keflavik (KEF)	1.46	1.89	2.24	2.74	6.82

Sources: (Airports Council International Europe, 2016a, 2016b; Groupe ADP, 2017; Ataturk Airport, 2017; Istanbul Sabiha Gokcen International Airport, 2017; Copenhagen Airports AS, n.d.; Zurich Airport, 2004, 2000; Eurostat, 2016; Helsinki Airport, 2016; Keflavik Airport, 2017; Budapest Airport, n.d.; Warsaw Chopin Airport, 2016; VINCI Airports, 2017; Vaclac Havel Airport Prague, 2016)

These include Burghouwt (2007), with an outline of European network carriers which are all included in the analysis here, and also Burghouwt, Mendes de Leon & De Wit (2015); Lieshout & Burghouwt (2013); Veldhuis (1997); Malighetti, Paleari & Redondi (2008); Grosche & Klophaus (2015); Grosche, Klophaus & Seredynski (2015); Dennis (1994, 1999). Airports which are considered as hubs and investigated within these studies include Basel/Mulhouse (BSL), Clermont-Ferrand (CFE), Nice (NCE), Luxembourg (LUX), Cologne-Bonn (CGN), Malaga (AGP). These are, however, not considered here due to their size and current non-hub focus. Having analysed this market and identified feasible hub airports, a dataset of 36 airports results, which includes both the largest airports in Europe in terms of passenger volume in 2016 (Airports Council International Europe, 2016b) as well as those airports which classify as hub airports.

Table 9 depicts the considered airport sample in descending order of 2016's passenger volume. The motivation to include large and small hub airports in the dataset is to analyse potential differences in the level of market concentration these various airport types are facing. Based on the above assumptions, these European hub airports and the level of competition they face, both in terms of the origin-destination market in their local catchments as well as on the transfer market, are analysed in Chapter 4 and 5, focusing on the following research questions.

In Chapter 4, the analysis focuses on hub airports and their secondary counterparts in the local catchment, and how the increased offer of flights and seats at the latter impacts the traffic development of European hub airports. This chapter therefore contributes a detailed analysis of the origin and destination (O&D) markets of the 36 largest European hub airports and their respective secondary airports in the catchment or hinterland. The first part of this chapter analyses the degree of market concentration in the local catchment, followed by an empirical estimation of this level on the output supplied at the hub airport in the second part. The following research questions are being investigated:

(1) How concentrated is the origin-destination market in the local catchment of European hub airports, and has there been a development to a less concentrated one in between 2000 and 2016 (Chapter 4.1 and 4.2)?

(2) What is the impact of market concentration on the output decisions, in terms of seats offered to a particular destination, at the European hub airports? As a measure for market concentration, the Herfindahl Hirschman Index is employed as explanatory variable in the regression analysis (Chapter 4.3.3).

(3) As discussed earlier, low cost carriers are presumed to have an impact on the rising constraints on hub airports' market power, since these particular airlines are often believed to locate their operations at smaller airports with spare capacity, i.e. those secondary airports within a hub airport's catchment, see, for example, Dobruszkes, Givoni & Vowles (2017). The third research question within this chapter therefore assesses the impact of low cost carrier presence on the output provided at hub airports (Chapter 4.3.4).

(4) Furthermore, potential competition from other modes of transport, such as (high-speed) rail, might constrain the market power of hub airports. The fourth research question therefore focuses on the evaluation of the effect of (high-speed) rail services on the seats offered at European hub airports (Chapter 4.3.5).

A similar structure can also be found in Chapter 5, here the focus is placed on the assessment of competition on the transfer market at European hub airports. This market in particular is characterised by a close interlinkage between a hub airport and its respective network carrier. The latter are those offering transfer connections for passengers via the hub airport. When assessing market concentration on the transfer market, the connections offered by network carriers and their alliance partner are thus taken into consideration. Based on this assumption, the chapter starts with a detailed analysis of the degree of market concentration, and the respective development over time, for the European hub airports in the dataset. Following this, the effects of a high degree of market concentration on the transfer connections offered via the hub are assessed empirically in the second part of the chapter.

(5) How concentrated is the transfer market, measured in the number of transfer connections and the capacities offered at each European hub airport, and has there been a development to a less concentrated market in between 2000 and 2016 (Chapters 5.1, 5.2 and 5.3)?

(6) What is the impact of market concentration on the output decisions, in terms of seats offered on a transfer connection, at European hub airports? A transfer connection is a route offered from origin A to destination B via a hub airport H. As a measure for market concentration, the Herfindahl Hirschman Index for each available transfer connection is employed as explanatory variable in the regression analysis (Chapter 5.4).

Chapter 3 provided a discussion of the characteristics of the airport market, with a particular focus on the relationship between hub airports and their network carriers, and on the current approaches to assess the degree of airport competition. This puts the specific research questions addressed within this thesis in context, and shows the overall added value. Concerning the latter, the dataset of European hub airports comprises more airports than previous studies in this field, which mostly focus on a smaller subset of these airports. Furthermore, the time span observed within the analysis in the following chapters covers a longer period than most previous studies. Therefore, the research in this thesis provides a comprehensive analysis of European hub airports and the level of potential competition these face. In addition to this, different factors, which are assumed to influence the degree of competition an airport faces, are tested empirically, using disaggregated data on the route level in order to obtain a detailed insight into the effects. In line with this, Chapter 4 starts with the analysis of the local catchment of the hub airport, and Chapter 5 continues with the assessment of the transfer market.

4 Competition in the Local Catchment of European Hub Airports

With both the liberalisation of the European aviation market and strong growth in the overall demand for air travel in the past decades new airline business models emerged, absorbing traffic growth and imposing competition on the existing carriers in the market (Morrison, 2001; Dobruszkes, Givoni & Vowles, 2017). Some of these new carriers, such as Ryanair, have been focusing their operations mainly at secondary[24] airports, which have hence been experiencing an increase in passenger volume and aircraft movements. Providing a greater array of possibilities for European passengers in terms of airports and destinations they can choose from, this development has been raising the question whether European hub airports are nowadays subject to a more competitive environment than a couple of decades ago.

Following this line of discussion, the research questions within this chapter focus on hub airports and their secondary counterparts in the local catchment, and how the increased offer of flights at the latter impacts the traffic development of the European hub airports. This chapter therefore contributes a detailed analysis of the origin and destination (O&D) markets of the 36 largest European hub airports and their respective secondary airports in the catchment or hinterland.

For this purpose, the traffic development at all considered hub and secondary airports is considered in the period from 2000 to 2016. This includes a depiction of overall traffic volume at the different airport types, the analysis of growth rates ascribed to different airline business models – full service carrier (FSC) and low cost carrier (LCC) – and the development of these over the considered period (Chapter 4.1). Following that, as proposed by Polk & Bilotkach (2013), one main line of airport market power assessment focuses on the degree of overlap of destinations between hub and secondary airports within a catchment. This degree of overlap between these is considered both at an aggregated as well as disaggregated level in Chapter 4.2, addressing research question (1) introduced in Chapter 1.

[24] In this thesis, secondary airports are those which are considered as potentially imposing constraints on market power at the hub airports in the respective catchment.

The Herfindahl Hirschman Index serves as a measure to determine the degree of overlap, or the level of market concentration, in a hub airport's catchment. On the aggregated level, the total scheduled airline seats offered at each airport in a catchment are used as basis for calculation. The disaggregated analysis focuses on the analysis of market concentration on the route level, i.e. investigating the degree of overlap between airports on a particular route, or to a specific destination (HHI_{route}). Furthermore, as an extension to the latter analysis, the distance-weighted Herfindahl Hirschman Index (HHI_{dist}) is introduced. This modified index advances the current application of the Herfindahl Hirschman Index by accounting for the size of the catchment area and the geographical location of substitute airports within it. This modified index takes account of the fact that airports which are located further away from the hub airport, thus imposing higher access times on passengers, are considered as less attractive substitutes.

Building on the analysis of market concentration in the catchment areas of European hub airports, Chapter 4.3 estimates the effect that the degree of market concentration has on the amount of scheduled airline services at each hub airport, addressing research question (2). Within the empirical models, it is controlled for a time-specific effect, covering the period from 2000 to 2016 in four-year intervals. The disaggregated Herfindahl Hirschman Indices are introduced as explanatory variables in order to assess the impact on the hub airports' output on a particular route. Furthermore, since low cost carriers have been playing an essential role in the growth of the European air transport market, the effect of the increasing presence of this business model in the hub airports' catchments is also investigated as well as the effect of potentially competing rail services on the short-haul market, thus focusing on research questions (3) and (4). Chapter 4.4 discusses the overall findings and concludes the chapter.

4.1 European hub airports and their local catchment

This chapter focuses on the determination of relevant catchment areas for all European hub airports considered in this thesis (Chapter 4.1.1). This approach is in line with the different steps conducted in the assessment of market power in an industry, including the definition of the relevant market, and as discussed in Chapter 2.2.2. Based on the identification of the relevant catchment area for each hub airport, Chapter 4.1.2 analyses the development of

European hub airports and their counterparts in the catchment area in the period from 2000 to 2016. A particular focus is placed on the distinct growth of full service carriers (FSC) and low cost carriers (LCC), and whether this is different across hub and secondary airports.

4.1.1 Definition of relevant catchment areas

When defining the relevant market for an airport it is important to differentiate between an airport's catchment area and the geographic market served. The Civil Aviation Authority (2010) highlights that the catchment area denotes the area surrounding the airport, which outbound and inbound passenger at the airport travel to or originate from. The catchment for an airport is therefore often defined by a certain time threshold passengers have to travel to access the airport. The geographic market comprises the destinations offered at the airport, i.e. airport pairs. As a first step, the catchment areas of the selected hub airports, and hence their potential substitute airports are determined by considering drive-time isochrones. The extent of isochrones can be distinguished by passenger type, time period, or airport access modes. According to passenger surveys conducted by ibid. in the UK, the benchmark for leisure passengers is at two hours and for business passengers at one hour driving time.

Detailed demographic information helps to obtain a comprehensive picture of the potential catchment area. Mandel (2014) emphasises that for each passenger segment and trip purpose as well as route a unique catchment area exists which has to be taken into consideration. It is also not just the catchment area of the hub airport itself but the overlap with other airports that determines the level of competition. Various studies (Table 10) investigate the size of and shift in airport catchment areas in more detail by accounting for traveller type, airport access, or airline product quality such as flight frequency and price.

Staub (2014) analyses a range of criteria influencing airport and airline choice in a predefined area in Germany, and applies the output of the model to identify catchment areas for those airports in the study. The results show that catchment areas deviate from the two-hour driving isochrones assumed in a range of other studies.

Table 10: Overview of definitions of airport catchment area

Study	Definition catchment area
ACI (2013)	Passenger point of view: considering the drive time (2hrs) and the potential amount of airports to be reached within this time
Boonekamp & Zuidberg (2016)	Airport catchment area: assignment of population on NUTS-2 level within 100km radius around selected airports
Competition Commission (2009)	Hypothetical monopoly test (SSNIP) employed to determine airport-specific catchment area
Civil Aviation Authority (2010)	Airport catchment area: (1) isochrones approach considering different driving times (congestion-free) and transport modes; depending on passenger willing to travel (e.g. depending on route and passenger type); rather used as 'benchmarks'; overlapping between catchments, and (2) historical usage patterns (using passenger survey data or airline booking patterns)
Civil Aviation Authority (2016)	Estimating the geographic area from which a large proportion of an airport's outbound passengers originate; catchment areas do not incorporate passenger price sensitivity and hence may overestimate competitive constraint Hypothetical monopoly test (SSNIP) employed to determine airport-specific catchment area
Fuellhart (2007)	Airport catchment defined as the radius of 75 miles surrounding the specific airports
Lieshout (2012)	Consideration of dynamic airport catchment areas: size determined by access time, flight frequency and/or air fares
Maertens (2012)	Airport catchment area: NUTS-3 level regions located within 100km by car from the relevant airport; presence of low cost carriers can increase catchment
Mandel (2014)	Airport catchment area variation according to passenger segment, trip purpose and routes; overlap with other airports determines the level of competition
Marcucci & Gatta (2011)	Airport catchment area: consideration of people within a two-hour-driving radius around the airport
Postorino (2010)	Airport catchment area: all users and passengers of an airport, application of accessibility indices to determine size of catchment; consideration of prefixed time value such as 2 hours for European airports; differentiation of primary and secondary catchment area (affected by e.g. income, population, employment)
Staub (2014)	Airport catchment area: differentiation by passenger type and route choice, static value cannot be assumed.
Starkie (2010)	Airport attractiveness determined by its relation to market demand (population density, income level, business activity, international trade links, tourism potential, quality of transport links - airport access time); differentiation of access time by passenger type; overlap of catchment areas: geographical segmentation of customer not possible
Thelle *et al.* (2012)	Airport catchment area: assuming "normal transport time": at least either 100 km or 1h drive time (airports argue that catchment areas exceed this limit), differentiation by passenger segment; overlap of routes as important factor

Source: own depiction

Lieshout (2012) further shows that the size of the catchment area and hence the potential competition differs across offered destinations. In this study, the access costs, airlines' airfares as well as airside time costs are considered. The model is tested for Amsterdam Airport (AMS) and shows that especially long-haul connections have a large catchment area and a different potentially competitive airport set than many short-haul connections. Destinations can be further differentiated according to their main travel purpose such as holiday locations. This approach to the definition of airport catchment areas yields a more dynamic picture compared to the static one resulting from the two-hour driving radius. Dobruszkes, Lennert & Hamme (2011) state that the accurate catchment area size can only be determined by conducting detailed analysis and surveys of the socio-demographic characteristics and choice criteria of potential passengers in the area surrounding the relevant airport. Since no comprehensive data on all the considered European hub airports in regard to the socio-economic characteristics of the passengers in the catchment is available for the purpose of this thesis, catchment areas are determined using both a one-hour and two-hour driving radius for each of the hub airports. For this purpose, the fastest free-flow driving time between a hub airport and each of its respective secondary airports is determined using Google (2017); toll roads are included if they represent the fastest route. Figure 8 and Figure 9 illustrate the examples of London Heathrow Airport (LHR) and Frankfurt Airport (FRA) and the respective airports within the catchment area.

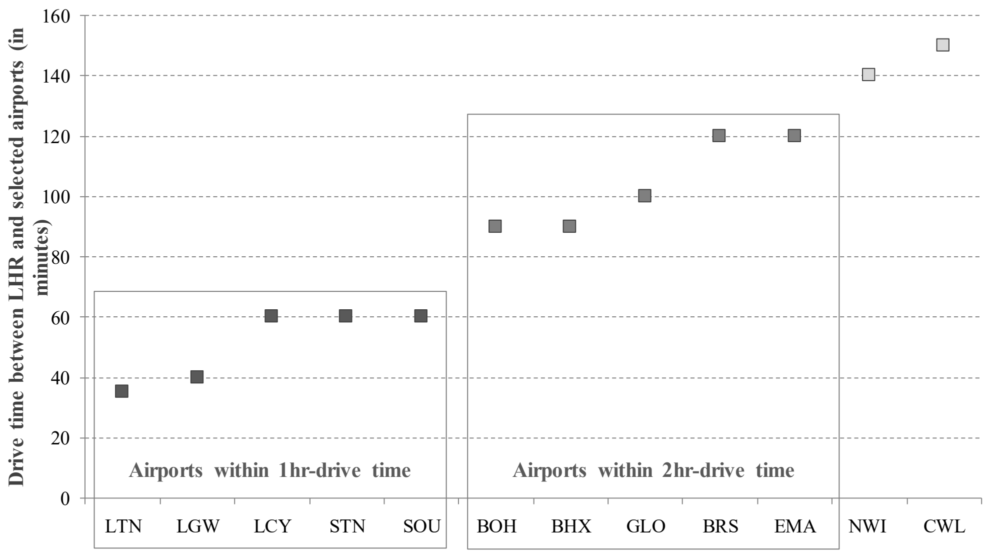

Figure 8: Local catchment of London Heathrow Airport

Source: own depiction, drive times from Google (2017)

Frankfurt Airport, for example, faces only one potential competitor within a one-hour driving radius whereas it is five airports for London Heathrow. Considering a two-hour radius, there are eight additional airports exhibiting potential competition for Frankfurt Airport and five more for London Heathrow Airport.

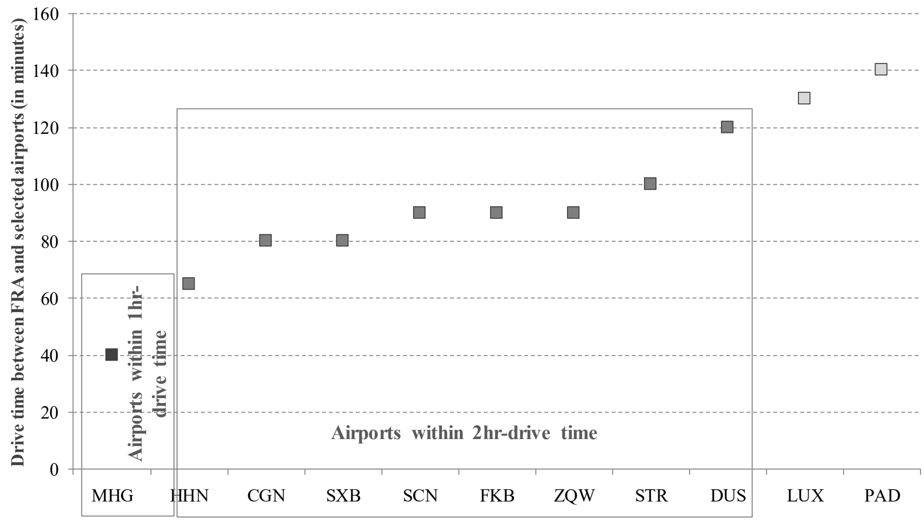

Figure 9: Local catchment of Frankfurt Airport

Source: own depiction, drive times extracted from Google (2017)

The airports in the local catchment for all hub airports are depicted in Table 42, ranked according to their passenger volume in 2016. Those airports within the local catchment of an airport have been selected that have scheduled passenger traffic according to the OAG database[25].

Hence, no explicit differentiation is made between passenger types and time of day. However, considering a one- and a two-hour catchment might provide a proxy for different passenger groups' willingness to drive to the airport. Furthermore, especially for short-haul connections passengers have the possibility to switch to other transport modes such as (high-speed) rail in order to get from A to B. The potential impact of this particular mode may have

[25] Not within the scope of the analysis within this thesis but an indication for future research is the consideration of catchment areas at each arrival airport. This means that in the determination of overlap between routes not only flights from the catchment area of Frankfurt Airport (FRA) to particularly London Heathrow Airport (LHR), for example, are considered but flights to all airports within the catchment of LHR.

an effect on the short-haul routes offered at an airport and will therefore be considered in more detail in Chapter 4.3.5

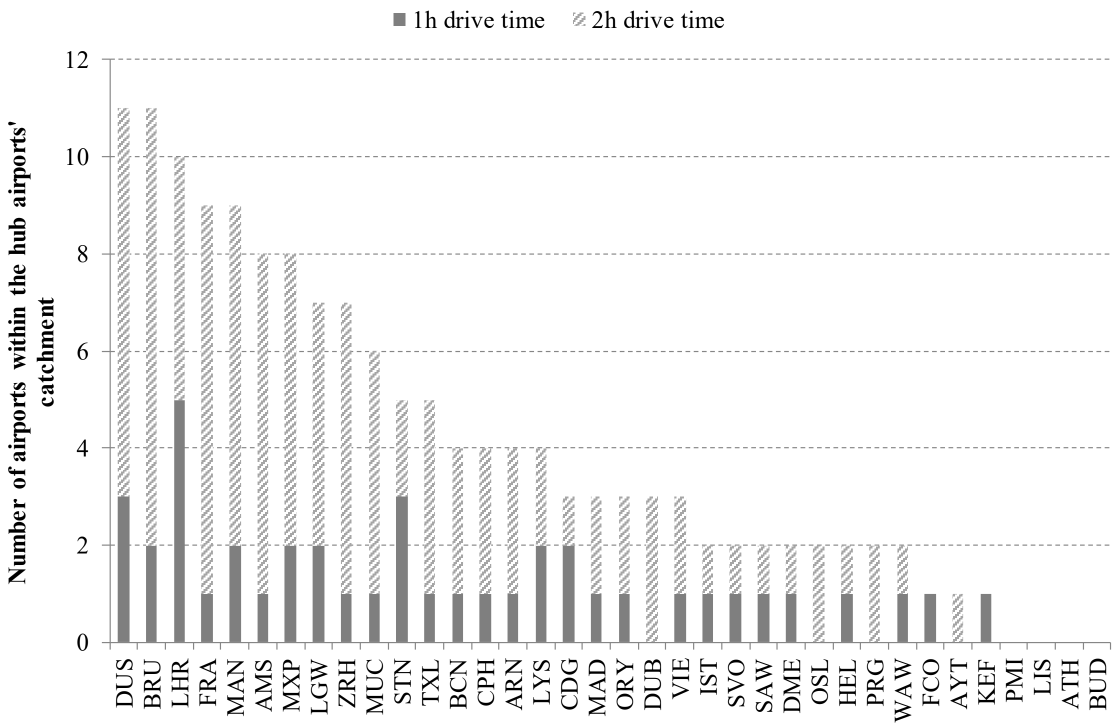

Figure 10: Secondary airports within catchment of European hub airports

Source: own depiction, drive times extracted from Google (2017)

4.1.2 Development of European hub airports within their catchment

This chapter provides an insight into the traffic development at both hub airports and their respective secondary airports (see Table 42), with a particular focus on both the growth of low cost traffic and its distribution across the different airport types.

Figure 11 depicts the aggregated number of seats offered at each airport type in the period from 2000 to 2016. The seats per year offered by each airport are depicted in logarithms in the figure to provide a better comparison between the different airports, the following discussion regarding the change in these over time refers to the actual amount of seats. Hence, considering total seats offered within each catchment, European hub airports' market share amounts to above 80 per cent in each period. In terms of overall size, the latter are hence dominating the market within their catchment. However, secondary airports have been experiencing faster growth within the considered period, with an increase in seats from 2000 to 2016 of more than 110 per cent, compared to an increase of almost 60 per cent at hub airports. In order to gain a better understanding of the factors driving this growth, and how this may affect the competitive constraints imposed on hub airports, the development of low cost carrier (LCC) and full service carrier (FSC) within this period is analysed.

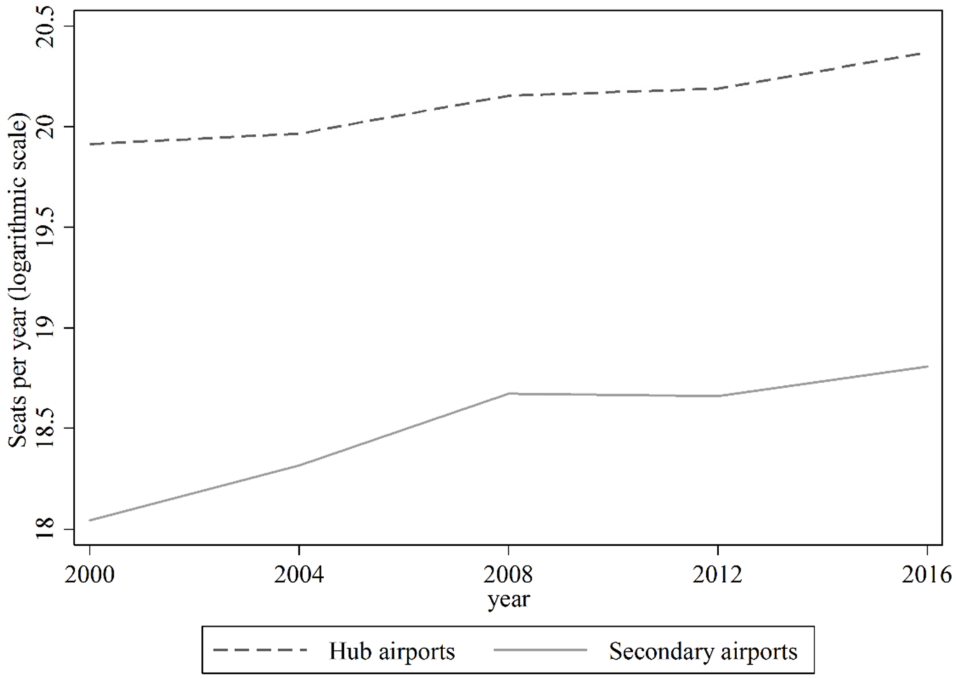

Figure 11: Development of seats offered at hub and secondary airports
Source: own depiction based on OAG data

For this purpose, Table 11 shows the aggregated number of seats and frequencies in 2000 and 2016 for both full service and low cost carriers[26] for all the considered hub airports and those secondary airports within their catchment. The absolute number of seats and frequencies offered by full service carriers (FSC) exceeds that of low cost carriers (LCC) in both years. However, LCC traffic has been increasing by more than 600 per cent (seats), and more than 500 per cent (frequencies). FSC have also increased their seats within that period, but only by 28 per cent; frequencies, however, have declined by 2 per cent, rationed by the

[26] An overview of low cost carriers within each region and year can be found in Appendix 8.3, all remaining airlines are considered as full service carriers within this analysis.

use of larger aircraft with a mean of 122 seats per flight in 2000, compared to 159 seats per flight in 2016.

Table 11: Change in seats and frequencies offered by LCC and FSC (2000 and 2016)

	LCC 2000	LCC 2016	FSC 2000	FSC 2016
Seats p.a. (in million)	29.55	227.41	484.18	620.97
Frequency p.a. (in thousands)	209	1332	3982	3904
Mean seats per flight	141	171	122	159

Source: own calculation based on OAG data

To see how the growth of LCC and FSC is distributed across the considered hub airports and their respective competitors in the catchment, the development of respective aggregated seats and frequencies across these airports is analysed. Table 12 shows the seats and frequencies per year as well as the mean seats per flight for the years 2000 and 2016. Here, it is distinguished between the type of carrier (FSC and LCC) and the type of airport (Hub and Secondary). Hub airports refer to all airports in the considered data set in Table 9, and secondary airports include all those airports in the respective catchment areas as outlined in Table 42.

Table 12: Change in offered seats and frequencies by airport type (2000 and 2016)

		Hub			Secondary		
	Carrier	2000	2016	Change	2000	2016	Change
Seats p.a. (in million)	FSC	426.36	559.23	31%	57.82	61.74	7%
	LCC	18.86	142.31	559%	10.69	85.10	696%
Frequency p.a. (in thousands)	FSC	3226	3387	5%	757	518	-32%
	LCC	135	814	503%	74	519	601%
Mean seats per flight	FSC	132	165	25%	76	119	57%
	LCC	139	175	26%	145	164	13%

Source: own calculation based on OAG data

At the hub airports, the number of seats offered by LCC has been growing from less than 20 million in 2000 to more than 140 million in 2016. At the seondary airports, seats have been increasing from about eleven million in 2000 to about 85 million in 2016. The same holds for offered frequencies by LCC at both airport types. Compared to this, FSC have been experiencing much lower growth rates in regard to seats offered per year within this period, which is also depicted in Figure 12. Dobruszkes (2013) points out that low cost carriers are more focused on short-haul routes, and hence on the European market, whereas full service carriers offer both short-haul and long-destinations.

However, low cost carrier traffic at secondary airports experienced a slight drop in seats and frequencies after 2008. At hub airports, a slowdown rather than a drop in growth can be observed at this point in time. This might imply that low cost carriers at secondary airports (*LCC secondary airport*) have been affected more severely by the financial crisis in 2008/2009 than those at hub airports (*LCC hub airport*). Or that in a time of economic downturn, low cost carriers have been focusing their operations more strongly on hub airports due to sufficient demand at these nodes.

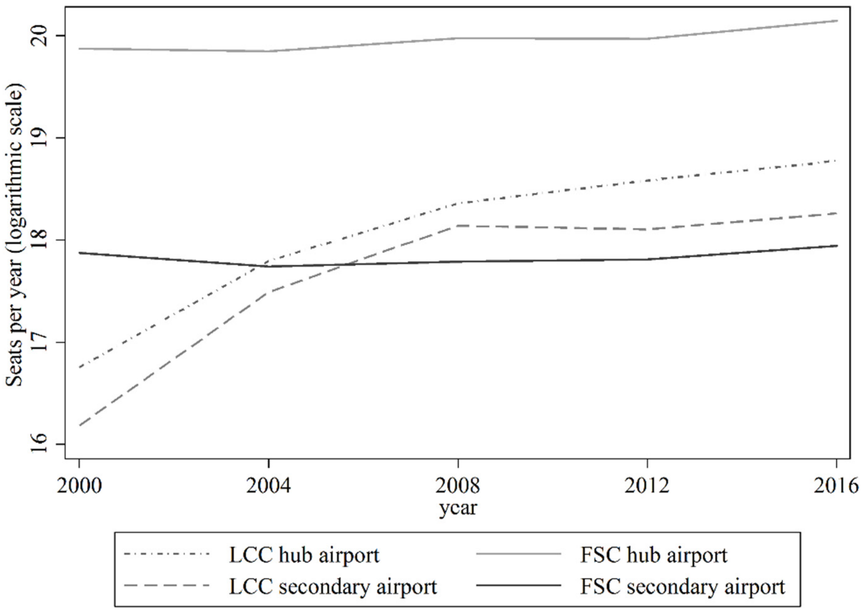

Figure 12: Distribution of seats across hub and secondary airports

Source: own depiction based on OAG data

Another development to be observed in this market is the change in the mean number of seats offered per flight. Based on the aggregated volume of traffic by full service carriers, seats per flight rose by more than 20 per cent and about 60 per cent at hub and secondary airports, respectively. The mean seats per flight can be raised by either employing larger aircarft or increasing seat density for the existing aircraft. In the empirical analysis in Chapter 4.3, the impact of market concentration in a hub airport's catchment as well as the potential competition by low cost carrier is investigated in more detail. Furthermore, the initial analysis in this chapter shows that both hub and secondary airports in Europe have been experiencing growth in terms of total offered seats in the period between 2000 and 2016. Low cost carrier traffic growth is not concentrated at secondary airports, but has been spread across the different types of airports. In terms of competition, hub airports may have reacted to increasing low cost carrier presence by providing capacities for these particular airlines, and thus meeting the growth of these airlines at secondary airports in the catchment. In order to obtain a more detailed insight into the effects of these developments on the behaviour of hub airports, the following chapter analyses the level of market concentration hub airports face.

4.2 Analysis of market concentration at European hub airports

The analysis of the European airport market shows an increase in offered seats both at hub and secondary airports, which is mainly driven by low cost carriers. Since hub airports are, on average, still significantly larger than the airports within their catchment, the degree of market concentration in each catchment as well as the respective development over time will be analysed in more detail. Applying the Herfindahl Hirschman Index as a measure for market concentration therefore yields further insight into the level of potential substitution between a hub airport and its secondary airports in the catchment. Hence, in a first step, the development of market concentration at European airports in the period between 2000 and 2016 is outlined (Chapters 4.2.1 and 4.2.2). Following the discussion of the properties of the Herfindahl Hirschman Index and potential inconsistencies of this index in Chapter 2.2.2, a weighting factor is introduced in Chapter 4.2.3, which accounts for the distance of each secondary airport from the hub airport in the respective catchment area. This implies that secondary airports closer to the hub airport have a higher substitution potential for passengers than those further away.

4.2.1 Development of aggregated market concentration

One line of argument in academia and industry highlights the growth of additional airports in the catchment area of European hub airports, resulting in an increased choice for passengers where to depart from (and arrive at) and thus decreasing market power in the airport industry. Within this chapter the focus is therefore on the development of market concentration in each of the European hub airport’s catchment areas. To analyse this, the

Herfindahl Hirschman Index is applied using each airport's total seats offered per year as a share of overall offered seats within the respective catchment (HHI_{aggr}):

$$HHI_{aggr} = \sum_{i=1}^{N} s_{aggr,i}^2 \tag{12}$$

Where $s_{aggr,i} = Q_{aggr,i}/Q_{aggr}$ represents the share of airport i's total output $Q_{aggr,i}$ in total output in the catchment (Q_{aggr}). Calculating the HHI_{aggr} therefore yields a single aggregated value for each hub airport catchment. Comparing the changes in this index over the considered time period from 2000 to 2016 provides a first insight in which catchment areas the degree of market concentration changed significantly, either positively or negatively.

Table 13 shows the HHI_{aggr} for each airport in 2000. For each of the following years the delta to the previous year is depicted, here the airports are sorted in descending order of passenger volume in 2016. From the discussion in Chapter 2.2, it can be seen that there is no clear definition of a specific threshold of the value of the Herfindahl Hirschman Index at which an industry or a market is considered to exhibit low concentration or, alternatively, a high level of competition. Most often, changes in concentration indices over time are considered in order to evaluate whether an industry has been exposed to increasing levels of competition. A similar approach will be followed within this analysis, in which (1) the change in the HHI_{aggr} for all European hub airports in the dataset will be considered, and (2) the level of this value will be further investigated.

In this first part of the analysis, i.e. observing changes in the HHI_{aggr} over time, several observations can be made from the calculation of the aggregated Herfindahl Hirschman Index (HHI_{aggr}) and its development for each European hub airport over time (Table 13):

(1) hub airports with a HHI_{aggr} value of 1 over the entire observed period,

(2) airports with slightly fluctuating values but rather remaining at the same HHI_{aggr} level,

(3) those airports with increasing HHI_{aggr} values, and

(4) those with a decreasing HHI_{aggr} over time.

The first category contains those airports with no competitors offering scheduled airline services in their catchment area, including PMI, LIS, ATH, and BUD (as can also be seen in

Table 42 in Appendix 8.1). Furthermore, MAD and KEF are within this category since the airports within their catchments either only offer a very small amount of seats or no scheduled seats at all during this period, which results in a constant HHIaggr of 1 from 2000 up to 2016.

Table 13: HHI_{aggr} for European airports

		Change in HHI_{aggr}			
Hub airport	2000	2000-2004	2004-2008	2008-2012	2012-2016
LHR	0.38	-0.08	-0.05	0.03	-0.04
CDG	0.55	-0.01	0.00	-0.03	0.00
AMS	0.35	0.02	-0.02	-0.02	0.01
FRA	0.41	-0.03	-0.02	0.02	-0.01
IST	1.00	-0.01	-0.15	-0.18	-0.10
MAD	1.00	0.00	0.00	0.00	0.00
BCN	0.94	-0.15	-0.08	0.10	0.08
LGW	0.40	-0.06	-0.05	0.03	-0.04
MUC	0.48	0.03	0.00	0.01	0.02
FCO	0.98	-0.12	-0.06	0.01	0.00
SVO	0.52	-0.08	-0.07	0.01	-0.01
ORY	0.55	-0.01	0.00	-0.03	0.00
SAW	0.00	0.99	-0.15	-0.18	-0.10
CPH	0.78	0.05	0.00	-0.02	0.02
DME	0.52	-0.08	-0.07	0.01	-0.01
DUB	0.60	-0.04	0.01	0.01	0.05
ZRH	0.44	-0.03	0.00	0.00	0.01
PMI	1.00	0.00	0.00	0.00	0.00
MAN	0.34	-0.05	-0.04	0.04	0.03
OSL	0.90	-0.03	-0.04	-0.08	0.08
ARN	0.82	-0.11	-0.06	-0.01	0.06
STN	0.45	-0.06	-0.05	0.03	-0.05
DUS	0.25	0.01	-0.01	0.01	-0.01
VIE	0.79	-0.02	-0.05	0.09	-0.02
LIS	1.00	0.00	0.00	0.00	0.00
BRU	0.29	-0.01	-0.01	-0.02	0.00
TXL	0.51	-0.05	-0.02	0.02	-0.02
ATH	1.00	0.00	0.00	0.00	0.00
MXP	0.41	-0.10	-0.03	-0.02	0.01
AYT	0.99	0.01	0.00	0.00	-0.01
HEL	0.89	0.04	0.01	-0.01	0.02
PRG	0.63	0.12	0.03	-0.05	0.03
WAW	1.00	-0.01	-0.05	-0.20	-0.06
BUD	1.00	0.00	0.00	0.00	0.00
LYS	0.44	0.02	0.02	0.04	0.00
KEF	1.00	0.00	0.00	0.00	0.00

Source: own calculation based on OAG data

In the second category, there is only a small number of airports with a rather constant HHI_{aggr} over time, meaning that the respective values in 2000 and 2016 are the same, including DUS, AYT, and VIE. The latter exhibits a high level of fluctuation over time, with a drop in the

HHI_{aggr} level up to 2008 and an increase up to 2016 again. Three airports within this catchment experienced a decline in scheduled airline seats between 2008 and 2012, with Bratislava Airport (BTS) having the steepest decline with seats dropping by more than 70 per cent (see Figure 13). VIE, on the contrary, saw an increase in offered seats within this period. Therefore, an increase in market concentration within this particular period can be observed.

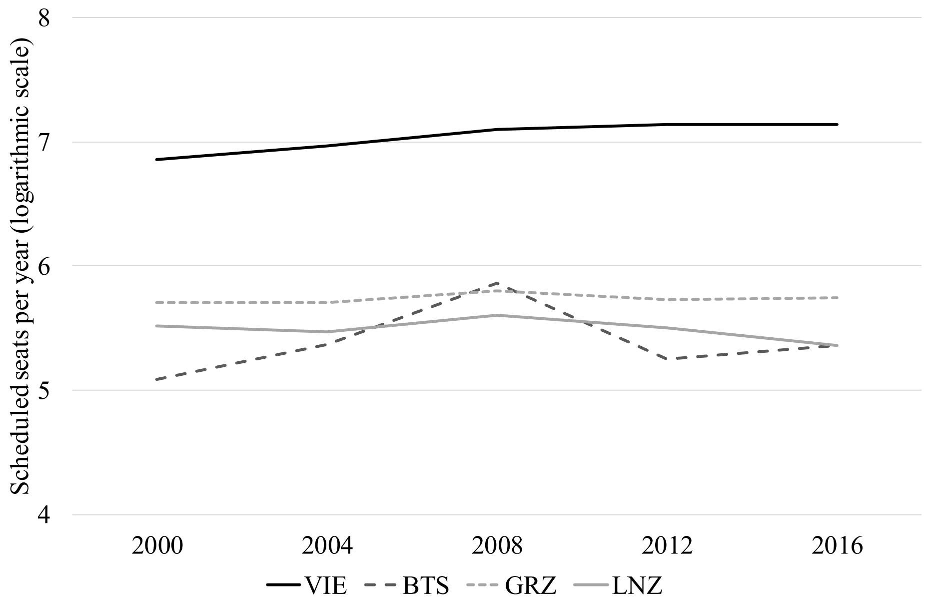

Figure 13: Development of scheduled seats at airports in VIE catchment
Source: Own calculation using OAG data

The third category incorporates those airports whose HHI_{aggr} in the catchment has been increasing over time: MUC, CPH, DUB, HEL, PRG, and LYS. The highest increase in market concentration can be found in the catchment area of PRG, with an observed increase in HHI_{aggr} of 0.12 from 2000 to 2004. Within this catchment, PRG is the largest airports, followed by Dresden Airport (DRS), with about half the number of seats offered in 2000 (own calculation based on OAG data). PRG almost doubled its offered seats between 2000 and 2004, whereas DRS only grew by two per cent in this period. Since the third airport in this catchment, Karlovy Vary Airport (KLV), is less than one per cent in terms of size compared to PRG, it does not have a significant impact on the degree of market concentration. MUC, as one of the largest European hub airports, has also seen an increase in the HHI_{aggr} in its catchment. Although with five additional airports representing a relatively high amount of competitors in the catchment, all these are rather small in terms of seats offered per year compared to MUC (Figure 14).

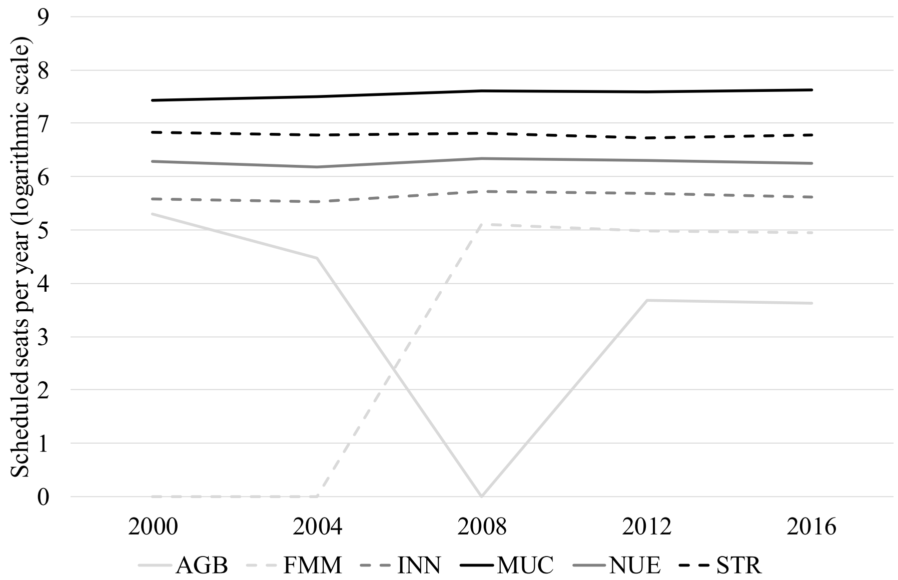

Figure 14: Development of scheduled seats at airports in MUC catchment
Source: own depiction based on OAG data

In the fourth category, three airports within the dataset are subject to a decrease in market concentration in each consecutive year: IST, SAW, and WAW. The decrease in market concentration at IST is due to an increasing number of airports offering scheduled services, namely SAW in 2004, and Cengiz Topel Airport (KCO) in 2008 and onwards. The same applies to WAW, which was the only airport operating in its catchment in 2000. From 2004 onwards, Lodz Airport (LCJ) started offering scheduled airline services, and from 2012 onwards also Nowy Dwor Mazowiecki Airport (WMI). The entrance of WMI into the market contributed to the steep decrease of 0.20 in the HHI_{aggr} in the period between 2008 and 2012.

With 18 European hub airports, the highest share of airports has seen a decrease in the HHI_{aggr} in the period between 2000 and 2016, including seven of the ten largest airports in Europe: LHR, CDG, AMS, FRA, BCN, LGW, FCO, SVO, ORY, DME, ZRH, MAN, OSL, ARN, STN, BRU, TXL, MXP. Airports that stand out in regard to the absolute decrease in HHI_{aggr} are the London airports LHR, LGW, and STN, the two airports in Moscow SVO and DME as well as ARN, FCO, and MXP. Taking LHR as an example of the development of market concentration for the London airports, the HHI_{aggr} has been decreasing by 0.12 in between 2000 and 2016, from 0.38 to 0.25. Figure 15 illustrates the development of the index over time, showing a slight increase in the period from 2008 to 2012. During this period, STN experienced a steep decrease in total seats offered, with about 18 per cent of the seats LHR offered in 2008, and less than ten per cent of these in 2012. In the following period from 2012 to 2016 a decrease in the HHI_{aggr} can be observed again, the growth of STN being one contributing factor.

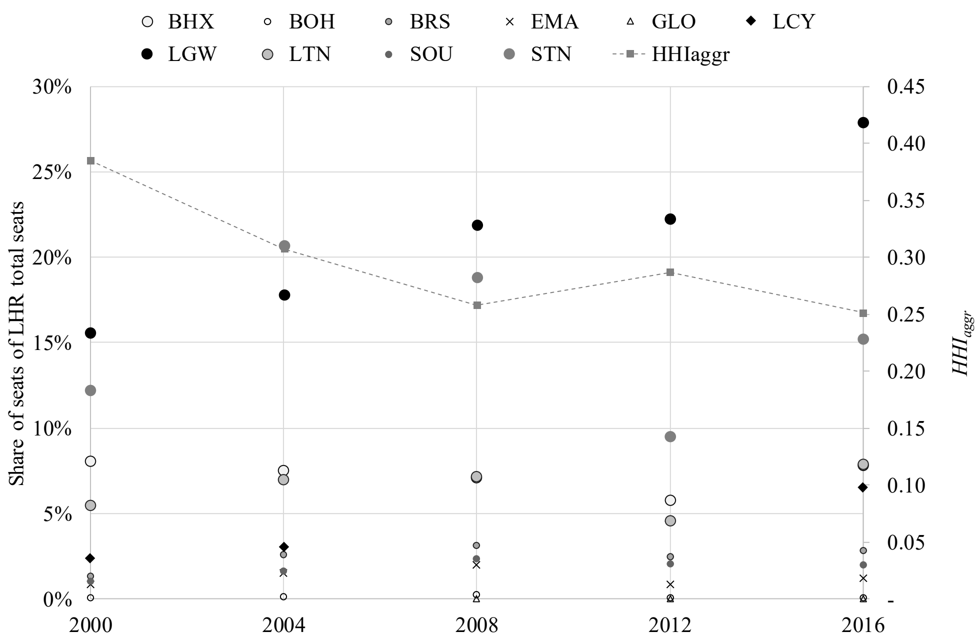

Figure 15: Development of HHI_{aggr} in the LHR catchment

Source: own depiction based on OAG data

Adding to these observations, in the second part of the analysis, the overall level of the HHI_{aggr} has to be considered. As discussed in Chapter 2.2 there are no fixed thresholds for Herfindahl Hirschman Index, or market shares in general, at which an industry or firm is implied to have market power. To obtain an indication how the level of the HHI_{aggr} developed across the European hub airport dataset, Table 14 depicts the mean, minimum and maximum values as well as the standard deviation of the index, averaged across airports and over time.

Table 14: Development of HHI_{aggr} for all European hub airports and over time

HHI_{aggr}	2000	2004	2008	2012	2016
Mean	0.67	0.66	0.63	0.62	0.62
Standard deviation	0.26	0.27	0.27	0.26	0.27
Minimum	0.25	0.26	0.24	0.25	0.24
Maximum	1.00	1.00	1.00	1.00	1.00
Median	0.60	0.64	0.61	0.61	0.57

Source: own calculation based on OAG data

It shows that the mean value of the HHI_{aggr} is above 0.60 across the entire observed period and that the value does not fall below 0.25 in this time. The mean HHI_{aggr} over time for each European hub airport is illustrated in Figure 16, comparing these to the mean as well as minimum Herfindahl Hirschman Index values across the dataset.

The dark shaded blocks in this figure highlight those airports which have been facing a decreasing HHI_{aggr} over the observed period. The majority of European hub airports in this category are well below the mean HHI_{aggr} of the dataset.

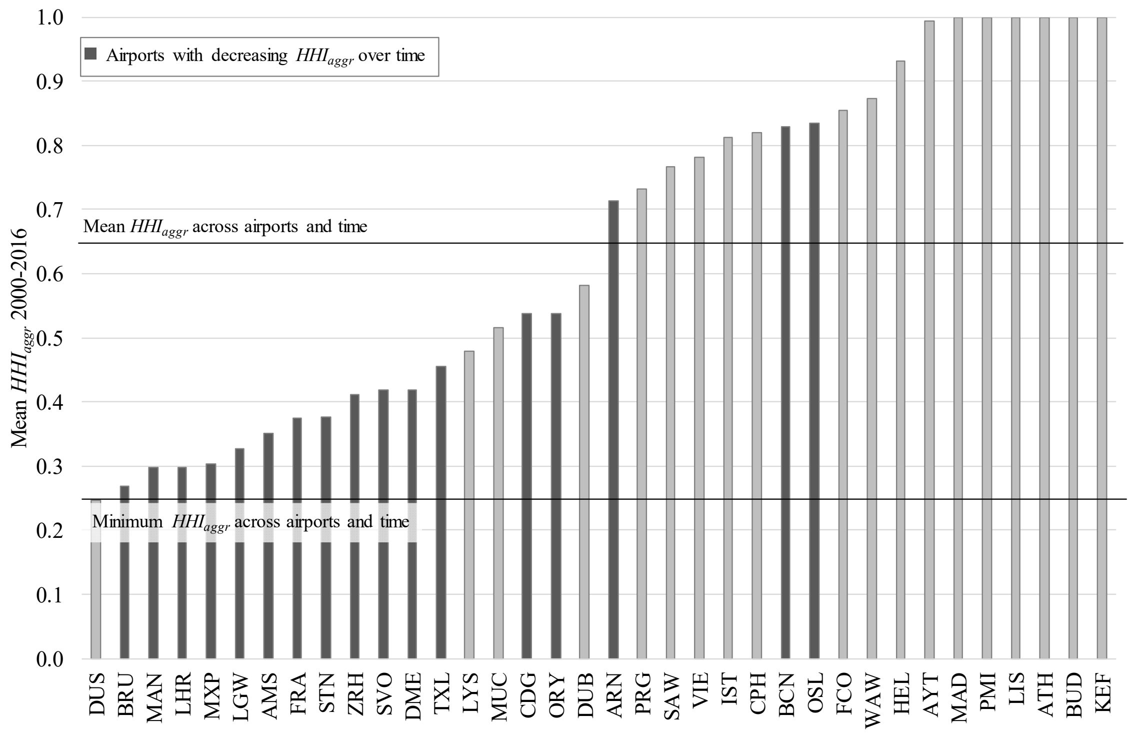

Figure 16: Mean HHI_{aggr} for European hub airports (2000-2016)

Source: own depiction based on OAG data

However, in order to derive a statement on the degree of aggregated market concentration for each airport, the number of competitors in each market has to be considered as well. As can be seen from (4) in Chapter 2.2.2, the number of firms is inversely related to the Herfindahl Hirschman Index, and the lowest value this index can take is determined by 1/N, assuming firms of equal size in the market (Bikker & Haaf, 2002). For example, if there are ten competitors in the market with equal market shares, the lowest value the Herfindahl Hirschman Index can take is 0.10. On the contrary, if there are only two firms of equal size in the market, the lowest value of the index is 0.50. Figure 17 depicts this specific relationship using the data for the European hub airports, i.e. the HHI_{aggr} decreases with the number of competing airports in the catchment, and thus the more firms there are in the market, the lower is the HHI_{aggr}.

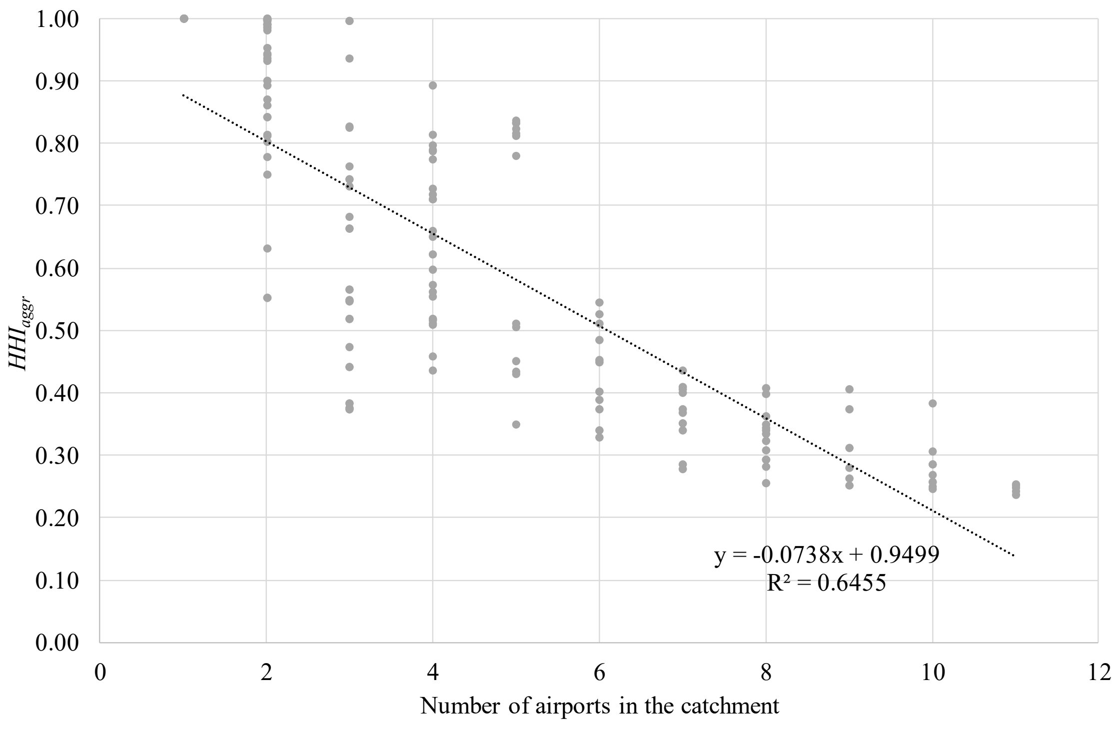

Figure 17: Correlation between HHI_{aggr} and number of airports in the catchment

Source: own depiction based on OAG data

Taking this correlation into account, it is interesting to consider the minimum value the HHI_{aggr} can attain for each airport and each year and compare the actual values to these. For example, in the catchment area of Amsterdam Airport (AMS) the number of airports rose from five in 2000 to eight in 2016, thus arriving at minimum attainable values of 0.20 and 0.13, respectively. The actual HHI_{aggr} values for AMS in these years are 0.35 and 0.34, respectively. This implies that the variance in firm size is larger in 2016 than in 2000, i.e. it can be assumed that although new competitors entered the market, these are rather small in terms of size compared to the largest airport AMS in the catchment. Looking at the 45 degree line in Figure 18 shows that no hub catchment has an HHI_{aggr} which is at the minimum attainable level.

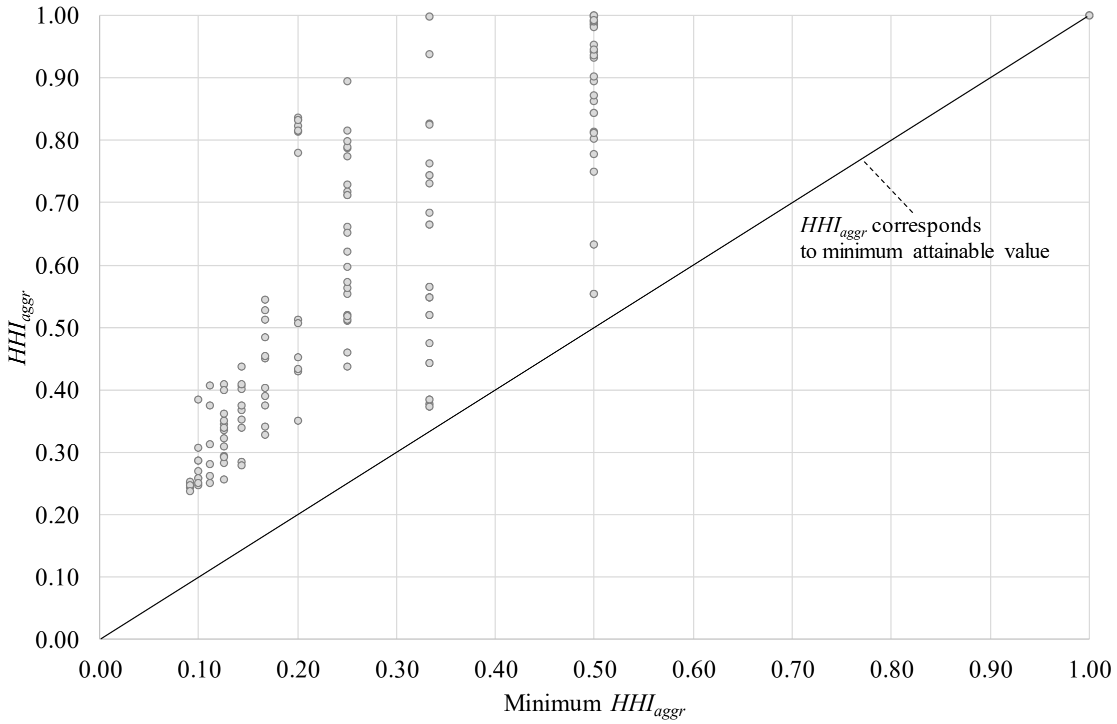

Figure 18: Comparison of actual HHI_{aggr} to minimum attainable value

Source: own depiction based on OAG data

One hub airport catchment can be observed, though, which faced a decreasing HHI_{aggr} over time and is moving close to its minimum attainable value, this includes the airports SVO and DME in Moscow. In this market, there are three firms (see Table 42), SVO, DME and Vnukovo Airport (VKO), thus leading to a minimum attainable HHI_{aggr} of 0.33. The actual value of 0.37 in 2016 implies that seats within this catchment are rather evenly distributed across the three airports.

Giving a high-level insight into the development of market concentration in the catchment areas of European hub airports, it can be observed that almost 60 per cent of these have seen a decrease in the HHI_{aggr} over the observed period between 2000 up to 2016. This development indicates that secondary airports within the catchment of hub airports have either started offering scheduled airline services, or extended their flight schedules within this period. Coming back to the initial argument outlined in Chapter 4.1, that European (hub) airports face an increasing level of competition due to smaller airports extending their services, the analysis here supports the argument of increased scheduled airline services at airports besides the hubs. However, from this initial analysis it cannot be concluded that European hub airports face an increasing level of competition from their counterparts in the catchment. The aggregated Herfindahl Hirschman Index here uses the total seats per year offered by each airport in a catchment. It therefore tells something about the distribution of size across the airports within a catchment, it does not, however, give insight into the overlap between destinations, and hence potential competition, these airports face from one another. Chapter 4.2.2 therefore focuses on the analysis of market concentration on the destination or route-level. This means that the degree of market concentration for each route or destination offered at the hub airports in the dataset is determined, taking into consideration the airports within the catchment. Investigating the overlap between offered destinations within a catchment thus yields insight into the substitution potential passengers have when wanting to travel to a specific destination.

4.2.2 Analysis of market concentration on the route-level

Continuing with the analysis of market concentration in the local catchment of European hub airports, this chapter focuses on the calculation and consecutive analysis of the disaggregated Herfindahl Hirschman Index (HHI_{route}). The intention of this detailed approach is to determine the degree of overlap between routes that are offered at a hub airport and its secondary airports within the catchment. Figure 19 illustrates this approach in more detail:

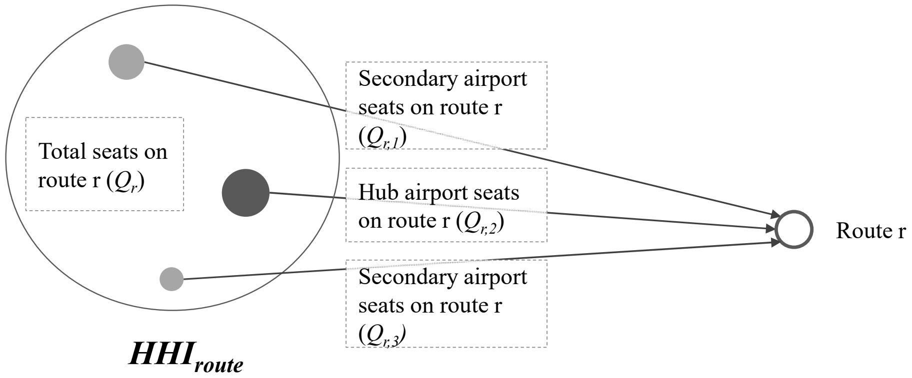

Figure 19: Calculation of HHI_{route} for European hub airports

Source: own depiction

The left-hand side of the figure comprises all airports in a hub airport's catchment (i, with i = 1, …, N), which all offer seats on a particular route r (or to a destination), with r = 1, …, M. Therefore, the total seats offered on route r (Q_r) per year are the sum of seats by all airports i in the catchment ($Q_{r,i}$) in this year. The disaggregated Herfindahl Hirschman Index (HHI_{route}) is thus calculated as follows:

$$HHI_{route,r} = \sum_{i=1}^{N} s_{r,i}^2 \tag{13}$$

Where $s_{r,i} = Q_{r,i}/Q_r$ represents the share of airport i's output $Q_{r,i}$ in total output in the catchment (Q_r) on route r. Calculating the HHI_{route} therefore yields a single value for each route offered at the hub airport. As in Chapter 4.2.1, the subsequent analysis of the HHI_{route} focuses on (1) the change of this index over time for different routes and by hub airport, as well as (2) the level across airports and the potential implications.

In order to observe the change of the HHI_{route} for all European hub airports in the dataset, each route is analysed individually in terms of changes in its HHI_{route} value over time. This approach is illustrated in more detail by employing Frankfurt Airport (FRA) as an example. Figure 20 depicts the delta in a HHI_{route} between two consecutive periods, including all years in the dataset.

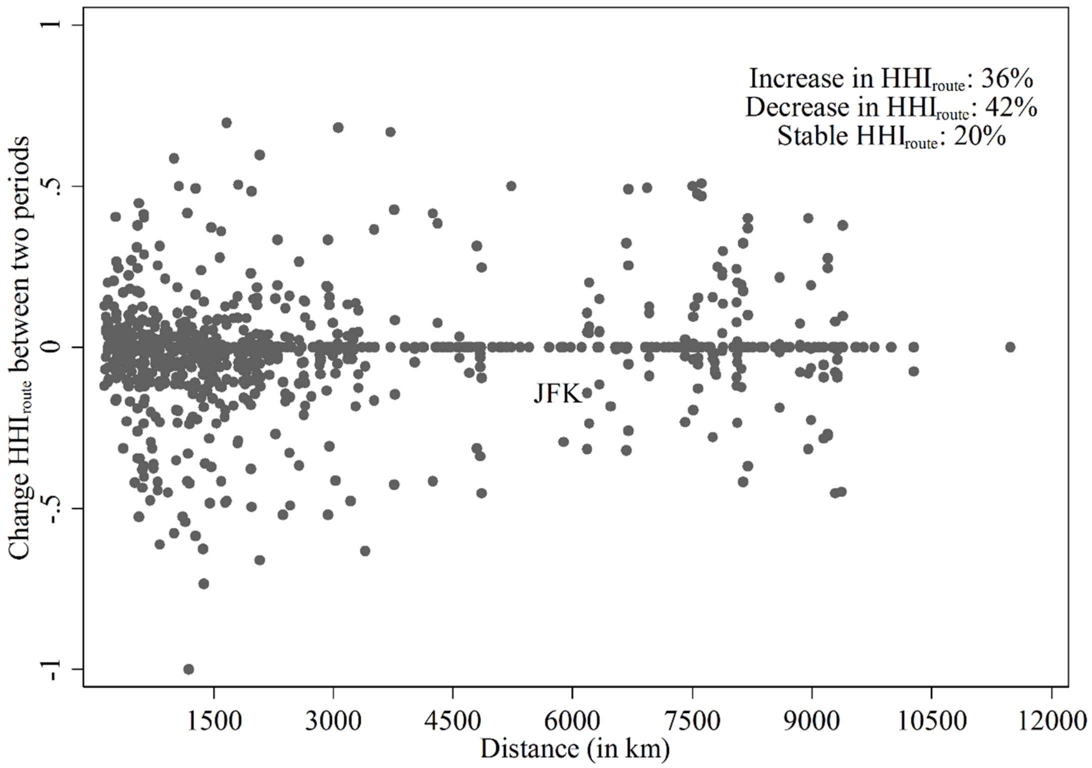

Figure 20: Development of HHI_{route} over time at Frankfurt Airport (FRA)

Source: own depiction

For example, the route from Frankfurt to New York John F. Kennedy Airport (JFK) had a HHI_{route} value of 0.79 in 2012 and a value of 0.65 in 2016, thus leading to a delta of -0.14, as can be seen in the figure. The amount of seats offered on this particular route in 2016 accounted for about 0.30 per cent of total seats offered at FRA in this year. Therefore, the observed decrease in concentration on this particular route adds to the total decrease in route concentration of 42 per cent at FRA over the entire observed period from 2000 to 2016. For FRA, 36 per cent of the offered seats over the entire period experienced an increase in market concentration, whereas 20 per cent of seats remained at the same level. Furthermore, two per cent of the routes in the period from 2000 to 2016 were offered within one period only. For FRA, it can thus be seen that the share of seats which experienced a decrease in market concentration exceeds that with an increase in the concentration level, suggesting a move towards a less concentrated catchment.

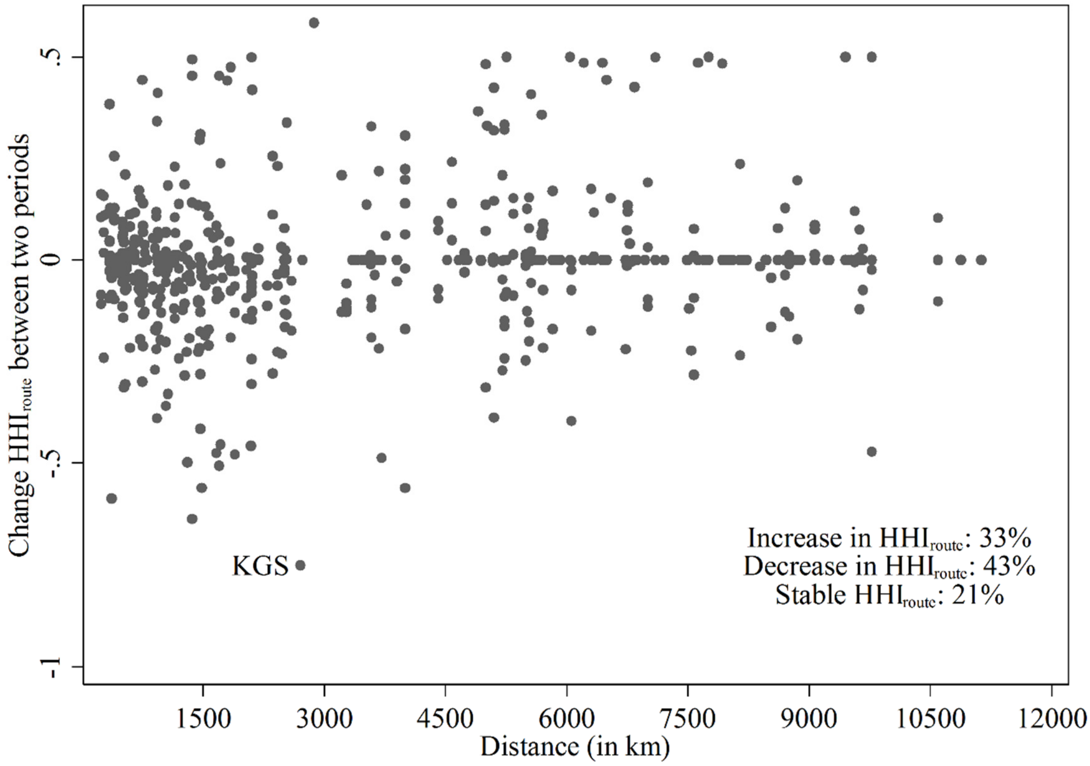

Figure 21: Development of HHI_{route} over time at London Heathrow Airport (LHR)

Source: own depiction

Another example is LHR, which shows a similar pattern in terms of changes in route concentration as FRA, with 43 per cent of total seats offered between 2000 and 2016 being subject to a decrease in the Herfindahl Hirschman Index. Therefore, the decrease in route concentration also exceeds the increase, which applies to 33 per cent of total seats in LHR's catchment in the years from 2000 to 2016. The route with the highest decrease in the HHI_{route} between two periods is LHR to Kos Airport (KGS) in Greece, with a value of 1 in 2012 and 0.25 in 2016. This means that LHR was the only provider of this particular route in 2012, whereas at least three more airports in the catchment started offering this destination in the period after that.

Table 15: Change in HHI_{route} at European hub airports over time

	Share of total airport seats in a year			
Hub airport	increase in HHI_{route}	decrease in HHI_{route}	stable HHI_{route}	Only offered once
MUC	44%	37%	16%	3%
MAN	44%	40%	11%	6%
DUS	43%	53%	0%	3%
LYS	43%	44%	8%	5%
ZRH	39%	40%	19%	2%
AMS	39%	42%	17%	3%
TXL	38%	46%	12%	4%
BRU	38%	55%	3%	4%
FRA	36%	42%	20%	2%
DUB	34%	31%	29%	7%
LHR	33%	43%	21%	2%
ORY	32%	54%	8%	6%
LGW	32%	56%	8%	4%
VIE	28%	24%	44%	4%
DME	28%	53%	8%	11%
SVO	28%	48%	21%	3%
OSL	27%	26%	45%	3%
MXP	27%	47%	23%	4%
BCN	26%	19%	51%	4%
CDG	24%	33%	40%	3%
STN	24%	43%	19%	14%
ARN	18%	28%	52%	3%
PRG	17%	15%	60%	8%
HEL	16%	10%	70%	5%
SAW	13%	60%	3%	24%
CPH	12%	10%	74%	4%
FCO	9%	12%	76%	3%
AYT	8%	18%	67%	6%
MAD	7%	9%	81%	3%
WAW	7%	14%	71%	8%
IST	6%	50%	37%	7%
KEF	0%	0%	85%	15%

Source: own calculation based on OAG data

For all airports and each year, the following four categories of route development can be observed:

(1) Increase in HHI_{route}: An increase in market concentration between two consecutive periods can be observed.

(2) Decrease in HHI_{route}: A decrease in market concentration between two consecutive periods can be observed.

(3) Stable HHI_{route}: The level of market concentration remained the same between two consecutive periods.

(4) A fourth category does not depict changes in the Herfindahl Hirschman Index but denotes those routes which have only been offered once at a hub airport.

Table 15 shows these developments for all European hub airports across the observed period, airports are ranked in descending order of the increase in the HHI_{route}.

At MXP, for example, 47 per cent of offered seats were subject to a decreasing HHI_{route}, compared to 27 per cent of routes experiencing an increase in the level of concentration. One reason for this might be the entry in 2002, and opening of a basis in 2003 of Ryanair at Bergamo Airport (BGY) (Orio al Serio International Airport, 2017). Following that, the airline has been expanding its operations quickly and has hence been imposing increasing competition on MXP. The same effect might apply for the case of BRU which saw increasing concentration for 38 per cent of offered seats but a decrease in concentration for 55 per cent of seats. Ryanair also opened a base at a nearby airport (CRL) in 2001 (Brussels South Charleroi Airport, 2017) and has been expanding operations quickly.

Taking the airports of London as another example, LHR, LGW, and STN have been subject to a decreasing HHI_{route} for a high share of their routes in the period between 2000 and 2016, with 43 per cent for both LHR and STN, and with 56 per cent for LGW. In addition, at STN there is a high share of seats scheduled per year which are only offered once, i.e. certain routes are only offered during one year across the considered period[27]. This implies that STN has experienced more fluctuation in routes than the other London airports. As can be seen in Figure 15, STN experienced a drop in total seats in between 2008 and 2012, potentially resulting from the economic crisis of 2008/09, inducing airlines to focus on high-demand routes and cutting back the amount of scheduled services.

Moving on from the level of change in market concentration the European hub airports have been facing over time, within the second part of the analysis an initial overview is obtained

[27] However, since four-year intervals are considered in this analysis, a route may have been offered in consecutive years, but is not offered in consecutive periods, which represent the covered intervals.

by considering the mean value of the HHI_{route} across all routes by hub airport. The resulting values are reported in Table 16 and sorted in ascending order of the mean value.

Table 16: Development of mean HHI_{route} for all European hub airports (all years)[28]

Hub airport	Mean	Median	Minimum	Maximum	Standard deviation
DUS	0.42	0.35	0.11	1.00	0.22
BRU	0.51	0.43	0.14	1.00	0.25
LGW	0.65	0.58	0.18	1.00	0.27
MAN	0.66	0.59	0.17	1.00	0.29
AMS	0.67	0.60	0.16	1.00	0.27
STN	0.70	0.64	0.22	1.00	0.26
LHR	0.71	0.74	0.15	1.00	0.29
FRA	0.71	0.72	0.17	1.00	0.29
LYS	0.72	0.66	0.28	1.00	0.21
SAW	0.73	0.68	0.48	1.00	0.19
SVO	0.74	0.72	0.33	1.00	0.25
DME	0.74	0.72	0.33	1.00	0.24
ZRH	0.74	0.80	0.26	1.00	0.26
TXL	0.76	0.89	0.23	1.00	0.26
MUC	0.77	0.89	0.20	1.00	0.25
ORY	0.78	0.81	0.34	1.00	0.20
MXP	0.80	1.00	0.21	1.00	0.26
DUB	0.87	1.00	0.35	1.00	0.21
CDG	0.88	1.00	0.34	1.00	0.18
IST	0.92	1.00	0.48	1.00	0.16
VIE	0.92	1.00	0.29	1.00	0.16
ARN	0.93	1.00	0.39	1.00	0.16
PRG	0.93	1.00	0.50	1.00	0.15
BCN	0.94	1.00	0.31	1.00	0.16
OSL	0.94	1.00	0.33	1.00	0.15
WAW	0.95	1.00	0.34	1.00	0.15
FCO	0.96	1.00	0.50	1.00	0.11
CPH	0.97	1.00	0.33	1.00	0.11
HEL	0.99	1.00	0.52	1.00	0.06
AYT	1.00	1.00	0.57	1.00	0.02
MAD	1.00	1.00	0.96	1.00	0.00
KEF	1.00	1.00	1.00	1.00	0.00
ATH	1.00	1.00	1.00	1.00	0.00
BUD	1.00	1.00	1.00	1.00	0.00
LIS	1.00	1.00	1.00	1.00	0.00
PMI	1.00	1.00	1.00	1.00	0.00

Source: own calculation based on OAG data

This mean HHI_{route} value across years and routes for each European hub airport is higher than the mean HHI_{aggr}, which is depicted in Figure 16, for all airports but SAW. MXP, for example, has a mean HHI_{aggr} of 0.30 but a mean HHI_{route} of 0.80, resulting in a delta of 0.50

[28] The mean HHI_{route} for each hub airport and each year is included in Appendix 8.2.

depicted in Figure 22, thus having very different implications for the level of market concentration apparent in the catchment area of MXP. While the mean HHI_{aggr} suggests that scheduled airline seats are rather evenly distributed across the airports in the MXP catchment, the mean HHI_{route} implies a rather high market concentration in the catchment, or alternatively, a low degree of overlap between airports in terms of routes offered. Figure 22 outlines the difference in the mean values of the HHI_{route} and the HHI_{aggr} for all European hub airports.

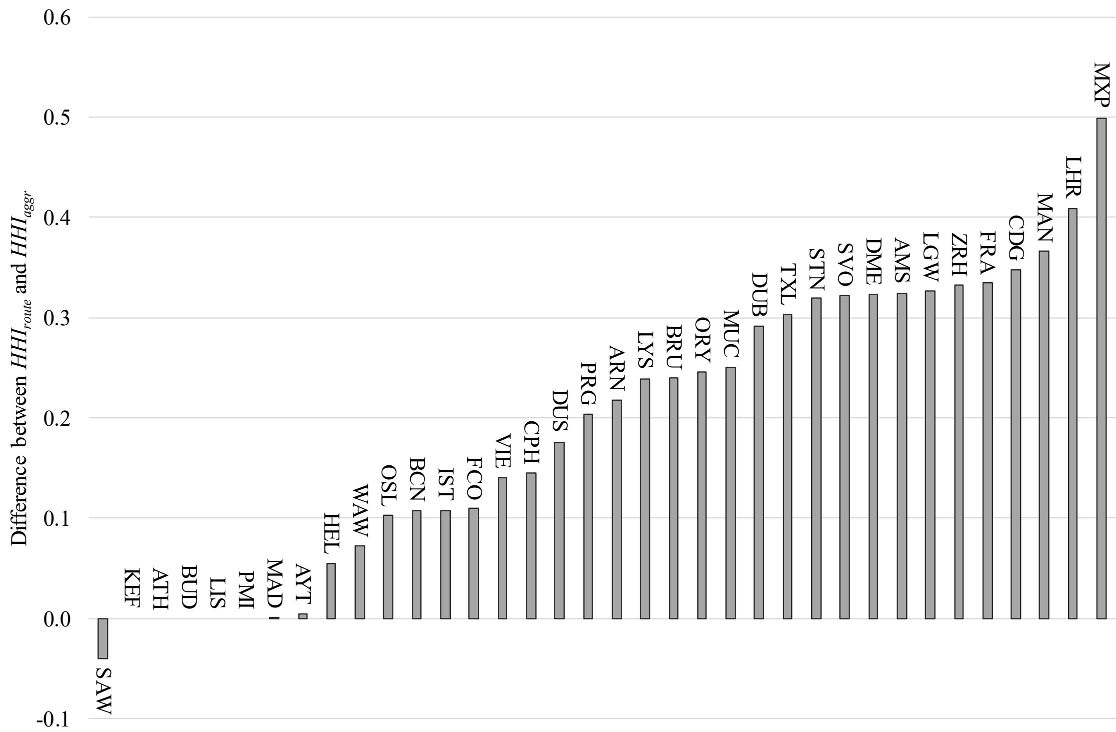

Figure 22: Difference between HHI_{route} and HHI_{aggr}

Source: own depiction based on OAG data

This overview outlines a high degree of deviation between the two Herfindahl Hirschman Indices for a high share of airports in the dataset. For the airports KEF, ATH, BUD, LIS, PMI, MAD, and AYT, there is either no or hardly any difference between the two average values. This is due to the fact that within the catchment of these airports no or only very small, in terms of scheduled airline services, other airports apart from the hubs are present. The deviation apparent for the other airports stems from the different aggregation level of the Herfindahl Hirschman Indices being compared. Whereas the aggregated index, HHI_{aggr}, uses the total seats per year offered at the airports as basis of calculation, the disaggregated one, *HHI*$_{route}$, takes the seats on the route level. Therefore, the latter draws a more accurate picture of the degree of overlap, or market concentration, a hub airports faces on its offered routes, and will therefore be applied as a reference to compare the degree of market concentration across European hub airports. Figure 23 sets the *HHI*$_{route}$ (y-axis) in relation to the share of seats which saw a decrease in market concentration (in the *HHI*$_{route}$) over the examined period (x-axis).

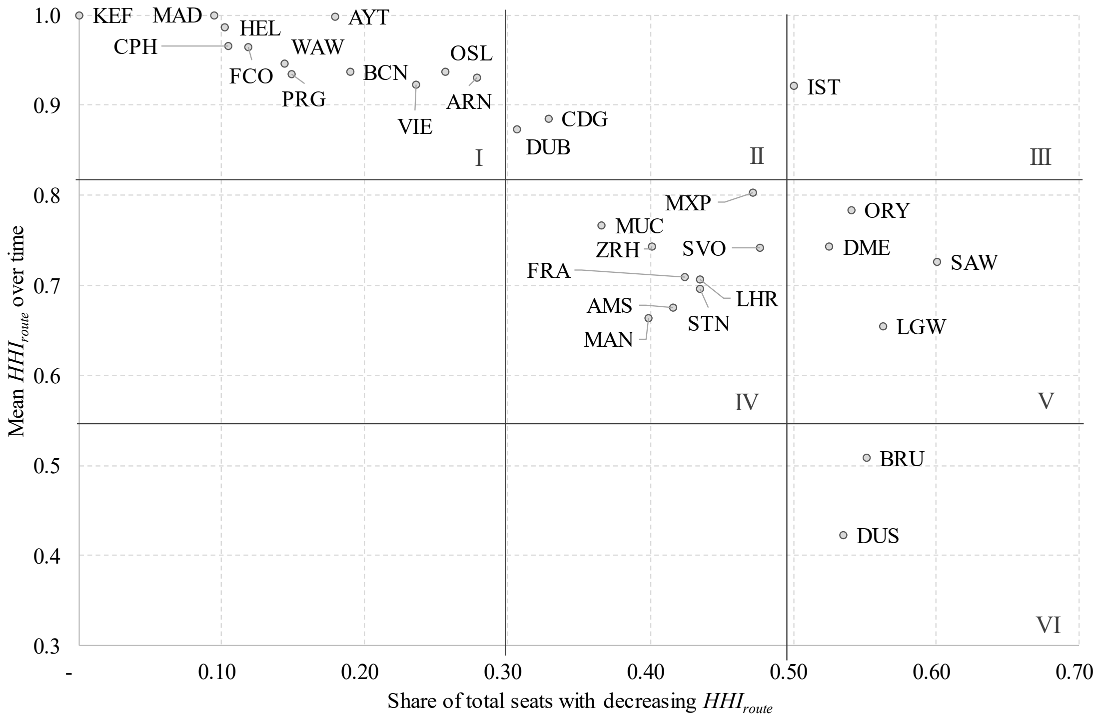

Figure 23: Mean *HHI*$_{route}$ and level of decrease in market concentration

Source: own depiction

Based on this overview, European hub airports can be classified into different categories regarding the development of market concentration within their catchment, with these boundaries not being a strict division, but rather an indication which airports have been facing particular developments:

I. Airports with a high value of the Herfindahl Hirschman Index (> 0.90) and a low share of seats with decreasing market concentration (< 30 per cent), including KEF,

CPH, MAD, HEL, WAW, AYT, FCO, PRG, BCN, VIE, ARN, OSL, and also those airports that do not have secondary airports within their catchment, PMI, LIS, BUD, ATH, and are hence not displayed here.

II. Airports with a rather high value of the Herfindahl Hirschman Index (> 0.80) but a higher share of seats with decreasing market concentration (> 30 per cent), including: CDG, DUB.

III. Airports with a high value of the Herfindahl Hirschman Index (> 0.8), but at the same time a high share of seats with decreasing market concentration (> 50 per cent), including IST.

IV. Airports with a Herfindahl Hirschman Index value of less than 0.80 and above 0.60, and with the share of seats with decreasing market concentration between 30 per cent and 50 per cent, including MXP, MUC, TXL, ZRH, SVO, LYS, LHR, STN, MAN, AMS, FRA.

V. Airports with a Herfindahl Hirschman Index value of less than 0.80 and above 0.60, and with the share of seats with decreasing market concentration and with a high share of seats with decreasing market concentration (> 50 per cent), including ORY, DME, SAW, LGW.

VI. Airports with a Herfindahl Hirschman Index value of 0.50 or less and with a high share of seats with decreasing market concentration (> 50 per cent), including BRU and DUS.

The threshold of 0.50 has been selected since this is the minimum attainable value of the HHI_{route} if there are two firms of equal size in the market. With more firms, this minimum attainable value is decreasing (as also discussed in the previous chapter). Being above this threshold therefore indicates that the overlap between the hub airport and its competitors in the catchment is only limited.

Based on this analysis, it becomes apparent that about half of the European hub airports investigated in this sample (categories I and II), face a high degree of market concentration in their respective catchment, indicated by the level of the Herfindahl Hirschman Index as well as its change over time. Almost another 50 per cent of the European hub airports also exhibits a relatively high value in terms of the Herfindahl Hirschman Index (Categories III, IV, V), but the share of seats which has been subject to a decrease in market concentration is higher, and thus points to a continuous shift towards a less concentrated catchment of these hub airports. Only two airports (category I) within the considered airport dataset have relatively low Herfindahl Hirschman Index values, and at the same time a high share of seats with decreasing market concentration, implying a high and increasing route overlap within the catchments of these airports. Assuming that a high route overlap indicates more choice for passengers departing from and arriving at this catchment area, then the latter two airports BRU and DUS face increasing competition from their counterparts in the respective catchment areas.

4.2.3 Adjusting the Herfindahl Hirschman Index for distance

An extension to the previous route-based analysis of market concentration in the catchment areas of European hub airports is the consideration of different airport access times within this area. It is assumed that the attractiveness of a secondary airport decreases with increasing distance from the hub airport. Wiltshire (2013) finds that a one per cent increase in distance, or access time, to an airport, leads to a decrease in passengers' likelihood to travel to this airport by four per cent. This decreasing substitution potential of further away secondary airports is hence accounted for by calculating the distance-weighted Herfindahl Hirschman Index (HHI_{dist}). The weight within this index accounts for the distance, or driving time, between each secondary airport and the hub airport, and hence for variation in access times.

Considering the application of the Herfindahl Hirschman Index, the incorporation of weighting factors has been introduced before, such as by Hannan (1997) and Lijesen (2004) (see Chapter 2.2.2 for a detailed discussion of this approach). Ibid. introduces a quality factor accounting for a better flight connection in terms of overall flight time. This quality factor is represented in the following analysis by the time it takes to access a particular airport within the hub airport's catchment. The adjustment of the route-level Herfindahl Hirschman Index HHI_{route} is therefore conducted in line with these previous approaches and elaborated in more detail in this chapter. This includes (1) the calculation of the weight being introduced as well as (2) the outline of differences in regard to the previously applied HHI_{route}.

In order to obtain the weighting factor w_d the driving time in minutes from each secondary airport i to the hub airport within a catchment area is determined (14). Since for each hub airport's catchment a maximum threshold of 120 minutes has been assumed (see Chapter 4.1.1), the individual drive time for each secondary airport ($DriveTime_i$) is divided by this.

$$w_{di} = 1 - 0.7\left(\frac{DriveTime_i}{120\ minutes}\right) \tag{14}$$

Furthermore, a threshold of 0.30[29] is introduced in order to avoid that the weight of the secondary airport tends towards zero, i.e. the weight of an airport cannot be less than 0.30[30]. This accounts for the fact that there is always a particular share of passengers willing to substitute to a secondary airport within the catchment. The introduction of the weighting factor w_{di} to the calculation of the Herfindahl Hirschman Index therefore yields:

$$HHI_{dist,r} = \sum_{i=1}^{N} (s_{r,i}^2) w_{di} \tag{15}$$

Table 17 provides an example of the application of the HHI_{dist} in a hub airport's catchment. The second column shows the number of seats per year offered on a particular route.

Table 17: Example of the calculation of HHI_{dist}

Airport	Seats per year	HHI_{route}	$DriveTime_i$ (in minutes)	$DriveTime_j/120$	w_{di}	HHI_{dist}
Hub	55000	0.076	0	0	1.00	0.076
Secondary 1	20000	0.01	40	0.33	0.77	0.008
Secondary 2	15000	0.006	80	0.67	0.53	0.003
Secondary 3	110000	0.303	110	0.92	0.36	0.109
Sum	200,000	0.395				0.195

Source: own depiction

[29] Appendix 8.4 provides a sensitivity analysis of the variation of the defined threshold. Selecting a rather high threshold with 0.30 is due to the assumption that passengers travelling for private or leisure reasons are more willing to travel longer distances, as discussed in Chapter 4.1.1, and this particular group constitutes a high share of overall travellers.

[30] The airport Secondary 3, for example, has a distance of 110 minutes' drive time from the hub airport. Dividing this by the total distance yields a distance share of 92 per cent. Multiplying this with the threshold factor and applying (14), yields a weighting factor of 0.36. Thus, instead of this airport having the same weight as those airports closer to the hub, it obtains a lower weight since it is further away and is hence a less attractive substitute.

Within the catchment, four different airports have scheduled airline services to this destination, each with distinct amount of seats. The HHI_{route} is then calculated using these and arriving at a value of 0.395 for this route. As can be seen from the example, the Secondary 3 airport is the one with the most seats on this route within this catchment. However, since this airport is furthest away from the hub airport, passengers may be less willing to substitute this for the services offered at the hub airport. Coming back to the example in Table 17, the HHI_{dist} is lower than the HHI_{route} with a value of 0.195, and thus representing the degree of overlap on this route faced by the hub airport in this catchment.

Table 18 outlines the results for the HHI_{dist} for all European hub airports over time. Comparing these results with those of the HHI_{route} shows that the mean value of the distance-weighted Herfindahl Hirschman Index is either higher or at the same level than those values for the HHI_{route}. The airports of DUS, BRU, and LYS have the highest delta in relation to the two indices. Adjusting for the distance within the catchment therefore reveals that routes are more concentrated at these airports than the HHI_{route} initially implied. This might be due to the fact that, considering the route-level, other secondary airports in the catchment, which are rather far away from the considered hub airport, are offering seats. Therefore, the potential degree of competition imposed by these secondary airports is not as strong as suggested by the HHI_{route}.

These two indices, the HHI_{route} and the HHI_{dist} are both included as variables in the empirical analyses in Chapter 4.3.3 in order to assess the impact of market concentration on the seat capacities offered at European hub airports, and to investigate the potentially different effect of a distance-weighted Herfindahl Hirschman Index.

Table 18: Development of HHI_{dist} for all European hub airports over time

Hub airport	Mean	Median	Minimum	Maximum	Standard deviation
DUS	0.24	0.16	0.06	1.00	0.28
BRU	0.33	0.22	0.07	1.00	0.31
AMS	0.58	0.45	0.10	1.00	0.29
LGW	0.58	0.48	0.12	1.00	0.28
LYS	0.60	0.48	0.17	1.00	0.24
STN	0.60	0.47	0.16	1.00	0.28
MAN	0.62	0.53	0.10	1.00	0.30
FRA	0.66	0.69	0.09	1.00	0.29
DME	0.66	0.56	0.23	1.00	0.25
SAW	0.66	0.59	0.44	1.00	0.20
SVO	0.67	0.60	0.23	1.00	0.26
ZRH	0.67	0.76	0.12	1.00	0.27
LHR	0.68	0.72	0.10	1.00	0.29
TXL	0.72	0.82	0.13	1.00	0.27
MUC	0.72	0.88	0.12	1.00	0.26
ORY	0.73	0.68	0.24	1.00	0.21
MXP	0.77	1.00	0.14	1.00	0.26
CDG	0.86	1.00	0.27	1.00	0.19
DUB	0.87	1.00	0.35	1.00	0.21
PRG	0.91	1.00	0.23	1.00	0.15
VIE	0.91	1.00	0.13	1.00	0.16
IST	0.92	1.00	0.44	1.00	0.16
ARN	0.92	1.00	0.32	1.00	0.16
BCN	0.93	1.00	0.20	1.00	0.16
OSL	0.93	1.00	0.19	1.00	0.15
WAW	0.94	1.00	0.22	1.00	0.15
FCO	0.95	1.00	0.43	1.00	0.11
CPH	0.96	1.00	0.31	1.00	0.11
HEL	0.98	1.00	0.28	1.00	0.06
AYT	1.00	1.00	0.30	1.00	0.02
KEF	1.00	1.00	0.96	1.00	0.00
MAD	1.00	1.00	0.96	1.00	0.00
ATH	1.00	1.00	1.00	1.00	0.00
BUD	1.00	1.00	1.00	1.00	0.00
LIS	1.00	1.00	1.00	1.00	0.00
PMI	1.00	1.00	1.00	1.00	0.00

Source: own calculation based on OAG data

Building on the analysis of market concentration in the catchment of European hub airports in Chapter 4.2, the following chapter focuses on the assessment of the impact of this on output decisions at the respective hub airports. As elaborated in Chapter 2.2, merely assessing the degree of market concentration does not give comprehensive evidence whether a firm possesses and subsequently abuses market power. In this chapter a detailed insight into the degree and change of market concentration at European hub airports was given. Investigating the effect of market concentration on the output, i.e. seat capacities, offered at these airports gives further insight whether abusive behaviour due to market power can be assumed.

4.3 Empirical analysis

In order to gain more insight into the effects of market concentration, this chapter conducts an empirical analysis to investigate the following research questions, as outlined in Chapter 1:

(2) What is the impact of market concentration on the output decisions, in terms of seats offered to a particular destination, at European hub airports? As a measure for market concentration, both the route-level (HHI_{route}) and the distance-weighted Herfindahl Hirschman Index (HHI_{dist}) will be employed as explanatory variables in the regression analysis.

(3) As discussed in Chapter 4.1.2, low cost carriers are presumed to have an impact on the rising constraints on hub airports' market power since these particular airlines are often believed to locate their operations at smaller airports with spare capacity, i.e. those secondary airports within a hub airport's catchment. The second research question within this chapter therefore assesses the impact of low cost carrier presence on the output decisions on the route level at hub airports.

(4) Furthermore, Chapter 3.2.1 highlighted the potential competition from other modes of transport, such as (high-speed) rail, which might constrain the potential market power of hub airports. The third research question therefore focuses on the evaluation of the effect of (high-speed) rail services on the seats offered per route at European hub airports. Since these particular transport services are assumed to be only competitive with aviation up to a certain range, measured in terms of journey time, only a particular market segment will be considered for the analysis.

According to these research questions, this chapter is structured into five main parts. The first part (Chapter 4.3.1) introduces and describes the variables employed in the empirical models, which in turn are introduced and discussed in Chapter 4.3.2. The application of these models can be found in Chapter 4.3.3, focusing on the effect of market concentration, Chapter 4.3.4, investigating the impact of low cost carrier, and Chapter 4.3.5 with the findings on the implications of competition from rail services.

4.3.1 Selection of variables

Since the previously stated research questions address the impact of market concentration, low cost carrier presence in the catchment areas of European hub airports, and implications of rail competition on the output of these airports, the dependent variables in the empirical estimations will be specified to represent this investigated causality. Hence these are reflected by the total seats (*Seats*) offered on a route *r* per year, the mean seats per flight on this route *r* (*MeanSeats*), and the mean number of flights per week (*Frequency*). The data to calculate these variables is extracted from the OAG database, which reports scheduled airline traffic, and includes the years 2000, 2004, 2008, 2012, 2016, all these variables are in logarithmic format. The reasoning is given in Chapter 4.3.2.

These dependent as well as the different explanatory variables are outlined in Table 19. Population and gross domestic product per capita, often used as a proxy for the income level, are outlined by various studies as the main drivers determining the level of air transport demand in a country (Dobruszkes, Lennert & Hamme, 2011; Kluge *et al.*, 2017). Therefore, within the estimation it is accounted for the level of potential demand on a particular route by including the size of the urban region at the destination in terms of population (*log(Pop)*) (United Nations / Department of Economic and Social Affairs, 2014). Furthermore, a variable is included which presents the average gross domestic product per capita of the arrival country (*log(Gdp)*) (The World Bank, 2017). Since demand is expected to be higher to destinations with both a higher total population and GDP per capita, the coefficients for these explanatory variables are presumed to be positive.

Table 19: Variables used in regression analysis

Variable	Description
log(Seats)	The number of seats offered at hub airport to a specific destination (route) per year, dependent variable (logarithmic variable).
log(MeanSeats)	The mean number of seats per flight offered at the hub airport on a particular route, dependent variable (logarithmic variable).
log(Frequency)	The number of flights per week offered to a particular destination, dependent variable (logarithmic variable).
log(Pop)	The population in the urban area at destination, measured in ‘000 persons living in a particular urban region (logarithmic variable)
log(Gdp)	The gross domestic product per capita in the arrival country (logarithmic variable).
Network	The route is operated by the network carrier of the hub airport, dummy variable which is 1 if the network carrier operates on a specific route.
HHI_{route}	The Herfindahl Hirschman Index on the route level (i.e. for each destination offered at the hub airport), calculated by summing the square of each airport’s seat share in total seats on a route in the catchment.
HHI_{dist}	The distance-weighted Herfindahl Hirschman Index on the route level (i.e. for each destination offered at the hub airport).
log(Distance)	Distance of the route, i.e. from origin to destination, in kilometres.
Year	Categorical variable indicating the year of the observation (reference year = 2000).
Ownership	Variable indicating the number of airports within the catchment which are under the same ownership structure.
Lcc	Variable indicating the number of low cost carrier in the catchment operating the same routes as the airlines at the hub
Hsr	Variable representing the ratio between the rail kilometres in a country to the total size of the country (measured in square kilometres)

Source: own depiction

Furthermore, a variable is included which accounts for the operation of a network carrier at the hub airport (*Network*). Since the main focus of this thesis is on hub airports, the respective network carriers operating a hub-and-spoke network via these airports play an essential role in determining the level of competition imposed by other airports. For example, a route may appear to be competitive, since it is offered by other airports in the catchment as well. If the network carrier at the hub airport offers a large share of seats on this particular route, the node character of the airport may imply that a large share of passengers might be transferring from this route to another flight and hence cannot substitute to another airport in the catchment. With this underlying assumption, the effect on the overall output on a route in the presence of the network carrier will be tested. The respective network carriers operating at each European hub airport considered in the dataset is outlined in Table 47 in Appendix 8.5.

In the empirical analysis, a dummy variable is applied which is equal to one if the route is offered by the according network carrier. Since the network carrier at European hub airports usually make up a high share of the total seats offered at these (Table 48), the sign of this variable's coefficient is expected to be positive.

As further explanatory variable and a proxy for the level of market concentration on a route both the route-level (HHI_{route}) and distance-weighted Herfindahl Hirschman Indices (HHI_{dist}) are included in the estimation, respectively. These two indices have been elaborated in detail in Chapters 4.2.2 and 4.2.3. According to the theory on (natural) monopoly discussed in Chapter 2.1.1, a negative coefficient of these variables is expected due to the assumption that a monopolistic market, represented by high market concentration, leads to a restriction of output in that particular market. Other studies have been integrating the Herfindahl Hirschman Index as an explanatory variable in a regression analysis to account for effects induced by competition. Fageda (2013), for example, focuses on the analysis of the Spanish airline market and whether liberalisation had an effect on the level of competition on thin routes. The empirical model tests the effect of increasing competition on prices and frequencies, including as explanatory variables instruments for demand (population, gross domestic product, and the number of tourists) and for route concentration, using the Herfindahl Hirschman Index. The results show that an increase in concentration at the airport level leads to a decrease in frequencies offered. Accounting for the effect of market concentration or competition on a particular route has previously also been applied by Givoni & Rietveld (2009), Fageda (2013), or Albalate, Bel & Fageda (2015).

Another explanatory variable is included which accounts for the distance between the departure and the arrival airport (*log*(*Distance)*), i.e. the distance on the route, and is measured in kilometres. The distance between two points is reported in the OAG database. It is expected that the number of seats offered as well as the mean frequencies per week on a route decrease with distance, thus the coefficient of these variables is presumed to be negative. However, in case of mean seats per flight (*log(MeanSeats)*) as dependent variable, a positive coefficient is expected. This variable represents a proxy for aircraft size, and long-haul destinations are served by larger aircraft such as the Airbus A340 or the Boeing 777 whereas short-haul traffic is usually covered by aircraft types such as Airbus A320 or Boeing 737.

A categorical variable is also introduced for each year (*Year*), with the year 2000 being the reference year, and thus the effect of each individual year can be measured. This allows for the incorporation of year-specific developments such as the financial crisis in the years 2008 and 2009, for example.

The ownership structure of airports within the same catchment and the effect on competition has been discussed in the case of different airports. For example, the ownership of several UK airports, especially in south-east England and lowland Scotland, by the company BAA Limited induced the Competition Commission (2009) to analyse in detail the potential adverse effects on competition of this common ownership. The evaluation revealed negative effects for competition, and thus lead to a divestiture of Stansted Airport (STN) and Gatwick Airport (LGW) to different owners. Furthermore, the report concluded that also Edinburgh Airport (EDI) and Glasgow Airport (GLA) need to be assigned to separate ownership in order to foster competition in the particular catchment. To include this aspect in the empirical estimations in the following chapters, a variable is included which accounts for the number of airports in the catchment area which are under the same ownership as the hub airport. See Table 49 in Appendix 8.6 for an outline of the common ownership across airports within a catchment. Since the effect of common ownership on the output offered at the hub airports is measured, a negative coefficient is expected: An adverse effect of common ownership is the restriction of competition on aspects such as price, service, or innovation, or the restriction of an overlap between routes offered at the different airports. If a route at the hub airport is also offered by another airport in the catchment which has the same owner, it would be expected that this leads to a reduction of output offered at the hub airport.

The effect of low cost carrier presence (*Lcc*) will be analysed in more detail in Chapter 4.3.4, which also includes a detailed description of this variable.

Furthermore, Chapter 4.3.5 investigates the impact of available rail services (*Hsr*) on the seats offered at the hub airport. Since rail is competitive with air services only up to a particular distance in terms of overall journey time, only a subset of the data will be considered for this particular analysis. This parameter is elaborated in detail in the respective chapter.

Table 20: Descriptive statistics of variables (values at the route level)

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Seats	24909	103709	174561	8	3718962
MeanSeats	24909	165.09	72.51	5	582
Frequency	24909	13.59	21.58	0.02	441
Pop	16926	3371	4874	141	38140
Gdp	24466	28986	16207	411	141543
Network	24909	0.47	0.50	0	1
HHI_{route}	24909	0.79	0.26	0.11	1
HHI_{dist}	24909	0.75	0.32	0.06	1
Distance	24909	2526	2483	100	11883
Ownership	24909	0.19	0.47	0	3
Lcc	24909	0.37	1.03	0	14

Source: own depiction

Table 20 provides the descriptive statistics for the variables considered in the empirical analysis. It shows that over a period of 16 years, 24,909 routes are considered. Population and GDP data is, however, only available for 16,926 and 24,466 of the considered routes, respectively. The number of seats per route is measured on an annual basis and these range from a minimum of 8 to a maximum of 3,718,962 seats per year. Market concentration on the route level, represented by HHI_{route}, has a mean value of 0.79, and the distance-weighted adjustment of this index, HHI_{dist}, a value of 0.74.

4.3.2 Model specification

In the following empirical analysis, panel data, or longitudinal data, is applied which means that both time-series as well as cross-sectional data is considered. In the cross-sectional case, the individual routes offered across the European hub airport sample are considered as the entities whereas the time-series dimension includes data for the years 2000, 2004, 2008, 2012, and 2016. Panel data is often applied to address the omitted variable bias in simple regression since with this approach changes in the dependent variable are observed over time (Wooldridge, 2002, p. 420; Stock and Watson, 2007, p. 349). In the analysis here, both an ordinary least squares (OLS) regression as well as models including time fixed effects are estimated. The models applied to each specific research question, and the respective estimation results are outlined in the following paragraphs.

Based on the first research question in this chapter, i.e. the effect of market concentration on the amount of seats offered at a hub airport on a particular route *r*, the following models are estimated in Chapter 4.3.3. Here, the hub airport's total number of scheduled airline seats, *log(Seats)*, the mean seats per flight, *log(MeanSeats)*, and the mean frequency per week *log(Frequency)*, on a particular route *r* are used as dependent variables, the respective equations are displayed in brackets:

1. OLS estimation for each year separately, testing for the effect of market concentration [(16) – (18); results in Chapter 4.3.3]
2. OLS estimation combining observations for all years, introducing a time fixed effect for each year, testing for the effect of market concentration [(19); results in Chapter 4.3.3]

As outlined, in the first step, a multiple regression is estimated by OLS for each year separately, based on the following equations, starting with the total seats on a route, *log(Seats)*, as the dependent variable:

$$\begin{aligned} log(Seats_r) = \beta_0 &+ \beta_1 log(Pop_r) + \beta_2 log(Gdp_r) \\ &+ \beta_3 HHI_{route,r} + \beta_4 Network_r \\ &+ \beta_5 log(Distance_r) + \beta_6 Ownership_r + u_r \end{aligned} \tag{16}$$

With *r* representing the route, *r* = 1, …, M, and and u_r is the error term. Continuing with the mean seats per flight, *log(MeanSeats)*, as dependent variable:

$$\begin{aligned} log(MeanSeats_r) & \\ = \beta_0 &+ \beta_1 log(Pop_r) + \beta_2 log(Gdp_r) \\ &+ \beta_3 HHI_{route,r} + \beta_4 Network_r \\ &+ \beta_5 log(Distance_r) + \beta_6 Ownership_r + u_r \end{aligned} \tag{17}$$

And the same equation with frequency per week, *log(Frequency)*, as dependent variable:

$$\begin{aligned} log(Frequency_r) \\ &= \beta_0 + \beta_1 log(Pop_r) + \beta_2 log(Gdp_r) \\ &+ \beta_3 HHI_{route,r} + \beta_4 Network_r \\ &+ \beta_5 log(Distance_r) + \beta_6 Ownership_r + u_r \end{aligned} \tag{18}$$

The results are displayed in Table 23, Table 24, and Table 25 in Chapter 4.3.3.

In the second model employed in this chapter, panel data including all routes over the observed period from 2000 to 2016 is applied to estimate the impact of market concentration on airport output. Since a relatively short time period with a high number of routes is considered, this is referred to as a short panel. Furthermore, a balanced panel is used, which means that only those routes are considered that are offered in each time period. Within this model, a time fixed effect is considered, which allows controlling for variables that are constant over routes but vary over time.

The purpose of employing this particular model is to observe the time fixed effects, i.e. to account for developments which took place in the observed periods, but which are not included in the model, and thus accounting for omitted variable bias. Therefore, in model (19), γ_t is treated as the unknown intercept which is to be estimated for each time period, with $t \in \{2000, 2004, 2008, 2012, 2016\}$. In the estimation, the first of these binary variables is omitted to prohibit perfect multicollinearity. The model can be estimated using OLS regression since the time fixed effects model represent a variation of the multiple regression model, also called Least Squares Dummy Variables Estimator (LSDV) (Stock & Watson, 2007:p.363; Wooldridge, 2010:p.308)

$$\begin{aligned} log(Seats_{rt}) &= \beta_0 + \beta_1 log(Pop_{rt}) + \beta_2 log(Gdp_{rt}) \\ &+ \beta_3 HHI_{route,rt} + \beta_4 Network_{rt} \\ &+ \beta_5 log(Distance_{rt}) + \beta_6 Ownership_{rt} + \gamma_t \\ &+ u_{rt} \end{aligned} \tag{19}$$

Here, the model will also be applied for all three dependent variables specified in (16), (17), and (18). The results are displayed in Table 26 in Chapter 4.3.3 for the HHI_{route} as well as for the HHI_{dist} in Table 27.

The same model as in (19) is applied to test for the effect of low cost carrier presence in the catchment of European hub airports. Therefore, continuing the outline of the models employed in the following chapters, the variable *Lcc* is included in the following way.

3. OLS estimation combining observations for all years, introducing a time fixed effect for each year, testing for the effect of low cost carrier presence in the catchment [(20); results in Chapter 4.3.4]:

$$\begin{aligned} log(Seats_{rt}) = \beta_0 + \beta_1 log(Pop_{rt}) + \beta_2 log(Gdp_{rt}) \\ + \beta_3 HHI_{route,rt} + \beta_4 Network_{rt} \\ + \beta_5 log(Distance_{rt}) + \beta_6 Ownership_{rt} \\ + \beta_7 Lcc_{rt} + \gamma_t + u_{rt} \end{aligned} \quad (20)$$

The model is also tested for the dependent variables *log(MeanSeats)* and *log(Frequency)*. The results are displayed in Chapter 4.3.4 in Table 28.

As a last step in the analysis of potential competition for European hub airports within their catchment, the effect of rail services on the capacities offered at hub airports is considered in model (21).

4. OLS estimation combining observations for all years, introducing a time fixed effect for each year, testing for the effect of rail services presence in the catchment [(21); results in Chapter 4.3.5]:

$$\begin{aligned} log(Seats_{rt}) = \beta_0 + \beta_1 log(Pop_{rt}) + \beta_2 log(Gdp_{rt}) \\ + \beta_3 HHI_{route,rt} + \beta_4 Network_{rt} \\ + \beta_5 log(Distance_{rt}) + \beta_6 Ownership_{rt} \\ + \beta_7 Lcc_{rt} + \beta_8 Hsr_{rt} + \gamma_t + u_{rt} \end{aligned} \quad (21)$$

As above, the model is also tested for the dependent variables *log(MeanSeats)* and *log(Frequency)*. Since this last model only considers a subset of the data which is considered in the other models the descriptive statistics are outlined in the respective chapter.

The Pearson correlation coefficient measures the strength of a linear relationship between two variables (Fahrmeier *et al.*, 2011:p.138). It can take values between -1 and 1, with these extrema representing a perfect linear relationship between two variables. In case this coefficient takes on the value 0, there is no relationship between the considered variables. In Table 21, only continuous variables are considered in order to detect the functional relationship between these.

Table 21: Pearson correlation coefficient for selected variables

	log(Seats)	*Seats*	*log(MeanSeats)*	*MeanSeats*	*log(Frequency)*	*Frequency*	*log(Pop)*	*Pop*	*log(Gdp)*	*Gdp*	HHI_{route}	HHI_{dist}	*log(Distance)*	*Distance*
log(Seats)	1.00													
Seats	0.64	1.00												
log(MeanSeats)	0.08	0.09	1.00											
MeanSeats	0.05	0.06	0.93	1.00										
log(Frequency)	0.96	0.61	-0.21	-0.22	1.00									
Frequency	0.64	0.94	-0.12	-0.16	0.66	1.00								
log(Pop)	0.22	0.18	0.39	0.41	0.11	0.05	1.00							
Pop	0.17	0.11	0.34	0.38	0.07	0.01	0.84	1.00						
log(Gdp)	0.19	0.18	-0.15	-0.16	0.23	0.20	-0.06	-0.06	1.00					
Gdp	0.19	0.17	-0.06	-0.05	0.20	0.17	-0.04	-0.06	0.88	1.00				
HHI_{route}	-0.19	-0.14	0.03	0.09	-0.19	-0.16	0.12	0.13	0.12	-0.02	1.00			
HHI_{dist}	-0.10	-0.08	0.04	0.09	-0.11	-0.11	0.12	0.12	0.12	-0.01	0.97	1.00		
log(Distance)	-0.13	-0.18	0.71	0.77	-0.33	-0.36	0.42	0.39	0.30	-0.18	0.18	0.16	1.00	
Distance	-0.04	-0.09	0.65	-0.05	-0.23	-0.26	0.46	0.46	-0.25	-0.13	0.22	0.20	0.90	1.00

Source: own depiction

In regard to these continuous variables in the model, a non-linear relationship is expected. For example, considering the correlation between seats per capita and the income level, measured in GDP per capita, Figure 24 depicts the non-linear relationship between these two variables. An increase in the GDP per capita, shown in ‘000 U.S. dollar, thus is assumed to have a smaller effect on the seats per capita at high levels of income than it does at the lower end of the income scale.

A similar relationship is assumed between the dependent variables and the explanatory variables *Pop* and *Distance.* Therefore, the dependent variables as well as *Gdp*, *Pop* and *Distance* are measured in logarithms.

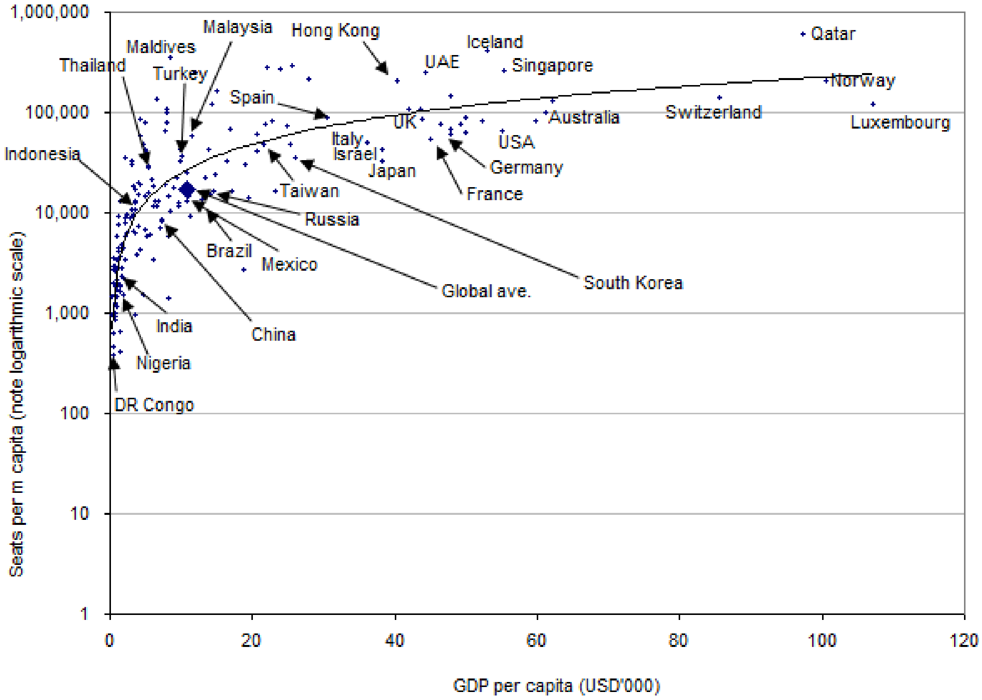

Figure 24: Airline seats per capita (log-scale) versus GDP per capita, by country (2014)

Source: CAPA - Centre for Aviation (2014)

In a non-linear model the coefficients are interpreted in a different way than in a linear model, depending whether either the dependent or independent or both variables are in logarithmic form, the interpretation of the respective coefficient is displayed in Table 22.

Table 22: Interpretation of the coefficients in logarithmic regression

Case	Regression specification	Interpretation of coefficient of coefficient of independent variable (β)
I	The independent variable is in logarithmic format (linear-log model)	A 1% change in the independent variable is associated with a change in the dependent variable of 0.01 times the coefficient of the independent variable (β).
II	The dependent variable is in logarithmic format (log-linear model)	A change in the independent variable by one unit is associated with a change in the dependent variable of 100 times the coefficient of the independent variable in per cent (β%).
III	Both the dependent and the independent variable are in logarithmic format (log-log model)	A one per cent change in the independent variable is associated with a change in the dependent variable in the magnitude of the coefficient, so the coefficient β is the elasticity of the dependent variable with respect to the independent variable.

Source: adapted from Stock & Watson (2007:p.273)

Having defined the different models, the following chapters will each address one of the research questions highlighted at the beginning of Chapter 4.3 and discuss the respective findings.

4.3.3 Effects of market concentration on airport output

The empirical estimation in this chapter looks into the potential competition a hub airport faces from its secondary airports in the catchment. In this case, the level of competition is approximated by applying the Herfindahl Hirschman Index as a measure for market concentration. The output of the hub airports is measured in terms of seats per year, *log(Seats)*, the mean seats per flight, *log(MeanSeats)*, and the mean number of flights per week, *log(Frequency)*. The impact of market concentration on these is then assessed using both the route-level (HHI_{route}) and the distance-weighted Herfindahl Hirschman Index (HHI_{dist}). The initial assumption is that the output at the hub airports decreases with increasing market concentration on a route, reflected by an increasing Herfindahl Hirschman Index. Therefore, a negative impact of the explanatory variables HHI_{route} and HHI_{dist} on the seats offered to a destination is expected. The chapter starts with the discussion of the results for the OLS estimation, as outlined in (16), (17), and (18), before continuing with a further specification of the empirical models and the comparison of respective results.

Table 23 shows the results of the regression using the seats offered per year on a particular route as dependent variable. In a first step, the following aspects are considered in assessing the validity of the results, see Stock & Watson (2007:pp.200–204):

- The standard error of the regression (*SER*), which estimates the standard deviation of the error term ε, i.e. it measures the spread of the distribution of the dependent variable around the regression line. A smaller value indicates that observations are closer to this line. It is reported in each for each specified model.
- The R^2 gives information on the fit of the model, i.e. it shows the fraction of the sample variance of the dependent variable which is explained by the explanatory variables.
- Ensuring no perfect multicollinearity.
- Standard error for each OLS estimator (displayed in parentheses under the respective coefficients), which estimates the standard deviation of the sampling distribution of *β*. A smaller standard error implies a more precise estimation.
- Standard errors are robust to heteroskedasticity; the models are adjusted to account for heteroskedasticity, since it is assumed that the variance of the conditional distribution of the error term (u_r) is not constant for $r = 1, \ldots, M,$ with r being the observations in the sample, i.e. the routes.
- The significance probability, the p-value, is reported for each estimated coefficient.

The estimation results for the dependent variable *log(Seats)* imply that the OLS estimate of the multiple regression line fit the data well. The *SER* is low for all models in Table 23, suggesting a low distribution of the error term around the regression line. The R^2 values for the different models are between 0.33 and 0.38, which denotes that between 33 per cent and 38 per cent of the variation in the dependent variable is explained by the selected variables. Low values of R^2 are not inherently bad, but it is rather important to assess the coefficient estimates and the distribution of residuals. An approach to deal with the potential presence of heteroskedasticity in a model is the use of heteroskedasticity-robust standard errors, as indicated in the table. Furthermore, it is important to exclude the existence of perfect multicollinearity. The statistical software Stata®, which is used for the empirical analysis in this thesis, provides a test for the existence of multicollinearity, which is applied to the estimation results here (Stata, n.d.). This test calculates the variance inflation factors (VIF) and tolerances for each explanatory variable. Multicollinearity exists if the largest VIF value is larger than 10 (or larger than 30 in other studies, ibid.), and the mean of all the VIFs is considerably larger than 1. These respective results for models (1a) to (1e) suggest that the explanatory variables are no perfect linear combination of the other independent variables, i.e. it says that no perfect multicollinearity exists between the variables. However, as Wooldridge (2009:p.99) points out, "… such statistics are of questionable value because they might reveal a "problem" simply because two control variables, …, are highly correlated". Since the main interest in this chapter is in the causal effect of market concentration on the seat capacities offered at the hub airport, the VIFs of other coefficient might not be as important. The standard errors as well as the significance for each estimator are outlined in the respective tables and discussed accordingly.

Assessing the results for the dependent variable *log(Seats)* across all considered time periods, it shows a positive coefficient for both the population and the gross domestic product per capita variables, both being statistically significant in each model. Since both the dependent and the independent variables are in log-format, a one per cent increase in population *log(Pop)* leads to a 0.47 per cent increase in seats offered in the year 2016. In the previous time periods this effect is slightly lower. For the GDP per capita, *log(Gdp)*, a one per cent increase in this variable means that total seats offered on a route per year increase by 0.40 per cent in 2016. This result confirms the assumption that higher demand on a route leads to more seats being offered on this.

The *Network* variable is also statistically significant across all five models in Table 23, and it has a positive coefficient as expected in the initial assumptions in Chapter 4.3.1. It implies that the presence of a network carrier on a particular route leads to an increase in seats offered per year by 137 per cent (in 2016).

Table 23: Results OLS estimation with *log(Seats)* as dependent variable (per year)

Variable	(1a) 2000	(1b) 2004	(1c) 2008	(1d) 2012	(1e) 2016
log(Pop)	0.33***	0.33***	0.36***	0.41***	0.47***
	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
log(Gdp)	0.44***	0.37***	0.35***	0.38***	0.40***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
HHI_{route}	-1.09***	-0.99***	-0.73***	-1.11***	-1.55***
	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)
Network	1.28***	1.45***	1.26***	1.27***	1.37***
	(0.06)	(0.05)	(0.05)	(0.04)	(0.05)
log(Distance)	-0.19***	-0.13***	-0.24	-0.16***	-0.21***
	(0.05)	(0.03)	(0.03)	(0.11)	(0.03)
Ownership	0.19***	0.27***	0.33***	0.28***	0.22***
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Intercept	5.62***	5.65***	6.31***	5.30***	5.37***
	(0.39)	(0.41)	(0.37)	(0.39)	(0.42)
Observations	2740	2976	3419	3692	3928
R^2	0.3782	0.3764	0.3535	0.3388	0.3463
SER	1.2818	1.2848	1.2654	1.3123	1.4185

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

In regard to the *Ownership* variable, a positive coefficient for all observed time periods can be observed, with all being statistically significant at the 99.9 per cent level. The positive effect of this specific variable is contrary to the expectation that an overlap in ownership between airports in the same catchment leads to a reduction in seats offered per year. It can be seen that the existence of an additional airport with the same ownership as the hub airport leads to an increase of seats at the latter by 22 per cent in 2016. This result is contrary to the assumption in Chapter 4.3.1, which expected a negative coefficient. Looking at Table 49 in Appendix 8.6 shows that the common ownership between a hub airport and its secondary airports is mainly with smaller airports in the catchment. Therefore routes offered at these smaller airports may be duplicated at the hub airport instead of each airport focusing on a particular segment, and thus yielding the positive coefficient for this variable.

Another control variable, *log(Distance)*, shows the expected sign in all models in Table 23: with an increase in distance by one per cent a decrease in offered seats by 0.21 per cent can be observed. This implies that a higher focus is placed on short-haul to medium-haul distances at the hub airports.

The main causal effect investigated in this chapter is that of market concentration, represented by the route-level Herfindahl Hirschman Index, on the output offered at the hub airports. Considering the variable *log(Seats)*, the independent variable HHI_{route} is statistically significant at the 99.9 per cent level across all considered time periods. Furthermore, it shows a negative coefficient as was expected in Chapter 4.3.1. This means that an increase in the Herfindahl Hirschman Index leads to a decrease in the seats offered on a route at the hub airport in 2016, for example. These findings confirm the assumption that an increase in market concentration in the catchment leads to a decrease of the output, in this case the number of seats offered on a route in a year, and thus represents a potential abusive behaviour due to limited competition.

Considering the dependent variable *log(meanSeats)*, which serves as a proxy for the aircraft size employed on a particular route, the models outlined in Table 24 are less significant than those for *log(Seats)* as dependent variable. All models exhibit no multicollinearity and standard errors are robust to heteroskedasticity. Both explanatory variables accounting for the level of demand on a particular route have a positive and statistically significant effect on the mean number of seats offered per flight. A one per cent increase in the population in the urban region of the destination airport leads to a 0.04 per cent increase in the mean number of seats per flight in 2016, for example.

Contrary to models (1a) to (1e), the *Network* variable in Table 24 is only statistically significant in 2000 and 2008, with opposing signs of the respective coefficients. In 2000, the presence of a network carrier on a particular route has a positive effect on the mean seats offered per flight, whereas this effect is negative in 2008. Furthermore, the standard errors for the estimators are rather high compared to the value of the coefficient, which implies a high spread around the regression line.

The *log(Distance)* variable is statistically significant and exhibits the expected sign. As previously outlined, an increase in mean seats per flight with increasing distance was assumed. This is due to larger aircraft being employed on long-haul routes compared to those being operated on short-haul destinations.

Regarding the *Ownership* variable similar observations as in Table 23 can be made, with it being statistically significant across all observed time periods, and an increase by one unit leading to a positive percentage change of the dependent variable.

Table 24: Results OLS estimation with *log(MeanSeats)* as dependent variable (per year)

Variable	(2a) 2000	(2b) 2004	(2c) 2008	(2d) 2012	(2e) 2016
log(Pop)	0.06*** (0.006)	0.06*** (0.006)	0.04*** (0.005)	0.05*** (0.004)	0.04*** (0.004)
log(Gdp)	0.02** (0.006)	0.02*** (0.006)	0.02** (0.006)	0.03*** (0.006)	0.04*** (0.006)
HHI_{route}	-0.17*** (0.03)	-0.001 (0.03)	-0.001 (0.03)	-0.05* (0.02)	-0.07*** (0.02)
Network	0.06*** (0.01)	-0.02 (0.02)	-0.02* (0.01)	-0.008 (0.01)	-0.002 (0.009)
log(Distance)	0.41*** (0.008)	0.37*** (0.009)	0.34*** (0.008)	0.31*** (0.007)	0.28*** (0.007)
Ownership	0.11*** (0.01)	0.15*** (0.01)	0.15*** (0.01)	0.10*** (0.01)	0.05*** (0.01)
Intercept	1.37*** (0.09)	1.52*** (0.10)	2.05*** (0.10)	2.15*** (0.09)	2.37*** (0.10)
Observations	2740	2976	3419	3692	3928
R^2	0.6235	0.5470	0.5226	0.5141	0.5004
SER	0.3366	0.3541	0.3217	0.2957	0.2731

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

The level of market concentration, HHI_{route}, is only statistically significant within three of the five observed time periods (2000, 2012, 2016), and has a negative coefficient. This implies that an increase in the route-level Herfindahl Hirschman Index leads to a decrease in aircraft size, represented by mean seats per flight. An increase in route concentration by one unit thus results in a decrease of aircraft size by 7 per cent in 2016, for example. Less output is therefore offered on these routes by employing smaller aircraft.

Considering the dependent variable *log(Frequency)*, the respective models are outlined in Table 25. All models exhibit no multicollinearity and standard errors are robust to heteroskedasticity. The explanatory variables and the respective coefficients are all statistically significant and exhibit the same signs as for the dependent variable *log(Seats)*.

Table 25: Results OLS estimation with *log(Frequency)* as dependent variable (per year)

Variable	(3a) 2000	(3b) 2004	(3c) 2008	(3d) 2012	(3e) 2016
log(Pop)	0.27***	0.27***	0.32***	0.36***	0.43***
	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
log(Gdp)	0.42***	0.34***	0.33***	0.35***	0.35***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
HHI_{route}	-0.91***	-0.99***	-0.73***	-1.06***	-1.48***
	(0.11)	(0.11)	(0.09)	(0.09)	(0.09)
Network	1.22***	1.47***	1.28***	1.28***	1.37***
	(0.06)	(0.06)	(0.05)	(0.04)	(0.04)
log(Distance)	-0.60***	-0.50***	-0.58***	-0.46***	-0.49***
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)
Ownership	0.08	0.11*	0.23***	0.18**	0.17**
	(0.05)	(0.05)	(0.04)	(0.06)	(0.06)
Intercept	0.30	0.18	0.31	-0.80*	-0.95*
	(0.39)	(0.39)	(0.36)	(0.38)	(0.40)
Observations	2740	2976	3419	3692	3928
R^2	0.4616	0.4429	0.4271	0.3832	0.3760
SER	1.2282	1.2535	1.2258	1.2702	1.3878

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

The effect of market concentration, HHI_{route}, on the route is negative across all years, implying that an increase in the Herfindahl Hirschman Index leads to a decrease of mean frequencies per week in 2016, for example. Here, the previous results are confirmed that increased market concentration results in a restriction of output.

Within the next step, Equation (19) from Chapter 4.3.2 is applied. Here, the entire observations across all considered years are applied in the regression analysis. A time fixed effect is included that controls for variables which are constant across entities, i.e. routes, but vary over time. The use of panel data and fixed effects in regression analysis is a way of controlling for omitted variable bias, by accounting for changes in variables that evolve over the considered time periods. Furthermore, within this estimation a balanced panel is employed, which means that only those routes are included which are offered within each time period. For example, the route from Amsterdam Airport (AMS) to New York John F. Kennedy Airport (JFK) is offered within each of the five time periods and therefore included in the panel data. The results of this estimation are displayed in Table 26, all models exhibit no multicollinearity and standard errors are robust to heteroskedasticity.

Table 26: Results OLS estimation with time fixed effects

Variable	(4a) *log(Seats)*	(4b) *log(MeanSeats)*	(4c) *log(Frequency)*
log(Pop)	0.30***	0.05***	0.26***
	(0.01)	(0.002)	(0.01)
log(Gdp)	0.39***	0.02***	0.37***
	(0.01)	(0.004)	(0.01)
HHI_{route}	-0.45***	-0.05***	-0.39***
	(0.04)	(0.01)	(0.04)
Network	0.92***	0.01	0.91***
	(0.02)	(0.007)	(0.02)
log(Distance)	-0.20***	0.34***	-0.54***
	(0.01)	(0.004)	(0.01)
Ownership	0.33***	0.11***	0.22***
	(0.02)	(0.006)	(0.02)
$Year^{2004}$	0.03	-0.01	0.04
	(0.03)	(0.01)	(0.03)
$Year^{2008}$	0.11**	0.03***	0.07*
	(0.03)	(0.01)	(0.03)
$Year^{2012}$	0.16***	0.09***	0.07*
	(0.03)	(0.01)	(0.03)
$Year^{2016}$	0.26***	0.17***	0.09**
	(0.03)	(0.01)	(0.03)
Intercept	6.36***	1.91***	0.50**
	(0.18)	(0.05)	(0.17)
Observations	9510	9510	9510
R^2	0.3542	0.6030	0.4629
SER	0.9647	0.2856	0.8872

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

In terms of the dependent variable *log(Seats)*, the coefficient for the HHI_{route} variable is statistically significant and exhibits a negative sign. However, the coefficient is lower than in the estimations for each year in Table 23, with a one unit increase in the Herfindahl Hirschman Index resulting in a 45 per cent reduction in the total seats being offered on that route per year. In regard to the time fixed effect, the year 2000 is omitted to avoid multicollinearity. Interpreting this coefficient means that a unit increase, here an increase by one time period, leads to a positive change in total seats offered. This means that total seats have been increasing by 26 per cent in 2016, by 16 per cent in 2012, and 11 per cent in 2008. The coefficient for the year 2004 is not statistically significant in any of the three models in Table 26, and therefore no statement can be made regarding the effect of this particular year on the different dependent variables. The same ranking for the different years also applies to models (4b) and (4c), with 2016 exhibiting the highest growth, and 2008 with the lower (or the same) coefficients as the year 2012.

For the dependent variable *log(MeanSeats)* a negative and statistically significant effect of HHI_{route} can also be observed, meaning that an increase in the level of market concentration leads to a decrease in the mean number of seats offered per flight, i.e. smaller aircraft are employed on routes with higher market concentration. Thus, an increase in HHI_{route} by one unit leads to a decrease in mean seats per flight by five per cent. In line with the results in Table 23 to Table 25, the coefficient of the *log(Distance)* variable is positive and statistically significant. With increasing distance, the aircraft size also increases with a one per cent increase in distance leading to a 0.34 per cent increase in mean seats per flight.

Table 27 shows the results for the estimation employing HHI_{dist} instead of HHI_{route} as explanatory variable. The former represents the Herfindahl Hirschman Index which has been adjusted for distance in the catchment of European hub airports, and which was discussed in Chapter 4.2.3. The coefficient of the variable accounting for market concentration on a route is only statistically significant for the dependent variables *log(Seats)* and *log(Frequency)*, with a one-unit increase in the adjusted Herfindahl Hirschman Index resulting in a 12 per cent decrease in both the total seats per year and the mean weekly frequency offered on a route. The effect of this adjusted index is hence smaller than the original one HHI_{route}.

The other coefficients are of the same magnitude as in the model with HHI_{route} as explanatory variable. However, the results in Table 27 show that the coefficients for 2008 and 2016 are also not statistically significant, therefore no valid statement can be made in regard to this particular effect.

Table 27: Results OLS estimation with time fixed effects, HHI_{dist} as independent variable

Variable	(5a) *log(Seats)*	(5b) *log(MeanSeats)*	(5c) *log(Frequency)*
log(Pop)	0.30***	0.05***	0.26***
	(0.01)	(0.003)	(0.01)
log(Gdp)	0.39***	0.02***	0.37***
	(0.01)	(0.004)	(0.01)
HHI_{dist}	-0.12***	-0.004	-0.12***
	(0.04)	(0.01)	(0.03)
Network	0.91***	-0.01	0.90***
	(0.02)	(0.007)	(0.02)
log(Distance)	-0.22***	0.34***	-0.55***
	(0.01)	(0.004)	(0.01)
Ownership	0.39***	0.12***	0.27***
	(0.02)	(0.006)	(0.02)
$Year^{2004}$	0.04	-0.01	0.05
	(0.03)	(0.01)	(0.03)
$Year^{2008}$	0.12	0.03***	0.08**
	(0.03)	(0.009)	(0.03)
$Year^{2012}$	0.18**	0.09***	0.08**
	(0.03)	(0.009)	(0.03)
$Year^{2016}$	0.28	0.17***	0.11***
	(0.03)	(0.009)	(0.03)
Intercept	6.20***	1.88***	0.36*
	(0.18)	(0.05)	(0.17)
Observations	9510	9510	9510
R^2	0.3471	0.6022	0.4577
SER	0.9699	0.2858	0.8915

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

Building on these results, the model is extended in the following chapter to account for the presence of low cost carriers in the catchment of European hub airports.

4.3.4 Impact of low cost carrier presence in the catchment area

Since the increase in low cost airlines has been driving a high share of growth of the European airport market, the effect of these carriers on the output provided at the hub airport will be investigated further in this chapter. It has been argued that the increasing presence of this airline business model has significantly raised the degree of constraints for market power at (European) hub airports (Thelle *et al.*, 2012; Morrison, 2001). To investigate this particular effect, an additional variable is introduced to the estimations discussed in Chapter 4.3.3. For this purpose, the number of low cost carriers in the local catchment that offer seats to the same destinations as the hub airport is identified. The approach in determining whether a particular route is offered by a potentially competing carrier is exemplified in Figure 25.

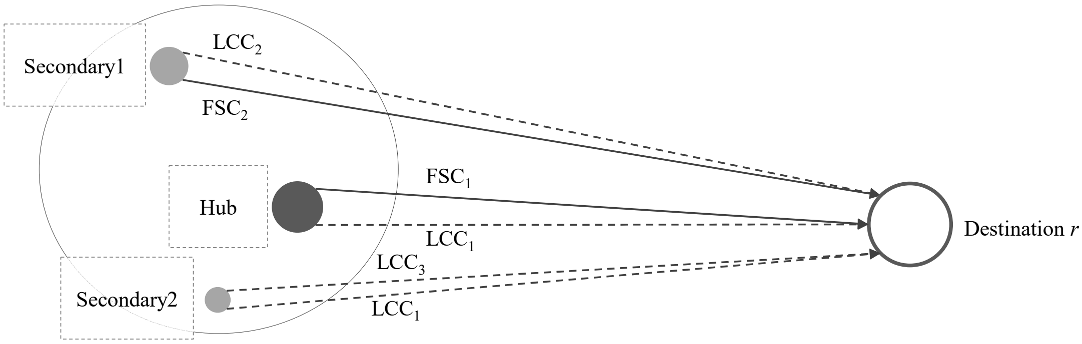

Figure 25: Low cost carrier competition in the primary airport's catchment
Source: own depiction

At the hub airport (Hub) a full service carrier (FSC) offers seats to destination *r* (FSC_1), as does a low cost carrier (LCC_1). At another airport in the catchment (Secondary1), a different full service carrier (FSC_2) offers seats to the same destination, as does a different low cost carrier (LCC_2). There is also another secondary airport in the catchment (Secondary2) that offers seats to destination *r*, in this case by two low cost carriers (LCC_1 and LCC_3), with LCC_1 being the same carrier operating at the hub airport. In this particular example, the explanatory variable *Lcc* has a value of 3, i.e. each low cost carrier offering seats at different airports in the catchment is counted. As the discussion showed, the presence of low cost carriers in the catchment is expected to increase competition for the hub airport, which is why a positive coefficient is presumed. Table 28 displays the results of the estimation in model (20), and thus the effect of low cost carrier presence in the catchment of European hub airports. All models exhibit no multicollinearity and standard errors are robust to heteroskedasticity.

Table 28: OLS estimation with time fixed effects and with *Lcc* as explanatory variable

Variable	(6a) *log(Seats)*	(6b) *log(MeanSeats)*	(6c) *log(Frequency)*
log(Pop)	0.31***	0.05***	0.26***
	(0.01)	(0.003)	(0.01)
log(Gdp)	0.39***	0.02***	0.36***
	(0.01)	(0.004)	(0.01)
HHI_{route}	-0.36***	-0.007	-0.34***
	(0.05)	(0.01)	(0.04)
Network	0.93***	0.01	0.91***
	(0.02)	(0.007)	(0.02)
log(Distance)	-0.20***	0.34***	-0.54***
	(0.01)	(0.004)	(0.01)
Ownership	0.31***	0.10***	0.21***
	(0.02)	(0.006)	(0.02)
Lcc	0.05***	0.02***	0.03***
	(0.009)	(0.003)	(0.009)
$Year^{2004}$	0.02	-0.01	0.04
	(0.03)	(0.01)	(0.03)
$Year^{2008}$	0.09***	0.02*	0.06*
	(0.03)	(0.009)	(0.03)
$Year^{2012}$	0.14***	0.08***	0.06
	(0.03)	(0.009)	(0.03)
$Year^{2016}$	0.23***	0.16***	0.08*
	(0.03)	(0.009)	(0.03)
Intercept	6.26***	1.86***	0.45**
	(0.18)	(0.05)	(0.17)
Observations	9510	9510	9510
R^2	0.3560	0.6058	0.4635
SER	0.9633	0.2846	0.8869

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

The results imply that the presence of low cost carriers at secondary airports in the catchment on a particular route increases the amount of seats offered by the airlines at the hub airport. Considering models (6a) to (6c) an increase in *Lcc* by one, i.e. one more low cost carrier is offering seats to destination *r*, leads to an increase of total seats per year by five per cent, an increase in mean seats per flight by two per cent, and an increase of frequency per week of three per cent. The coefficients are all statistically significant at the 99.9 per cent level. Airlines at the hub airports therefore react to low cost carrier presence in the catchment by increasing seat capacities on respective routes. Since low cost carriers are mainly focusing on the passenger segment of the private or leisure traveller, airlines at the hub airport might be reacting to an increased supply of flights and seats at the secondary airports on these particular routes in order to provide an attractive offer for all passenger groups. In addition to this, a positive and statistically significant effect can also be observed across the different time periods, with 2016 again being the period of highest growth.

As discussed earlier, another constraint for hub airports' market power can potentially be imposed by available rail services within a country. The following chapter therefore places particular focus on this aspect and how it affects the seat capacities offered at hub airports.

4.3.5 Impact of rail services on the short-haul segment

As highlighted in Chapters 3.1 and 3.2, rail services can impose competition for air services in terms of faster journey times. However, this only applies up to a certain distance. The Directorate-General for Mobility and Transport (2010) states that up to a distance of 400 kilometres conventional rail services can compete with air services in terms of journey time. High-speed rail services are even competitive up to a distance of 800 kilometres. Therefore, for the analysis in this chapter only a specific distance segment is considered, and destinations with a distance of more than 800 kilometres are excluded from the observations.

The variable *Hsr* accounts for the density of the rail network in a particular country, and hence serves as a proxy for the potential to substitute to this transport mode instead of using air services. It is calculated by dividing the total rail kilometres in a country by the overall country size, which is measured in square kilometres. Data on both parameters are extracted from The World Bank (2017). It thus depicts the available rail kilometres per square kilometre in a country. It is assumed that a higher ratio is an indicator for a more connected rail network, and hence a higher degree of potential competition for air services, i.e. the coefficient of this variable is expected to be negative since better rail connections are assumed to lead to less air services being offered, see also Albalate, Bel & Fageda (2015).

Table 29 reports the descriptive statistics for the different variables considered in this analysis. As can be seen, the number of observations is lower than in the estimations in the previous chapters, due to only a subset of the short-haul market being considered here.

Table 29: Descriptive statistics of variables (values at the route level)

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Seats	5972	174549	266580	21	3718962
MeanSeats	5972	105	50	5	400
Frequency	5972	28	33	0.02	441
Pop	3760	1829	2489	251	16187
Gdp	5971	34160	12293	1840	103838
Network	5972	0.60	0.49	0	1
HHI_{route}	5972	0.76	0.27	0.15	1
HHI_{dist}	5972	0.70	0.32	0.07	1
Distance	5972	492	175	32	800
Ownership	5972	0.25	0.56	0	3
Lcc	5972	0.48	1.07	0	10
Hsr	5673	0.07	0.04	0.01	0.25

Source: own depiction

Applying model (21) from Chapter 4.3.2 yields the results displayed in Table 30, for all three dependent variables considered throughout Chapter 4.3. All models exhibit no multicollinearity and standard errors are robust to heteroskedasticity.

The results in Table 30 show the expected negative sign for the variable *Hsr*, the coefficient is statistically significant at the 99.9 per cent level. An increase in the ratio of rail kilometres to total country size, *Hsr*, leads to a decrease in total seats, mean seats per flight, and flight frequency offered on a particular route. Concerning total seats and frequencies, Albalate, Bel & Fageda (2015), employing a dummy variable to account for the availability of high-speed rail services, confirm that competition from this transport mode leads to a reduction in the amount of seats being offered on a route: An increase in the coverage of the high-speed rail network (*Hsr*) hence leads to a decrease in total offered seats, in mean seats per flight, and in flight frequency per week.

Table 30: OLS estimation with time fixed effects and with *Hsr* as explanatory variable

Variable	(7a) *log(Seats)*	(7b) *log(MeanSeats)*	(7c) *log(Frequency)*
log(Pop)	0.28***	0.11***	0.17***
	(0.03)	(0.008)	(0.03)
log(Gdp)	0.65***	0.005	0.65***
	(0.04)	(0.02)	(0.04)
HHI_{route}	-0.37***	-0.05	-0.32***
	(0.10)	(0.03)	(0.09)
Network	1.15***	0.12***	1.03***
	(0.06)	(0.02)	(0.06)
log(Distance)	-0.05	0.15***	-0.20***
	(0.06)	(0.02)	(0.05)
Ownership	0.26***	0.13***	0.13***
	(0.03)	(0.01)	(0.03)
Lcc	0.08***	0.03***	0.05***
	(0.02)	(0.006)	(0.02)
Hsr	-4.33***	-1.84***	-2.49***
	(0.39)	(0.14)	(0.32)
$Year^{2004}$	-0.17**	-0.03	-0.14**
	(0.06)	(0.02)	(0.05)
$Year^{2008}$	-0.19**	0.04***	-0.23***
	(0.06)	(0.02)	(0.05)
$Year^{2012}$	-0.21**	0.14***	-0.35***
	(0.07)	(0.02)	(0.06)
$Year^{2016}$	-0.13	0.25***	-0.39***
	(0.07)	(0.03)	(0.06)
Intercept	3.33***	2.87***	-3.49***
	(0.61)	(0.22)	(0.54)
Observations	2570	2570	2570
R^2	0.3349	0.2619	0.3124
SER	0.9789	0.3556	0.8442

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

These results can be interpreted in two ways. First, a well-connected rail network may represent a good alternative for passengers, inducing less demand for air services, and hence a reduction in offered seats on affected routes. Second, a reduction in seats offered may be observed since rail services act as complement for flights at the hub airport. Depending on the direct connection to the latter, rail may provide feeder services to an airport, and thus replace flights on a particular route. Since the analysis in this chapter does not distinguish between high speed rail and conventional rail services, no statement can be made regarding the specific impact of high speed rail. However, what can be concluded is that the presence of this transport mode does have a negative effect on the capacities offered at European hub airports. Therefore, attention has to be paid to this particular transport mode, when assessing the competition faced by airports in general, with the focus being placed on the short-haul market.

In addition to this specific observation, the coefficient of the *log(Distance)* variable behaves in the same way as in the previous estimations in this chapter. Considering the short-haul market up to 800 kilometres, the coefficient of this variable is only statistically significant for the dependent variables *log(MeanSeats)* and *log(Frequency)*, though. A one per cent increase in distance leads to an increase in mean seats by 0.15 per cent, and a decrease in frequency by 0.20 per cent, a smaller impact than can be observed for the dataset including all range segments. This observation is intuitive, since very short distances face additional competition from road and bus services, thus being less attractive routes for airlines to offer. Also, aircraft size, with mean seats per flight being a proxy for this, increases with distance as elaborated in Chapter 4.3.1.

The different findings in Chapters 4.2 and 4.3 regarding the level of market concentration in the local catchment of European hub airports and the respective impact of this on the seat capacities offered at European hub airports are summarised and discussed in Chapter 4.4.

4.4 Assessing potential competition in the catchment of European hub airports

The constraints imposed on hub airports' market power by their counterparts within the local catchment has been the main focus of this chapter. Starting off with a detailed analysis of the market concentration in the local catchment of the considered European hub airports, the chapter proceeded to empirically assess the impact of various factors, which are believed to either constrain an airport's market power or contribute to this. These include the presence of low cost carriers within a catchment, the availability of rail services, and the degree to which routes offered at hub airports overlap with other airports.

In terms of low cost carriers potentially exposing hub airports to an increased level of competition by offering the same routes at secondary airports, and thus providing a substitute for passengers, two main findings can be derived from the analysis in this chapter. First, low cost carrier growth has been rather evenly distributed across hub airports and secondary airports, therefore disproving the argument that low cost carriers are often focusing only on secondary, smaller airports. A current example of this development can be observed between the low cost carrier Ryanair and the hub airport Frankfurt (FRA). From summer 2017 onwards, Ryanair started to offer flights on different routes, which are mostly considered as holiday destinations (Frankfurt Airport, n.d.). Flights between Munich Airport (MUC) and Dublin Airport (DUB) were also initiated by this carrier in 2017 (Munich Airport, n.d.). Low cost carriers have been, however, the drivers of growth at both hub and secondary airports, compared to full service carriers. The further growth of low cost carrier operations at hub airports strongly depends on available capacities at these in the future, though.

The second finding refers to the empirical analysis within this chapter, estimating the effect of low cost carrier presence in the catchment on the operations at hub airports. The statistically significant results show that in case a route is offered by low cost carriers in the hinterland of European hubs an increase in seats offered at the hub airport can be observed. Both total seats and weekly flight frequencies are higher in case a route is also operated by a low cost carrier in the catchment. It seems that hub airports and their carriers are hence incentivised to react to developments in the catchment in order to keep providing attractive products to their passengers, and prevent these from substituting to other, secondary airports.

In addition to this, short-haul routes at hub airports are assumed to be exposed to competition from rail services. To assess this relationship, a variable accounting for the quality of the rail network in a country was introduced to the regression analysis in this chapter. Testing for the effect on seat capacities offered on routes at hub airports shows that an increasing quality of the rail network results in less seats being offered on a route. The reasoning for this may be twofold, with competitive rail services, in times of overall journey time, being an attractive substitute for passengers, thus reducing demand for air services. Furthermore, if a hub airport is well connected to the rail network, the latter may act as a complement for air services. Short-haul feeder routes at hub airports may thus be replaced by rail connections.

Complementing these analyses, the degree of market concentration in the catchment of the considered European hubs is assessed by applying the Herfindahl Hirschman Index on the individual route level. It cannot be assumed that a hub airport faces competition from another airport in the catchment if both merely offer the same route. The seat capacities offered at each airport make the difference for passengers deciding which airport to depart from or arrive at. The analysis of market concentration therefore contributes to assessing the degree of route overlap hub airports face on each of their individual destinations.

As the discussion in Chapter 2 showed, market power cannot be inferred directly from the degree of market concentration in an industry, and there is no predefined threshold at which an industry seems to be more or less concentrated. Analysing the level of and change in the above mentioned route-level Herfindahl Hirschman Index, however, provides a first good insight how European hub airports are positioned within their respective catchment areas. First, if hub airports experience a higher overlap, thus facing less market concentration, on the routes they offer over time, this implies that passenger may have more alternatives to choose from, thus contributing to the degree of competition different airports engage in. Applying this assumption, the majority of European hub airports experienced, to a small degree at least, a decrease in the level of market concentration within the catchment over the considered period from 2000 to 2016 (Table 43).

Regarding the level of market concentration, however, for most of these airports a rather high Herfindahl Hirschman Index can be observed. If firms in a market are of equal size, the minimum value this index can take is the inverse of the number of firms. Thus, assuming that there are two equally sized firms in a market, the lowest attainable value will be 0.50, more firms imply a lower minimum attainable value. Comparing the route-level Herfindahl Hirschman Index at European hub airports against this 0.50 threshold, reveals that most airports face a rather high degree of market concentration (Figure 26).

Bringing together these two interpretations of the Herfindahl Hirschman Index, a high-level indication in regard to market concentration for each hub airport can be obtained. Brussels Airport and Dusseldorf Airport, for example, both face a relatively low degree of market concentration in their catchment, which has also been decreasing over time. On the other side of the scale are Madrid Airport and Helsinki Airport with hardly any overlap in regard to their offered routes, and no observed decrease in this market concentration over time. Other major European hubs, including Amsterdam Airport, Frankfurt Airport, and London Heathrow Airport, all exhibit a mean route-level Herfindahl Hirschman Index between 0.60

and 0.70 in 2016, but with an observed decrease in this value over time. The market position of Paris Charles de Gaulle in its catchment is even more pronounced with a mean HHI_{route} value of almost 0.90. Potential competitors within this airport's catchment are scarce, and seem to focus on different market segments. Paris Orly Airport, for example, is within this catchment, and also exhibits a relatively high degree of market concentration. Potential overlap in routes between these two is on routes with high demand, apart from that the airports are focusing on distinct segments.

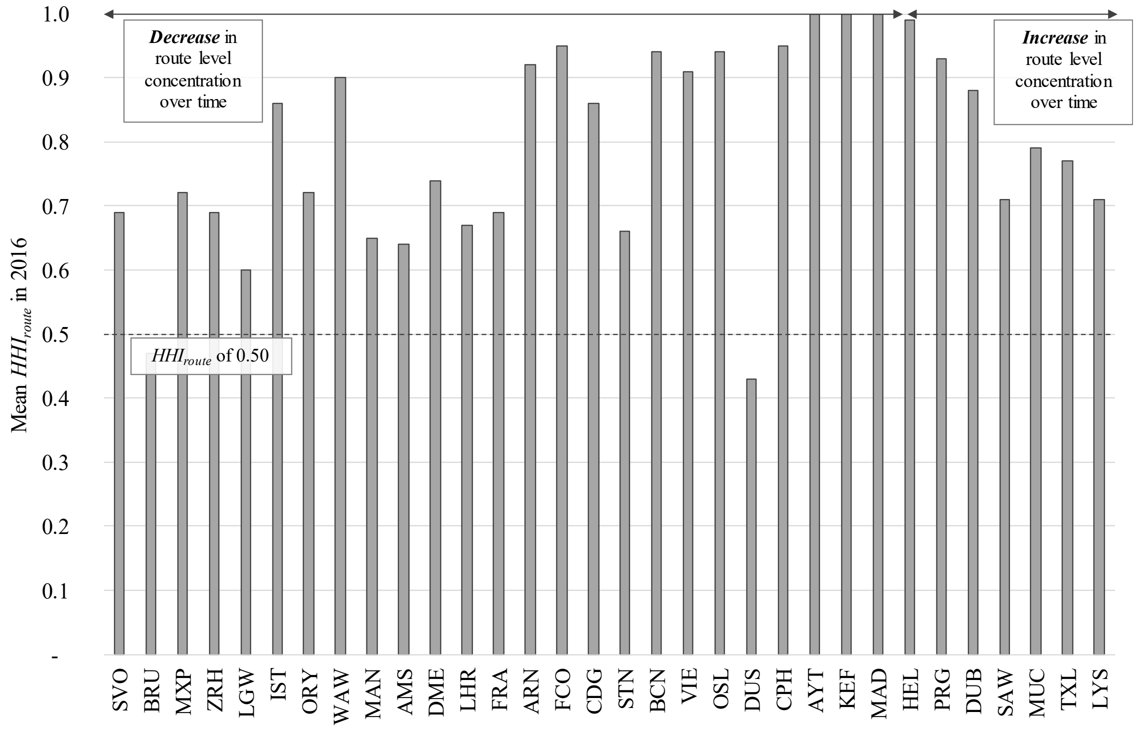

Figure 26: Development of market concentration in the local catchment

Source: own depiction

Complementing these results are the findings from the empirical assessment of the impact of market concentration on the hub airports' seat capacities. Here, the statistically significant outcomes show that an increase in the Herfindahl Hirschman Index on a route leads to a decrease in seats offered by the hub airport, thus implying a limitation of output on routes with high market concentration. Translating this to the analysis of market concentration in the catchment of European hub airports suggests that a high amount of routes at these airports may be subject to output restrictions, in the form of frequency reductions and/ or decreases in aircraft size. How these reductions in output affect the prices charged to passengers cannot be definitely concluded, relying on monopoly theory, though, implies that a reduction in the amount of goods and services by a firm enables this to increase prices. This is also confirmed by Fageda (2013), who estimates the effect of market concentration on a route on both the number of frequencies offered and the ticket prices to this particular destination. The results show that an increase in the Herfindahl Hirschman Index on a route leads a decrease in frequencies and an increase in ticket prices, thus confirming the results of the analysis within this chapter. Paying careful attention to the degree of route concentration at hub airports, observing this development over time, and considering additional developments in the catchment of European hub airports that impose competitive constraints on these, such as the presence of low cost carrier and (high-speed) rail networks, therefore provides a comprehensive approach to the investigation of airport competition.

The focus on different market segments by European hub airports and their secondary counterparts in the catchment, resulting in a limited overlap between routes, may therefore only provide little constraints for market power. However, since one particular characteristic of a hub airport is the functioning as a node for airlines operating a hub-and-spoke network, the transfer market and the respective competition airports face here has to be considered along with the local catchment. The following chapter hence analyses this particular market at each of the European hub airports in the dataset in more detail.

5 Competition for Transfer Traffic at European Hub Airports

Regarding the discussion on airport competition, supporting arguments highlight the increasing competition especially on the transfer market, and that this is restraining large hub airports from abusing their market power (Thelle *et al.*, 2012; Lieshout & Burghouwt, 2013; Pavlyuk, 2012; Bruinsma, Rietveld & Brons, 2000; Forsyth, 2010). This chapter therefore focuses on this particular market segment at European hub airports[31], in order to assess the degree of constraints potentially imposed on airports' market power. The market segment of transfer traffic is not inherent to every airport but mostly to hub airports. The latter's distinct characteristic is that an airline designs its network in a way that flights are both temporally as well as spatially concentrated at these airports. This allows airlines to bundle traffic on different flights, hence to offer a larger network of destinations to its passengers, and to exhaust economies of density (Reynolds-Feighan, 2001; Burghouwt, 2007). Dennis (1994) defines a hub as "an integrated interchange point where one or two specific airlines operate waves of flights" (p. 211).

These definitions already highlight the close relationship between the network airline and its hub airport. Since airlines are customers of airports, the competition imposed on these airlines also affects the airport, as discussed in Chapter 3. As depicted in Figure 27, transfer passengers are, inter alia, the customers of an airline, since they select their most feasible connection in terms of overall travel time, price or other relevant choice factors. This airline operates its node at one or more airports within its network to which the passengers are then assigned. Within the analysis in the following chapters, the flights of network carriers as well as their respective alliance partners are considered, when identifying the degree of market concentration European hub airports face on the transfer market. Addressing the degree of competition on this market is hence referring to the competition between network carriers, and airline alliance partner, via their respective hub airports.

[31] Within this section the same sample of European airports as outlined in Table 9 is considered.

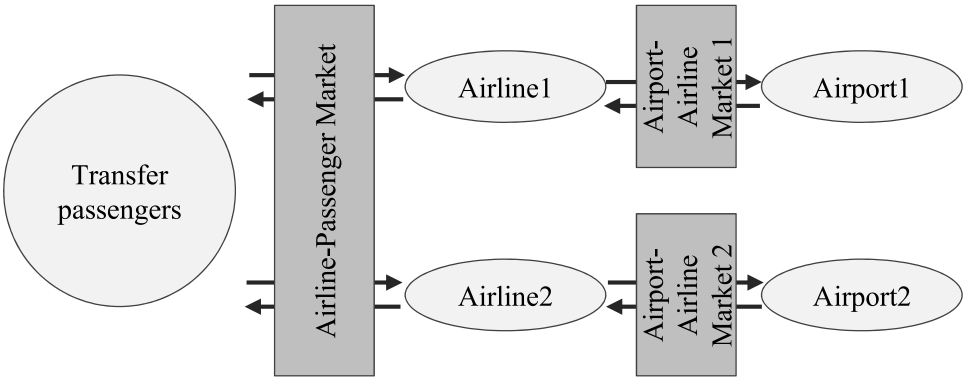

Figure 27: Airline and airport market structure

Source: Allroggen & Malina (2010)

In Chapter 5 the focus is thus placed on the assessment of competition on the transfer market at European hub airport by assessing market concentration on this market, the respective development over time, and the empirical estimation of the effects of a high degree of market concentration on the transfer connections offered via the hub.

Since the close relationship between network carrier and hub airports is essential in assessing the degree of market concentration the latter face on the transfer market, Chapter 5 starts out with an overview of this relationship for the considered European hub airports (Chapter 5.1). The intention of this chapter is to show how close each of the considered European hub airports is interlinked with its respective network carrier. The subsequent Chapter 5.2 provides both an overview of different methodologies that are applied to determine the amount of transfer connections offered by network carriers at hub airports, and outlines the current state of research in this regard.

Building on these approaches, Chapter 5.3 determines the available transfer connections at each of the European hub airports in the dataset, and analyses the degree of overlap between these and other hub airports. For this purpose, the degree of market concentration is assessed by using the Herfindahl Hirschman Index on the individual transfer connection level, hence referring to research question (5) outlined in Chapter 1. Whether high market concentration has an effect on the number of seats offered on an individual transfer connection is analysed in Chapter 5.4, addressing research question (6). Here, an empirical model is estimated, employing the Herfindahl Hirschman Index on the individual transfer connection level as explanatory variable. Chapter 5.5 brings together the different strands of analyses in this chapter and discusses the implications regarding the competition on the transfer market at European hub airports.

5.1 Network carrier share at European hub airports

Hub airports are, inter alia, characterised by the specific relationship with their network carrier, which organises its network in a hub-and-spoke structure. This particular structure implies that the carrier bundles its flights within the node, the hub airport, in order to derive benefits (see Chapter 3.1.2 for a detailed discussion). Due to this, most of this carrier's flights are directed via the hub airport, thus potentially generating a high amount of the traffic at this airport. The dominance of this carrier may enable it to charge a hub premium, thus abusing the market power it gained due its high market share at the airport. The network carrier is also the one, often in cooperation with several airline alliance partners, which offers transfer connections to passengers, and thus constitutes the transfer market at a hub airport. Since this transfer market is the focus of the analysis in Chapter 5, evaluating the dominance of the network carrier at the hub airport is an initial step in understanding the importance of this market for the hub airport.

For this purpose, the share of these airlines at their respective hub airports, in terms of their share in total seats offered at the respective airports, is determined and outlined in Figure 28. The designated network carrier at each hub airport as well as their share in the hub airports' operations across all five years are depicted in Table 47 and Table 48 in Appendix 8.5. Here the development of these shares from 2000 to 2016 can be observed, with some hub airports experiencing major changes in terms of their network carrier relationship. Figure 28 only shows the years 2000 and 2016 in order to observe the change over the entire period. The 45° line separates the hub airports into those which saw an increase in its network carrier's share, and those that did not. Most hub airports in the dataset experienced a decreasing share of network carrier operations. One reason for this might be the steep low cost carrier growth in the period between 2000 and 2016, as discussed in Chapter 4. These particular carriers have been picking up operations at European hub airports, and therefore taking up shares of total seats being offered. The observed decrease in network carrier operations thus does not necessarily have to be due to the network carrier cutting back on operations.

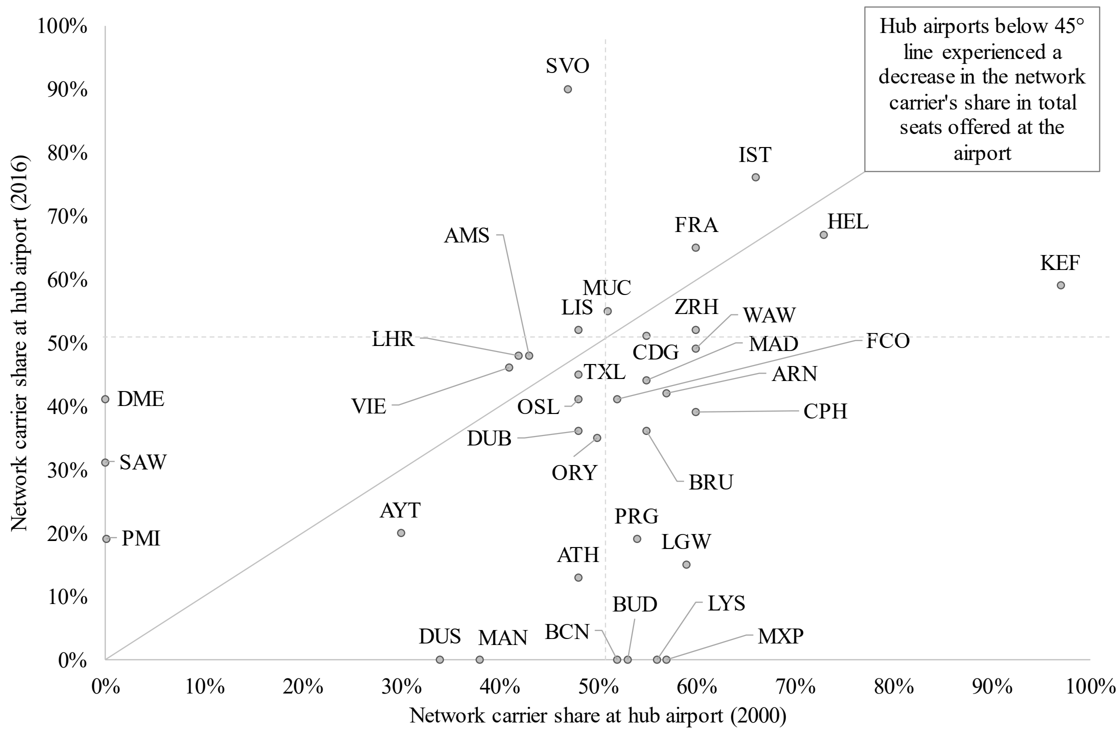

Figure 28: Share of network carrier in total seats offered at European hub airports
Source: own calculation based on OAG data

Hub airports which saw an increase in the network carrier's share include some of the largest airports in Europe, in terms of total passenger numbers. At Frankfurt Airport (FRA), for example, the share of its network carrier Lufthansa in total aircraft seats offered has been increasing from 60 per cent in 2000 to about 65 per cent in 2016. Next to this increase, the share is rather high, which implies that the hub airport strongly depends on the continuation of the network carrier's operations, since replacing these amount of seats by other carriers probably takes several years, if even possible at all. At Istanbul Airport (IST), the network carrier Turkish Airlines (TK) also increased its share in total seats offered from 2000 to 2016, from less than 70 per cent to about 75 per cent. Another strong increase in carrier dominance took place at Moscow Sheremetyevo (SVO), with the share of Aeroflot (SU) rising from less than 50 per cent in 2000 to about 90 per cent in 2016. These developments, shortly outlined here, play an important role when determining the amount of transfer connections offered at each hub airport in the considered time period (Chapter 5.3).

In addition to understanding the magnitude of network carrier operations at a specific hub airport, the distribution of these carriers' operations across their entire network is an important criterion to assess the dependency between airport and airline. Addressing the distribution across an airline network means to identify the share of network carrier's seats at each airport in the network. An approach to bring these two elements together is proposed by Maertens (2012), the countervailing power of an airline (*CVP*):

$$CVP_{A/C} = sc * MS_{A/C}(1 - MS_{C/A}) \quad (22)$$

With *C* depicting the carrier and *A* the airport. The market share of an airline at a particular airport is expressed by $MS_{A/C}$, and $MS_{C/A}$ depicts the share of the airport within the airline's total network, both are measured in percentage. These respective market shares have been calculated using the inbound and outbound scheduled seats listed in the OAG database for the years 2000, 2004, 2008, 2012, and 2016. In order to account for different types of carriers, i.e. business models, and the associated relationship with the airport, an indicator (*sc*) is included, which accounts for the level of sunk cost a carrier incurs at an airport, and described in more detail in Table 31.

Table 31: Interpretation of indicator accounting for sunk cost

Level of sunk cost (sc)	Application case
0.2	Carrier C is a network carrier and has its hub at airport A
0.5	Carrier C is a network carrier and no important hub at airport A
0.8	Carrier C is a low cost carrier and has its base at airport A
1	Carrier C is a low cost carrier and has no aircraft based at airport A

Source: Maertens (2012)

Since the analysis in this chapter focuses on the relationship between a hub airport and its network carrier, *sc* is equal to 0.2, meaning that carriers have a high amount of sunk cost at these airports, which may prohibit them from switching operations easily. Figure 29 depicts the results for this index for the year 2000 and 2016, Table 50 in Appendix 8.7 shows the results for all years.

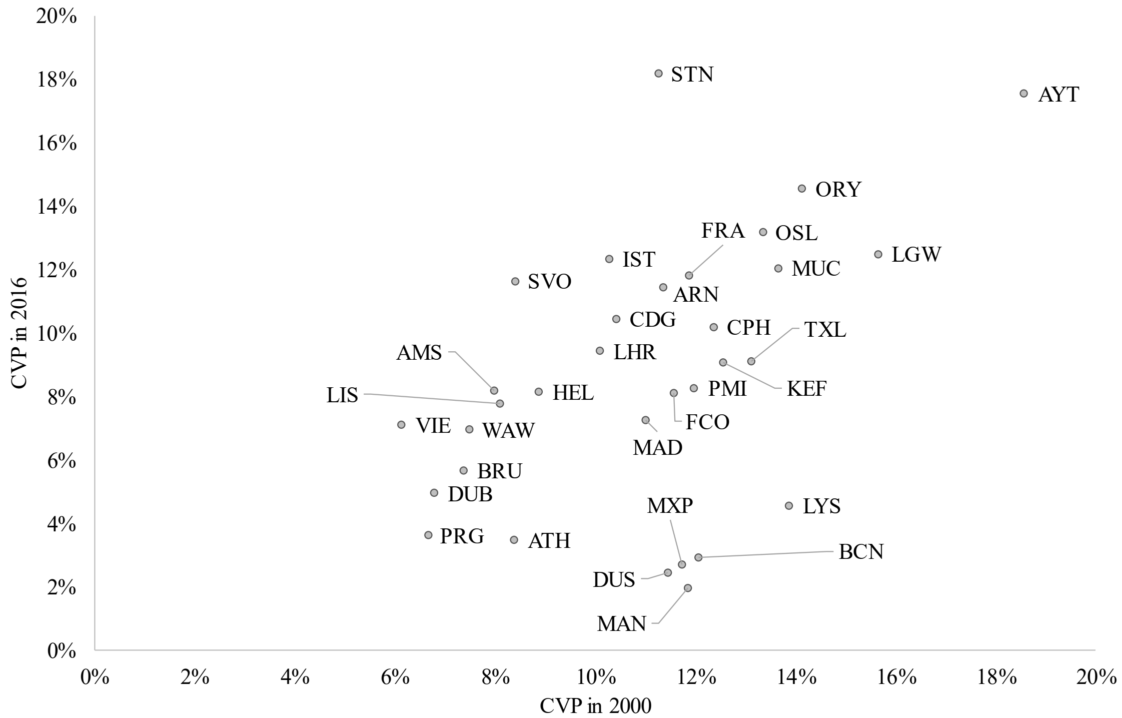

Figure 29: Countervailing Power Index for network carriers at European hub airports

Source: own depiction

According to Maertens (2012), a higher percentage represents a higher degree of countervailing power by the network carrier, i.e. the network carrier has more power over the hub airport in negotiating terms and conditions of its operations. As Figure 29 shows, overall, the CVP is rather low for network carriers at their respective hubs. In the analysis by Maertens (2012), Bergamo (BGY), for example, faces a CVP of about 55 per cent for its largest carrier Ryanair. Here, airports with the highest index are London Stansted (STN), and Antalya (AYT). This implies that the respective network carriers operating at these airports, British Airways (BA) and Turkish Airlines (BA), respectively, have a high degree of bargaining power over these airports. Both these carriers do not have their node at these airports, but contribute a high share of overall operations. Therefore, relocating operations to another airport may be easier than in case these were their nodes.

Those airlines with a multi-hub strategy are also further at the right end of the scale, including Lufthansa at FRA and MUC, for example, implying that this carrier can exercise some buyer power in negotiating service levels and airport charges, since it is able to switch operations between hub airports to some degree. However, keeping in mind the argument by Elliot (2016) that a dominant airline at an airport has the means to exercise some degree of buyer power, also those airlines with a very high share of operations at their respective hub airports may be able to successfully negotiate operating conditions.

According to the analysis in this chapter, a high-level overview of the relationship between European hub airports and their respective network carrier can be obtained. It shows, in general, that network carriers are in a dominant position at the hub airports they are operating at. But these carriers also depend on the hub airports by having established their node at these, which cannot be easily relocated to another airport. The importance of this node in terms of participating in the competition on the transfer market will be analysed in the subsequent chapters. A carrier with a high share of seats offered at the hub is also assumed to provide a high amount of transfer connections, thus contributing to this market playing an important role in the competitive position of the hub airport. As a next step, the following chapter outlines the methodology which is applied to determine the amount of transfer connections at each European hub airport in the dataset.

5.2 Methodological approaches to measure connectivity

The transfer market at a hub airport is defined as the passenger segment that switches between flights at the hub airport (H), in order to get from the origin (A) to the desired destination (B), and is exemplified in Figure 30. To denote this concept the term transfer connection is employed in the subsequent chapters. The amount and quality of transfer connections passengers can choose from are determined for each of the considered European hub airports.

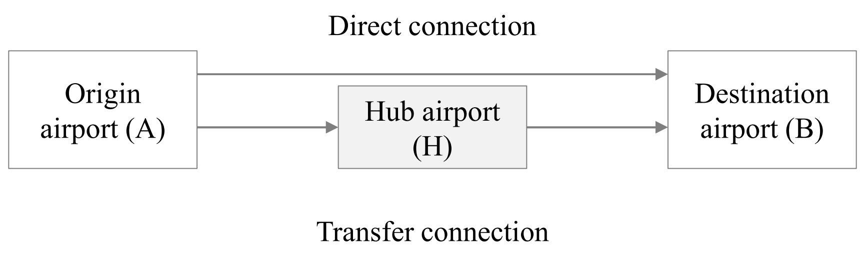

Figure 30: Definition of transfer and direct connections

Source: own depiction

Nowadays, the concept of self-hubbing is gaining popularity among passengers, enabled by both new airline business models and online platforms, which facilitate the matching of flights that do not belong to the same airline group, alliance, or have code share agreements (Malighetti, Paleari & Redondi, 2008; Fageda, Suau-Sanchez & Mason, 2015; Fichert & Klophaus, 2016; Maertens, Pabst & Grimme, 2016). However, this particular form of connecting between flights at an airport will not be in the focus of the analysis, and only those flights are considered which are between the same airline, airline group or airline alliance.

Chapter 5.2.1 outlines different methodological approaches to identify transfer connections at hub airports, including a discussion on the feasibility of the different indicators for the analysis here. Chapter 5.2.2 provides an insight how these measures are currently applied to identify the number and capacities of transfer connections provided at an airport. It also gives a first overview of the degree of overlap between these connections across different European airports.

5.2.1 Overview of methodologies to measure transfer connections

A range of measures to determine transfer connections exists, which are shortly outlined in order to identify the approach or different elements most suited for the analysis in the following chapters. Table 32 gives an overview of the different models and their specifications, which are subsequently discussed in more detail.

The Bootsma connectivty determines the number of connections at an airport. In this case a transfer connection between two direct flights at a hub airports exists if there is a minimum amount of time (60 minutes) between these as well as a maximum time above which connections are no longer feasible. The maximum connecting time differs by the stage length of the two direct connections (Burghouwt & Redondi, 2013).

Veldhuis (1997) introduces the Netscan model and applies it to measure the degree of competition between airline networks in Western Europe, by comparing the level of connectivity offered at the different hub airports. For this purpose, an index is introduced which measures the "connectivity units (CNU)" (p. 182) at each airport. It incorporates the number of frequencies on a destination pair, including both direct and indirect connections, the overall travel time as well as a factor accounting for the potential transfer time a passenger faces, when making a connection at the hub airport. Further, ibid. distinguishes between onward and hub connectivity. The former denotes the number of connections a passenger can access at destination B when flying from hub airport H, hub connectivity denotes the concept of transfer connections explained above. The analysis finds that connectivity growth is taking place at hubs, i.e. via hub connectivity, and not via direct connections excluding the hub airports, using data for 1994 and 1996.

Table 32: Overview of measures with an application to aviation

Model	Definition
Bootsma connectivity	Calculates the number of connections, indirect connections meet predefined minimum and maximum connecting (waiting) time, connections are classified according to connecting time.
Netscan Connectivity Units	Measures the number of direct and indirect connections, weighted by their quality in terms of transfer and detour time relative to a theoretical direct flight.
Weighted connectivity	Measures the number of direct and indirect connections, weighted by their quality in terms of transfer and detour time, based on Netscan Connectivity Units and Bootsma connectivity.
Shortest path length (SPL)	Number of connections lying on shortest O&D path; the shortest path is the path involving the minimum number of steps from origin to destination.
Quickest path length (QPL)	Number of connections lying on quickest O&D path; the quickest path is the path involving the lowest travel time from origin to destination.

Source: Burghouwt & Redondi (2013:p.38)

Burghouwt & De Wit (2005) introduce the weighted connectivity index, which is based on both the methodology by Veldhuis (1997) and on the Bootsma connectivity. In order to obtain the weighted indirect connectivity of an airline network, the index accounts for the transfer time and quality of an indirect connection compared to a direct one, by incorporating factors accounting for the inconvenience caused for passengers. An aggregated index is calculated by summing the weighted connectivity indices for all possible flight combinations on the individual airport level for the years 1990 and 1999. Burghouwt & De Wit (2005) use the results to group the considered European airline hubs into different categories such as European hubs or directional/ hourglass hubs. The study also finds that airline networks are increasingly concentrated in regard to their temporal dimension since the deregulation of the

European airline market. As this model also uses scheduled airline data to calculate its index, the methodology provides a feasible option for application in the following sections.

In general, the shortest path length (SPL) approach determines the shortest path, in terms of the number of steps involved, between two points. All feasible connections via an airport are compared to this and ranked accordingly. The quickest path length approach, on the contrary, determines the quickest path by determining the shortest travel time between two points. Malighetti, Paleari & Redondi (2008) apply the SPL approach to determine the centrality of an airport, i.e. how well is this airport connected to the overall network. The minimum path length of this particular airport to all other airports in the network is calculated. The level of centrality of an airport is defined by its degree of betweenness. This term is introduced by ibid. to denote the amount of minimum paths available from the specific airport, i.e. the more minimum paths available from a particular airport, the higher the betweenness and thus the more central an airport is within the overall network.

Nieße & Grimme (2013) also apply the shortest path length to the air transport sector. Here, the quality of a connection is determined by introducing a frequency factor, i.e. by accounting for the number of flights offered at the hub airport between an origin and destination pair within a predefined time period, and also for the frequency of respective return flights. For this purpose, the average shortest travel time and the average highest path velocity are calculated. The first index takes into account the total flight time and, incorporating frequency, the time the passenger has to wait until the next available flight to the same destination in case a connection is missed. The second concept covers the average speed from the origin to the destination point, including potential transfer times and accounting for the times of departure and arrival. The latter addresses the case if these slots are at rather inconvenient times for passengers and are therefore less attractive. In a case study including all global airports with available data in 2012, the European hub airports perform best in terms of the average shortest travel time and for the second indicator, it is those airports with a high share of long-haul destinations ranking first.

Based on these different approaches, the analysis in the following chapter will focus on the calculation of the amount of transfer connections at European hub airports, and the potential competition an airport faces on each of these connected airport pairs. Therefore, requirements for the applied methodology rely on the following assumptions, as outlined by Burghouwt & Redondi (2013):

- The accessibility vs. centrality of an airport, which addresses the difference between indirect and hub connectivity; in this case hub connectivity denotes the concept of transfer connections outlined above.
- The temporal coordination of a network which addresses the potential transfer time passengers are facing at a hub airport; the analysis in Chapter 5.3.1 will refer to the eligible transfer times applied in current models on hub connectivity.
- The routing factor which is the ratio of the actual time it takes to get from the origin to the destination airport and the theoretical distance between these two points; the analysis in Chapter 5.3.1 will apply a routing factor currently used in models on hub connectivity/ transfer connections.
- The maximum number of steps allowed on a passenger journey from origin (A) to destination (B); since Chapter 5 focuses on the competition hub airports face on the transfer passenger segment, the analysis will be limited to only including two-step connections, i.e. from the origin to the hub airport (step 1), and from the hub airport to the destination (step 2).
- Local vs. global models with local models focusing on a particular airport and global models focusing on a particular connection; here, the focus will be on the application of a local model since European hub airports are at the centre of investigation, and not a particular connection between two airports.

Based on these assumptions, the methodology to determine feasible transfer connections at the considered European hub airports is outlined in Chapter 5.3.1, relying on the current application of connectivity measures in the airport sector. Before moving to this, a short overview is given in the next chapter on how these measures are currently applied.

5.2.2 Current assessment of the transfer market at airports

These approaches to determine the amount of transfer connections, or the level of connectivity, as denoted by different authors, have been applied to different European airports in order to see how well these are connected to various regions, or to determine the overlap between transfer connections among particular hub airports. A range of these studies, and their respective approach as well as resulting findings are outlined in this chapter. The intention of this is to obtain an overview of the research landscape in terms of competition on the transfer market for European hub airports.

In his analysis on airline hub operations in Europe, Dennis (1994) highlights that the competitive position of European hub airports depends on the geographical location of an airport, enabling the connection of destinations across different regions, and on relevant facilities and infrastructure, which provide sufficient capacities to facilitate minimum connecting times between flights. Based on these assumptions, the performance of European network carriers is compared in terms of the quality of transfer connections provided for passengers, using data for 1992. The extent of hubbing, i.e. the amount of transfer connections, is measured by the connectivity ratio, which is the relationship between the number of actually achieved connections to the number of connections to be expected. A high value therefore indicates a well-connected and integrated network. In the analysis, Lufthansa at Frankfurt Airport, KLM at Amsterdam Schiphol Airport, and Sabena at Brussels Airport perform best. Dennis (1999) also applies this connectivity ratio, and, in addition, calculates the hub potential of several European hub airports by multiplying a hub airport's European frequencies with the frequencies offered to a particular region (e.g. North America). The product represents the market share of each airport in the total offered seats across all considered airports. The overall picture shows that the European transfer market is dominated by London Heathrow Airport, followed by Frankfurt Airport, Paris Charles de Gaulle Airport, and Amsterdam Schiphol Airport.

Burghouwt & Veldhuis (2006) apply the Netscan model[32] to analyse the competitiveness of connections on the transatlantic market, i.e. analysing flight connections between Northwest Europe and U.S. airports, and using data for the period between 2003 and 2005. An extension to the analysis by Veldhuis (1997) is the assessment of market concentration on the considered market. For this purpose, the Herfindahl Hirschman Index is calculated on the

[32] This particular model introduces a quality index which is 1 if a flight is a direct connection and hence considers both the quantity (frequency) and quality of a connection (Burghouwt & Veldhuis, 2006).

route (airport-pair) level by determining the shares of each alliance in the total capacity offered on this route, the same approach is also applied in Lieshout *et al.* (2016). Since concentration might be high on routes with low demand, Burghouwt, Lieshout & Veldhuis (2008) account for demand effects between two points in assessing the competitive posititiion of transfer traffic at Amsterdam Schiphol Airport. The demand on a route via the hub (H) is estimated by incorporating the total seat capacities at both the origin and destination airports as well as the distance between these two points in a simple gravity model. Passenger choice between alternative transfer routes is then determined by applying a generalised cost function, which integrates attributes such as travel and transfer time as well as ticket price. According to the attractiveness of each alternative, the share of each alliance on a particular route is calculated. Resulting from that, the study shows that the main competitors for AMS are oneworld at LHR, and Star Alliance at Frankfurt Airport. Hub airports in the U.S. also impose some degree of constraint on AMS, especially Newark Airport (EWR), or Chicago O'Hare Airport (ORD). Ibid. also distinguish Amsterdam Schiphol Airport's competitors by geographical market served. Hence, on routes to and from Asia/Pacific, Europe, the Middle East, or Africa, Frankfurt Airport and the Star Alliance are the main competitors for the airline network out of AMS.

Another application of the model by Veldhuis (1997) can be found in Matsumoto, Burghouwt & Veldhuis (2009) for hub airports in the East and Southeast Asian market. Lieshout & Burghouwt (2013) also apply the Netscan model in order to determine the level of competition hub airports face on the transfer passenger market. The degree of competition is identified by assessing the level of concentration of transfer connections offered at the 13 largest European hubs in 2008, using the Herfindahl Hirschman Index. London Heathrow Airport (LHR) and Zurich Airport (ZRH) are those airports with the lowest concentration levels, indicating a higher level of competition for these airports than the others in the sample. Furthermore, ibid. differentiate the concentration of transfer connections by geographical market and identify the main competitors for each considered hub airport. Concerning geographical markets, Amsterdam Schiphol Airport, Madrid Airport and Lisbon Airport exhibit a high Herfindahl Hirschman Index on the Latin American market. On the market to Middle Eastern destinations, Lisbon Airport faces the highest degree of market concentration. Furthermore, Frankfurt Airport, Paris Charles de Gaulle and London Heathrow all constitute each other's main competitors.

The Netscan model is also applied by the Airports Council International Europe (2016a), which outlines a range of developments concerning the change in the amount of transfer connections in the European air transport market, i.e. determining connectivity levels for different airports. As already addressed in Chapter 3.2.1, the report distinguishes European airports according to their connectivity levels, and outlines the changes in these across the different hubs, with the two Istanbul airports IST and SAW having the highest growth in connections offered in the considered period from 2006 to 2016.

In order to investigate the competition faced by four major European hubs – London Heathrow Airport (LHR), Paris Charles de Gaulle Airport (CDG), Amsterdam Schiphol Airport (AMS), and Frankfurt Airport (FRA) – in 1998, Bruinsma, Rietveld & Brons (2000) apply a generalised cost function approach to determine passenger choice in regard to transfer flights. The function includes the ticket price for a travel alternative, the total travel time and a variable determining the rescheduling costs, which account for the time a passenger has to wait in case a connecting flight is missed. Within the analysis, the authors differentiate between passenger types and find that AMS has the most competitive offer in economy class, regarding an average trip between a European and an intercontinental destination. The most competitive offer in business class can be found via CDG airport.

Malighetti, Paleari & Redondi (2008) apply the shortest path length approach to assess the connectivity of the European air transport network, with a particular focus on the self-hubbing potential, and identify the best connected airports in Europe in terms of average minimum travels times in 2007. Since not only flights of the same airline, alliances or code share agreements are taken into account, airports other apart from the main European hubs are ranking highest: Amsterdam Schiphol Airport, Munich Airport, Copenhagen Airport, and Brussels Airport. Redondi, Malighetti & Paleari (2011) build on this analysis, and focus on the evaluation of the degree of competition between hub airports on a global scale. In their analysis they concentrate on total travel times, including transfer times. Travel times for all potential airport pairs are determined, referring to both direct and transfer connections and the related total travel times. For this purpose, the authors select an off-peak period since they argue that flights which are added during peak periods to meet increasing demand may bias the outcome regarding the evaluation of competitiveness of a hub airport. The quickest alternative plus 20 per cent is considered to be the maximum feasible travel time a passenger would accept. Furthermore, an airport counts as a hub if one of its connecting flights does not exceed the 20 per cent threshold of the quickest alternative of this connection. The results show that Frankfurt Airport (FRA) covers 34.1 per cent of all considered airport pairs in 2008 compared to London Heathrow Airport (LHR) with a coverage of 33.6 per cent. Furthermore, the assessment includes the level of overlap in these connections with other hubs. The main competitor of FRA is CDG, and of LHR it is FRA.

Grosche & Klophaus (2015) also analyse the competitive position of different European hubs in terms of transfer connections, particularly in regard to the emerging Gulf airports. Similarly to the previously outlined studies, the authors classify a connection as feasible if it is in the range of a predefined minimum and maximum connecting time, and if it does not exceed a specific detour factor which is based on the direct connection of an airport pair[33]. Further, there has to be a return trip for the considered airport pair and the connections have to be offered by the same airline, alliance or supported by a codeshare agreement. Similar to Nieße & Grimme (2013), this study also considers the convenience of departure and arrival times of connections, and benchmarks these with a pre-defined reference connection, which exhibits a feasible alternative for passengers. Due to the type and availability of data (2009 and 2012), this study also concentrates on the supply side, and derives conclusions from this in terms of the level of competition European hub airports face. The findings are interesting in that they show, as also confirmed in Redondi, Malighetti & Paleari (2011) and Lieshout & Burghouwt (2013), competition is strongest amongst European hubs, especially among CDG, FRA, and LHR. The Gulf airports considered here – Abu Dhabi Airport (AUH), Dubai International Airport (DXB), and Doha Airport (DOH) – are not yet posing a competitive constraint in terms of the overlap in connections they have with the major European hubs.

More hub airports across a wider time span (2009 to 2015) are considered by Grosche, Klophaus & Seredynski (2015). Real booking data is applied to identify those connections

[33] The maximum connecting time is the minimum connecting time plus 120 minutes for destinations below 5000 kilometres and minimum connecting time plus 180 minutes for destinations above 5000 kilometres. The detour factor for the first category is 1.5 and for the latter it is 1.3.

which are actually being offered, and not just hypothetically being able due to airline scheduling. The study employs passenger data by Amadeus to determine whether monopoly routes are those with low passenger demand. At London Heathrow, for example, monopoly routes on the transfer market account for one per cent of overall passenger demand, the same applies to Frankfurt Airport. For CDG this figure amounts to two per cent. Origin-destination markets with more than five alternative transfer connections constitute more than 80 per cent of passenger volume at CDG, FRA and LHR. These numbers imply that hub airports are exposed to competition on the transfer market. Again, looking at the main competitors for each airport in the dataset, it shows that LHR, FRA, and CDG are in each other's top ranks, and that the emerging hubs in the Middle East are not (yet) the ones imposing the highest competition. Further, the constraints for European hub airports are higher than for Middle Eastern hubs. The approach applied in this paper constitutes a development of previous analyses by integrating the demand side into the assessment. However, due to data non-availability on passenger numbers on individual origin-destination markets, this aspect will not be considered in the further analysis in this chapter.

The transfer market between Europe and Asia, and the respective level of competition for European hub airports is the focus by Seredynski (2016). The findings shows that Dubai Airport (DXB) is the leading provider, followed by Doha Airport (DOH), of transfer connections on this market segment, which can be attributed to their better geographical location compared to the European hubs. The analysis with data for the year 2014 shows that hub airports only have a very small share of connecting routes where they have a monopoly, e.g. Frankfurt Airport (FRA) has a monopoly for three per cent of its hub transfer traffic. In addition to the paper by Grosche, Klophaus & Seredynski (2015), this analysis also focuses on the degree of competition imposed by direct connections. It shows that at FRA, LHR, and CDG, for example, 17, 16, and 13 per cent, respectively, of the transfer connections are also offered by direct connections on the origin-destination market. Seredynski (2016) also examines the potential shift in market share, if the quality of a connection via a competing hub is increased. This shows that FRA and LHR, for example, have their main competitor in Dubai Airport since they are prone to lose most of their traffic to this airport. Furthermore, competition for European hub airports has been increasing over the investigated time period (2009 to 2014).

This overview shows that there are a range of studies investigating the transfer market, and potential implications for European hub airports over time. However, these studies consider only a subset of the airports considered within this thesis, and the analysis often only refers to one or two time periods. The analysis in the following chapters analyses a larger dataset of European hub airports and across a wider timespan, from 2000 to 2016. The assessment of the level and change of transfer connections as well as the degree of overlap between these for the considered European hub airports is therefore the focus of Chapter 5.3.

5.3 Market concentration on the transfer market

Drawing from the discussion in the previous chapter, Chapter 5.3.1 discusses the applied methodology to determine transfer connections at airports, and subsequently transfer connections for each European hub airport in the dataset are calculated. The overlap of transfer connections across hub airports is discussed in Chapter 5.3.2, by applying the Herfindahl Hirschman Index to this particular market.

5.3.1 The market for transfer connections at European hub airports

Based on the previously outlined approaches to determine the amount and quality of transfer connections via airport nodes, this chapter focuses on the assessment of amount and quality of transfer connections at the selected European hub airports (Table 9). These transfer connections are calculated by using the OAG database for the years 2000, 2004, 2008, 2012 and 2016, which yields scheduled airline traffic for an entire year (see Table 8). By using scheduled airline data, the potentially available transfer connections at a hub airport are determined. Having identified a connection therefore does not give an indication to the level of actual demand on this particular connection. Calculating the particular amount of seats being offered on this connection provides an approximation to the potential demand on a transfer connection.

In order to identify viable flight connections at each of the considered hub airports a set of assumptions is applied to the data (see also Figure 31):

1. Only flights by network carrier and their respective alliance partners are considered, these are outlined in Appendix 8.5.

2. Definition of maximum and minimum connecting times between flights, based on the outline in Burghouwt & Redondi (2013):
   - Short-haul connection: minimum waiting time of 60 minutes; maximum waiting time of 180 minutes
   - Short-haul to long-haul connection: minimum waiting time of 60 minutes; maximum waiting time of 300 minutes
   - Long-haul to long-haul connection: minimum waiting time of 60 minutes; maximum waiting time of 720 minutes
3. Application of a routing factor: direct travel time times a factor of 1.5, based on the assumptions discussed in Burghouwt & Redondi (2013)
4. Selection of a particular week during off-peak season during which transfer connections are considered, due to reasons outlined in Redondi, Malighetti & Paleari (2011) and discussed above.

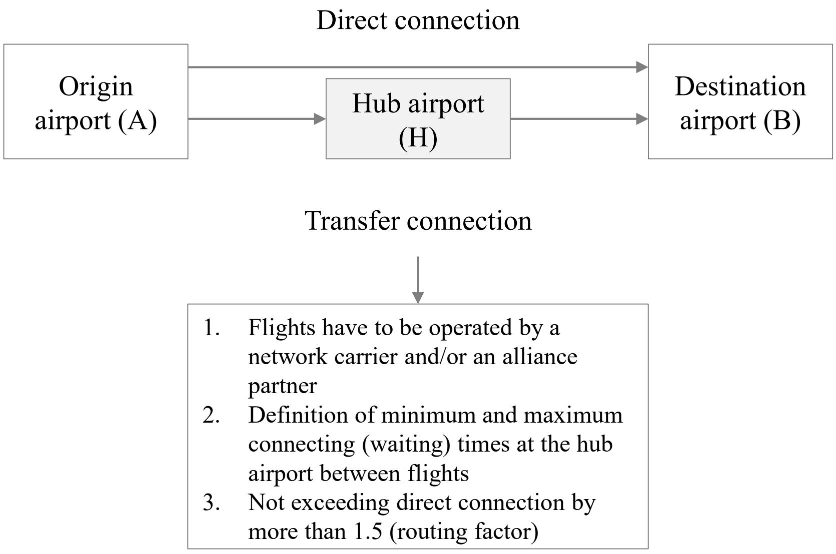

Figure 31: Underlying assumptions to determine feasible transfer connections

Source: own depiction

First, for each hub airport only those flights are considered which are either offered by the network carrier operating at that hub (Table 47), or by an airline which is a member of the same alliance as the network carrier (Table 51). Furthermore, at least one leg of the connecting flights offered via the hub has to be by the airline which has its base at the hub airport. In the case of Frankfurt Airport (FRA), for example, at least one leg has to be operated by its network carrier Lufthansa. This requirement is imposed since transfer connections are often defined by a single ticket by one airline or its alliance partners as well as baggage check-through at the hub airport (Airports Council International Europe, 2016a).

The second assumption concerns the minimum as well as maximum feasible connecting time, or waiting time, between flights at a hub airport. The thresholds applied in the following analysis are based on values mainly applied in the literature on airport connectivity analyses, including Malighetti, Paleari & Redondi (2007) and Redondi & Burghouwt (2010). Hence, for a transfer flight connecting two airports within Europe, i.e. a short-haul to short-haul connection, a minimum waiting time of 60 minutes and a maximum waiting time of 180 minutes are assumed. For a connecting flight between a European and an intercontinental destination, i.e. a short-haul to long-haul connection, a maximum transfer time of 300 minutes is assumed. In case the transfer connection is between two intercontinental destinations, a maximum connecting time of 720 minutes is considered. All connecting flights exceeding these thresholds are eliminated from the dataset.

In a third step, a routing factor is applied which is determined by multiplying the direct travel time between two destinations by 1.5. If the overall travel time of a connecting flight exceeds this time threshold it is eliminated from the dataset.

Last but not least, only one particular week during an off-peak period within each year is considered, in this case the last full week in September of each year[34]. According to Redondi, Malighetti & Paleari (2011), using scheduled traffic data during peak periods may lead to biased results regarding the level of connectivity at a hub airport, since some flights are only scheduled during these peak periods. Hence, the focus on a regular week during the off-peak season ensures consistency of flights throughout the year.

Based on these assumptions, Figure 32 shows the number of transfer connections for all European hub airports in the dataset for the respective weeks in September in 2000 and 2016. The airports are ranked in ascending order of the total number of transfer connections offered

[34] The following weeks are considered in each observed year: 18.-24.09.2000; 20.-26.09.2004; 22.-28.09.2008; 24.-30.09.2012; 19.-25.09.2016

in 2016. The number of transfer connections for each considered time period and the respective change in offered connections is outlined in Table 54 in Appendix 8.10.

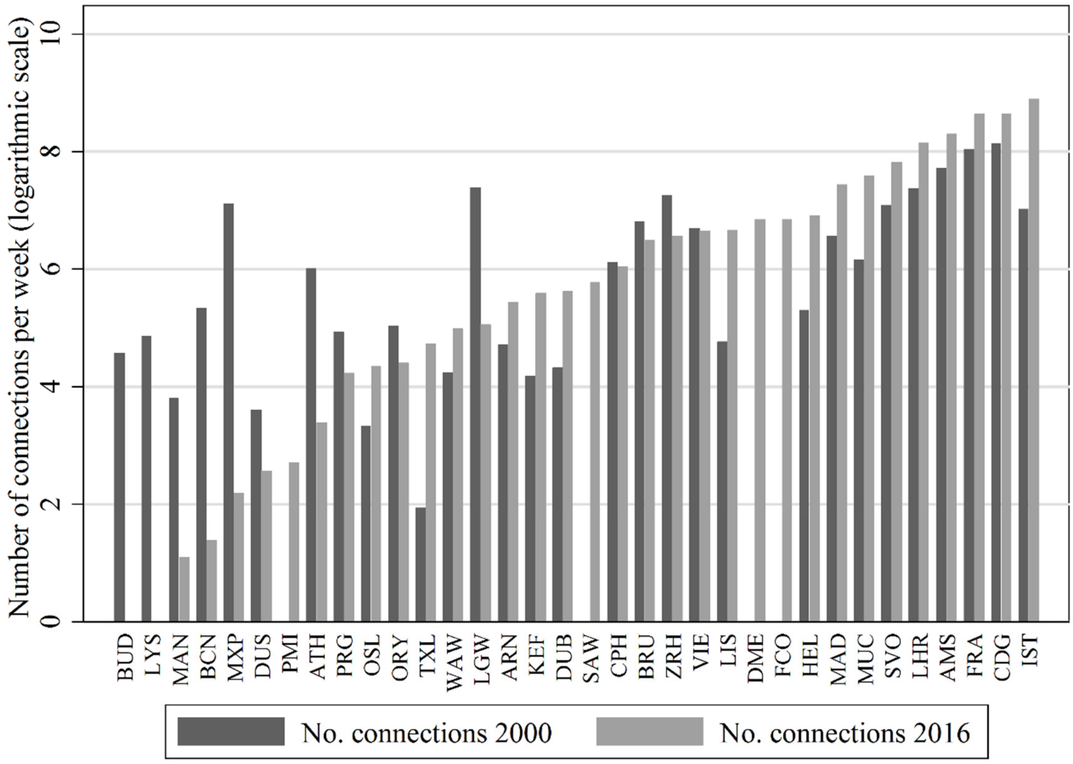

Figure 32: Development of connectivity levels across European hub airports

Source: own depiction

This initial analysis reveals the difference in the number of transfer connections offered at the European hub airports, and outlines those airports which have been either winning or losing in terms of number of transfer connections offered over the observed time period. According to the total amount and percentage change in the number of connections offered at each hub between 2000 and 2016, five different hub categories can be identified:

(1) Disappearing hubs, including those hub airports which have been offering less than ten transfer connections during the observed week in 2016.
(2) Declining hubs, including those hub airports which faced a steady decline in the number of transfer connections across all time periods considered (negative growth rates across all time periods), or which saw a decline in the number of connections by more than 50 per cent between 2000 and 2016.

(3) New hubs, including those hub airports which saw a more than 90 per cent increase in transfer connections offered between 2000 and 2016, and which had less than 100 transfer connections per week in 2000, implying that operations started at the beginning of the observed period.
(4) Emerging hubs, including those hub airports whose transfer connections increased by more than 50 per cent in between 2000 and 2016, or that had between 100 and 400 transfer connections per week across the observed period.
(5) Incumbent hubs, including hub airports with more than 400 or more transfer connections per week within each observed time period, i.e. between the years 2000 and 2016.

The first category includes those airports which have been offering transfer connections in 2000 but none or less than ten transfer connections per week in 2016. De-hubbing due to cessation of network carrier operations affected Antalya (AYT), Barcelona (BCN), Budapest (BUD), Lyons (LYS), Manchester (MAN), and Milan (MXP) airports. In the case of Budapest airport, the network carrier Malév went bankrupt and had to stop operations (Bilotkach, Müller & Németh, 2014), whereas in the case of the other airports the respective network carriers relocated their operations to other airports, which is reflected by decreasing shares of these carriers in the total airport seat capacity. Airitalia (AZ), for example, had a share of 57 per cent in total seats in 2000 at Milan Malpensa Airport, which decreased to a share of less than one per cent in 2016. At the airports of BCN, MAN, and LYS the respective network carriers also cut their offered seat capacities to less than one per cent of the total seats offered within the observed period.

Declining hubs, the second category, are those airports which have been losing a significant share of transfer connections. These airports include Athens (ATH), Dusseldorf (DUS), London Gatwick (LGW), Paris Orly (ORY), Palma de Mallorca (PMI), and Prague (PRG) airports.

As new hubs those airports are considered which have started offering transfer connections in or after the year 2000. Based on the number of connections offered in these considered time periods, Rome Fiumicino Airport (FCO), Moscow Domededovo Airport (DME), Istanbul Sabiha Gökcen (SAW), and Berlin Tegel (TXL) are classified as having newly started operations as airline nodes.

Emerging hubs are those airports whose number of transfer connections has increased significantly between 2000 and 2016, including Copenhagen (CPH), Lisbon (LIS), Helsinki (HEL), Reykjavik (KEF), Dublin (DUB), Warsaw (WAW), Stockholm (ARN), and Oslo (OSL) airports.

Compared to that, incumbent hubs are those airports which have also mostly been gaining in terms of their overall transfer connections, and which offered at least 400 transfer connections per week across the entire observed period. This category comprises the airports of Frankfurt (FRA), Paris Charles de Gaulle (CDG), London Heathrow (LHR), Amsterdam (AMS), Moscow Sheremetyevo (SVO), Madrid (MAD), Istanbul (IST), Munich (MUC), Zurich (ZRH), Brussels (BRU), and Vienna (VIE).

This high-level categorisation in terms of number of transfer connections offered gives a first indication as to the importance of the transfer traffic market at the different hub airports. For those airports with a high amount of weekly transfer connection, the competition on this particular market plays a more important role than for those airports that offer only a little amount of connections per week.

In addition to the number of transfer connections offered, the geographical location of origin and destination give an indication to the type of hub operations. Therefore, European hub airports are analysed in regard to the range segments of transfer connections. For this purpose, connections are categorised according to the origin and destination of the transfer connection. The first range segment denotes those flights which have their origin as well as destination within Europe[35], i.e. covering the short-haul to short-haul market. The second range segment contains those transfer connections which have its origin within a European country and its destination in a country outside Europe (or vice versa), i.e. short-haul to long-haul or vice versa. And the third segment comprises transfer connections which have both their origin and destination outside Europe.

[35] For an overview of countries within Europe, according to the OAG database, see Appendix 8.9.

Based on these definitions, in order to obtain a high-level classification of hub airports according to the main range segment they serve, each airport is assigned to one of the above categories, depending on the highest share of offered connections within a specific category:

(1) Short-haul market, including those airports which offer the highest share of transfer connections (weighted by seats) on the short-haul to short-haul market.
(2) Short-haul to long-haul market, including those airports which offer the highest share of transfer connections (weighted by seats) on the short-haul to long-haul market.
(3) Long-haul market, including those airports which offer the highest share of transfer connections (weighted by seats) on the long-haul to long-haul market.

The data on these different range segments is extracted from the OAG database and yields the distribution of transfer connections across range segments for 2000 and 2016, depicted in Figure 33 and Figure 34.

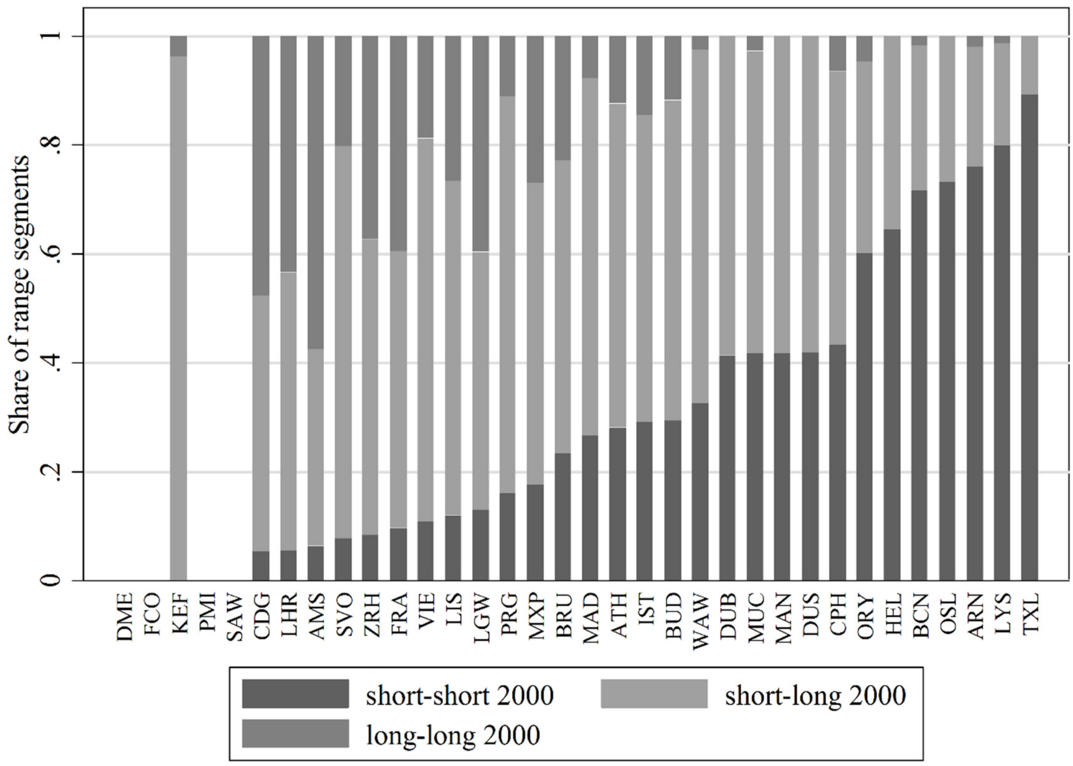

Figure 33: Distribution of connections across range segments (2000)

Source: own calculation based on OAG data

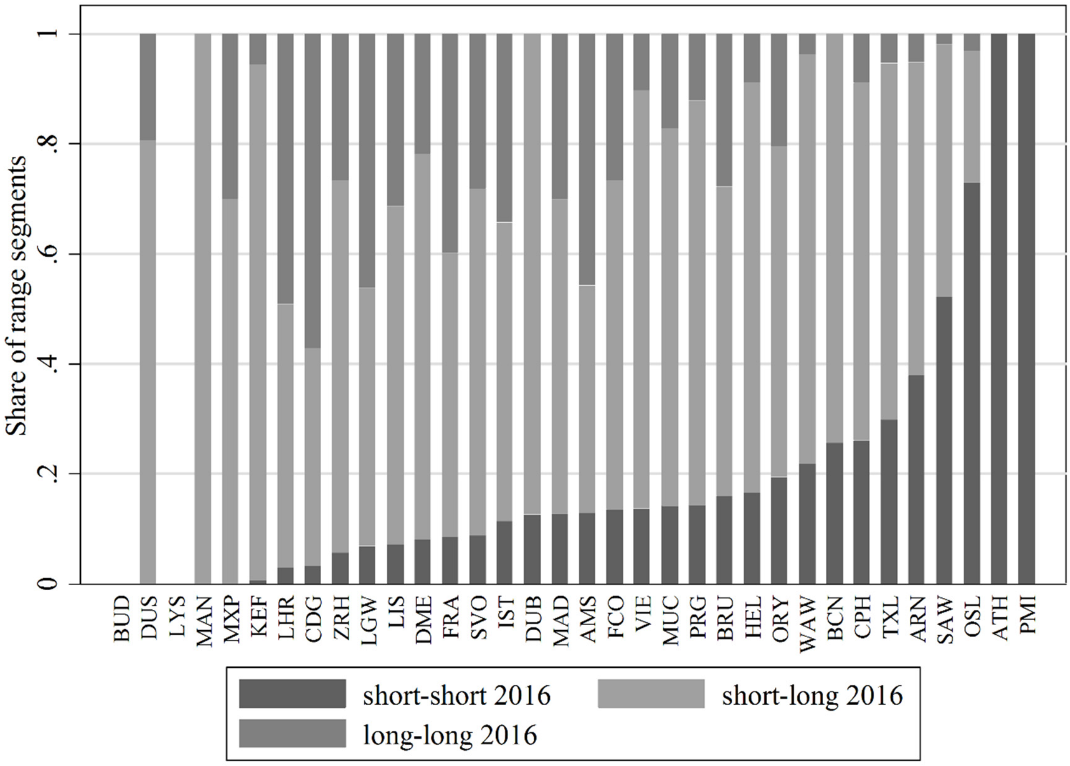

Figure 34: Distribution of connections across range segments (2016)

Source: own calculation based on OAG data

Incumbent hubs, such as London Heathrow (LHR), Frankfurt (FRA), or Paris Charles de Gaulle CDG), have a strong focus on the long-haul segment, with either offering long-haul to long-haul or short-haul to long-haul connections. The short-haul to short-haul segment at these airports accounts for less than ten per cents of seats offered. Contrary to that, airports with a high share of its connections between European destinations include Berlin Tegel (TXL), Dublin (DUB), Helsinki (HEL), or Oslo (OSL).

Based on the hub airport categorisation according to the number and change of offered transfer connections, and according to the range segment an airport mainly focuses on, four different hub airport types are obtained (I-IV), which are illustrated in Figure 35.

Group I contains those airports which faced a declining amount of transfer connections over the observed time period, as does Group IV. The airports of the latter group have a stronger focus on the short-haul segment than those in Group I. Groups II and III comprise hub airports which have mainly been experiencing growth regarding the number of transfer connections being offered between 2000 and 2016. Airports within Group II have a strong long-haul focus, whereas those in Group III have a larger share of transfer connections on the short-haul to short-haul market.

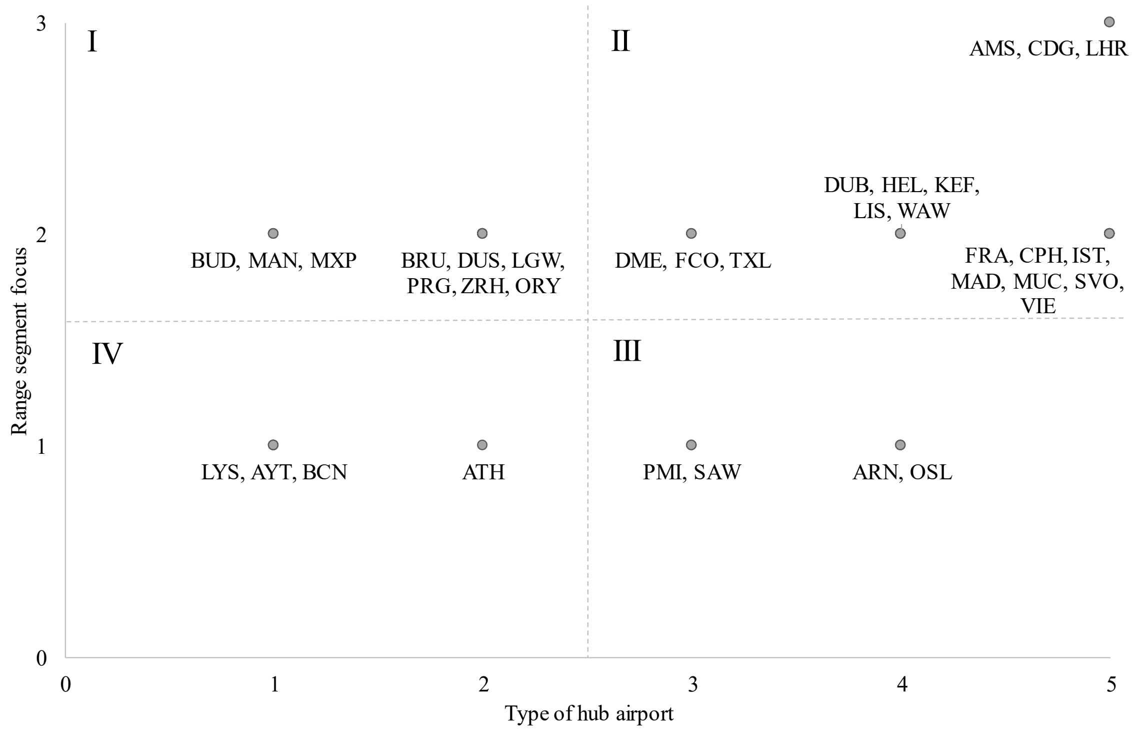

Figure 35: Hub airport categorisation

Source: own depiction

This initial categorisation of the European hub airports investigated in this thesis already implies that these airports and their respective network carriers focus on distinct market segments. As can be seen in Figure 35, AMS, CDG, and LHR are those airports with a strong focus on connecting long-haul destinations, whereas FRA and MUC have a high share of transfer connections between the short-haul and long-haul market.

In order to assess the degree of competition European hub airports face on the transfer market, it is necessary to analyse individual transfer connections and the degree of overlap these face with other hub airports. For example, a transfer connection via FRA might be Hamburg Airport (HAM)-FRA-Singapore Airport (SIN). This transfer connection may also be offered via one of the investigated European hubs, but also via another hub airport such as Dubai (DXB), for example. Therefore, it is important to consider the distribution of offered seats on this connection across all airports offering it. The following chapter analyses the level of market concentration for transfer connections at the European hub airports over a time period from 2000 to 2016.

5.3.2 Analysis of market concentration for individual transfer connections

The potential level of competition the considered European hub airports face in regard to their transfer market is determined by calculating the degree of market concentration for each transfer connection offered at each of the hubs during the considered time period. Figure 36 illustrates this concept in more detail. As outlined before, a transfer connection is a connection from origin A to destination B via a hub airport H. In the example, the connection from A to B can be made by transferring via three different hub airports, with each of these airports offering a particular amount of seats on this specific connection. Hence, in order to calculate the Herfindahl Hirschman Index for this connection, all possible transfer connections and the respective seats offered are taken into consideration. A feasible transfer connections is determined based on the assumptions outlined in Chapter 5.2.1.

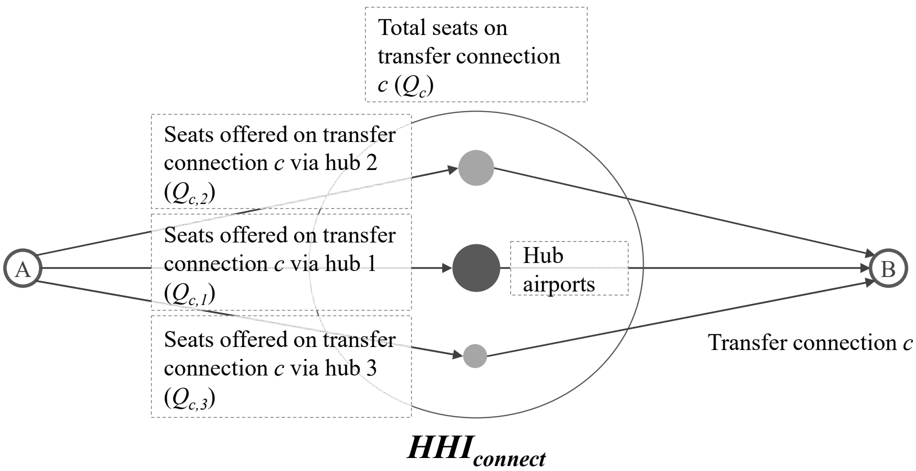

Figure 36: Calculation of $HHI_{connect}$ for European hub airports

Source: own depiction

The total seats offered on a transfer connection are depicted by Q_c, which is the sum of each hub airport's *i* seats on this transfer connection $Q_{c,i}$, with i = 1, …, N, and c = 1, …, K. The Herfindahl Hirschman Index for each transfer connection ($HHI_{connect}$) is thus calculated:

$$HHI_{connect,c} = \sum_{i=1}^{N} s_{c,i}^2 \tag{23}$$

Where $s_{c,i} = Q_{c,i}/Q_c$ represents the share of hub airport i's seats $Q_{c,i}$ in total seats offered on a transfer connection (Q_c). Calculating the $HHI_{connect}$ therefore yields a single value for each transfer connection offered at the hub airport.

Table 33 gives an overview of this index for all considered European hub airports, taking into consideration all time periods, i.e. from 2000 to 2016. The hub airports are ordered in ascending order of their mean $HHI_{connect}$. A first apparent observation from the analysis of the $HHI_{connect}$ in Table 33 is the median value of one for 31 of the observed 35 airports. This means that for at least 50 per cent of the transfer connections offered at these hub airports, the respective airport is the sole provider of this particular connection. Furthermore, compared to the minimum $HHI_{connect}$ values, the mean values for each airport are relatively high, implying that a high share of transfer connections is rather concentrated at a particular hub airport. However, these might be connections between origin-destination pairs with low passenger demand.

Table 33: $HHI_{connect}$ for European hub airports (all years combined)

Hub airport	Mean	Median	Minimum	Maximum	Standard deviation
ZRH	0.58	0.51	0.06	1.00	0.42
LHR	0.67	0.59	0.06	1.00	0.38
FCO	0.69	0.64	0.06	1.00	0.38
MXP	0.69	0.66	0.08	1.00	0.38
CPH	0.72	1.00	0.08	1.00	0.38
FRA	0.74	1.00	0.06	1.00	0.38
DUS	0.75	1.00	0.11	1.00	0.37
MUC	0.75	1.00	0.07	1.00	0.38
AMS	0.75	1.00	0.06	1.00	0.38
HEL	0.75	1.00	0.08	1.00	0.38
DUB	0.76	1.00	0.16	1.00	0.37
BUD	0.76	1.00	0.13	1.00	0.38
WAW	0.76	1.00	0.14	1.00	0.37
MAN	0.77	1.00	0.13	1.00	0.37
KEF	0.77	1.00	0.16	1.00	0.37
PRG	0.77	1.00	0.13	1.00	0.37
BRU	0.77	1.00	0.09	1.00	0.38
VIE	0.79	1.00	0.10	1.00	0.38
CDG	0.80	1.00	0.06	1.00	0.38
ARN	0.81	1.00	0.08	1.00	0.38
MAD	0.81	1.00	0.07	1.00	0.38
TXL	0.84	1.00	0.19	1.00	0.37
IST	0.85	1.00	0.06	1.00	0.38
SVO	0.87	1.00	0.08	1.00	0.38
LGW	0.87	1.00	0.13	1.00	0.38
OSL	0.88	1.00	0.14	1.00	0.38
LIS	0.89	1.00	0.07	1.00	0.38
ATH	0.89	1.00	0.13	1.00	0.38
SAW	0.89	1.00	0.20	1.00	0.35
BCN	0.92	1.00	0.15	1.00	0.38
LYS	0.93	1.00	0.18	1.00	0.33
DME	0.96	1.00	0.19	1.00	0.37
PMI	0.96	1.00	0.38	1.00	0.31
ORY	0.99	1.00	0.35	1.00	0.33

Source: own calculation based on OAG data

Since these figures are accumulated for the time periods considered in this analysis, a more detailed insight into the development of market concentration on the transfer market for European hub airports is obtained by looking at the yearly $HHI_{connect}$ values. These are outlined in Table 34, the hub airports are ranked in ascending order of their $HHI_{connect}$ value in 2016. Here, no hub airport exhibits an $HHI_{connect}$ value below 0.40 for either the year 2000 or 2016, with Milan Malpensa Airport (MXP) facing the lowest level of market concentration in 2016 with an $HHI_{connect}$ of 0.37. For the analysis of competition on the transfer market, not only the degree of market concentration for each hub airport is essential but also the development of this Herfindahl Hirschman Index over time.

Table 34: Development of mean $HHI_{connect}$ for European hub airports over time

Hub airport	2000	2004	2008	2012	2016
MXP	0.71	0.68	0.66	0.43	0.37
DUS	0.75	0.74	0.76	0.75	0.42
ZRH	0.64	0.62	0.55	0.53	0.53
LHR	0.71	0.74	0.63	0.64	0.66
WAW	0.81	0.81	0.82	0.75	0.66
CPH	0.80	0.70	0.71	0.71	0.68
MAN	0.75	0.79	0.71	0.71	0.68
FCO	n/a	0.68	0.70	0.68	0.68
PRG	0.74	0.77	0.79	0.80	0.72
FRA	0.74	0.75	0.75	0.73	0.72
MUC	0.75	0.77	0.74	0.76	0.73
BRU	0.77	0.89	0.85	0.76	0.74
KEF	0.75	0.72	0.79	0.81	0.75
AMS	0.75	0.77	0.76	0.73	0.75
HEL	0.88	0.76	0.74	0.71	0.75
DUB	0.74	0.68	0.72	0.84	0.75
ARN	0.84	0.89	0.82	0.79	0.75
CDG	0.79	0.84	0.80	0.79	0.75
VIE	0.74	0.79	0.81	0.82	0.77
MAD	0.83	0.86	0.80	0.80	0.80
TXL	0.92	n/a	0.98	0.84	0.81
OSL	0.88	0.95	0.93	0.90	0.81
IST	0.81	0.83	0.85	0.85	0.86
LGW	0.85	0.92	0.89	0.91	0.86
SVO	0.90	0.86	0.84	0.88	0.86
LIS	0.85	0.88	0.91	0.89	0.87
SAW	n/a	n/a	n/a	1.00	0.89
DME	n/a	0.95	0.97	0.97	0.96
ORY	0.99	0.99	1.00	1.00	0.97
PMI	n/a	0.86	0.98	0.97	0.97
ATH	0.85	0.90	0.90	1.00	1.00
BCN	0.91	0.93	0.96	0.88	1.00
AYT	n/a	n/a	1.00	1.00	n/a
BUD	0.61	0.79	0.82	n/a	n/a
LYS	0.91	0.93	0.93	0.96	n/a

Source: own depiction

By this, it can be observed whether potential competition imposed by overlapping transfer connections has been increasing over the course of the observed period for the individual airports in the dataset. At MXP, a significant decrease in the index is apparent. However, MXP is categorised as a disappearing hub airport in Chapter 5.3.1, and hence the importance of the transfer market in terms of imposing competition on the airport is rather negligible. In the following discussion of the development of the $HHI_{connect}$ and of the implications for potential competition on the transfer market, the focus is thus placed on the hub airports in Categories II and III in Figure 35, i.e. the new, emerging, and incumbent hub airports.

Starting with the new hub airports, SAW, DME, TXL, and FCO, the latter exhibits the lowest value in 2016 with 0.68. All other airports have a value of at least 0.80 suggesting a high degree of market concentration on the respective transfer market. TXL shows the largest decrease in market concentration over time, considering the change in the mean $HHI_{connect}$ over time (Table 34). With respect to these new hub airports, this analysis implies that the transfer connections offered via these are still within a market segment which is not yet offered to a large degree via other hubs airports. Although the transfer market at these airports is still of rather little importance due to the limited amount of total transfer connections offered, the level of market concentration suggests that competition may be lacking for the hub airports on this market.

Moving to the emerging hub airports, including CPH, WAW, KEF, HEL, DUB, ARN, OSL, and LIS, none of these shows a continuous decrease in the mean $HHI_{connect}$ over time, but they rather exhibit fluctuations in the level of market concentration. However, CPH, WAW, HEL, ARN, and OSL experienced an overall decrease in the mean $HHI_{connect}$ comparing 2000 and 2016, thus potentially facing more competition on the transfer market. This negative trend in regard to market concentration on the transfer market suggests that competition is increasing for these airports.

In the category of the incumbent hub airports, including LHR, CPH, FRA, MUC, AMS, CDG, VIE, MAD, IST, ZRH, and SVO, all airports but AMS, IST, and VIE exhibit a decreasing mean $HHI_{connect}$ in the period between 2000 and 2016. This decreasing level of market concentration on the transfer market implies that more overlap between transfer connections exists over time, and that the level of competition on this particular market is increasing. However, the absolute value of the $HHI_{connect}$ for all these hub airports is relatively high when comparing it to the minimum values obtained for transfer connections outlined in Table 33. Here, for both LHR and AMS the minimum $HHI_{connect}$ value obtained on a transfer connection is 0.06, implying that there is a high number of competitors on this particular connection. Comparing the mean values for these two airports in 2016 to this, 0.66 and 0.75, respectively, shows a significant delta.

Furthermore, to determine a rough threshold to compare these $HHI_{connect}$ values against, in addition to the minimum value obtained on some routes, the number of firms in the market, and the respective minimum attainable value the Herfindahl Hirschman may take in case of equal market shares, serves as an indicator (see Chapter 2.2.2). The minimum attainable value of the Herfindahl Hirschman Index decreases with the number of firms in the market, as illustrated in Figure 18 in Chapter 4.2.1. With two firms in the market that have the same output level, a minimum attainable value of the Herfindahl Hirschman Index of 0.50 results. Comparing the mean $HHI_{connect}$ values of all years (Table 34) to this threshold shows that only three airports are below or near this threshold, MXP in 2012 and 2016, DUS in 2016, and ZRH in 2008, 2012, and 2016. The minimum attainable value might be even lower if there are more firms in the market, implying an even higher delta between the actual $HHI_{connect}$ and the lowest possible value. This observation suggests that transfer connections at European hub airports are characterised by a relatively high level of market concentration.

Although the analysis of market concentration of the transfer market at European hub airports suggests that these transfer connections experience only limited overlap with other hub airports, it cannot be concluded that hub airports are abusing their potential market power in this segment. Further analysis is required, and the following chapter therefore focuses on the market concentration on specific regional markets. By this, it can be seen whether hub airports are active in particular regions, and thus on a particular market segment, as became apparent already by the analysis of range segments in Figure 35.

5.3.3 Analysis of market concentration for region-specific transfer markets

Building on the $HHI_{connect}$ discussed in the previous chapter, an aggregated and region-specific Herfindahl Hirschman Index is analysed (HHI_{region}). For this purpose, the following regions are considered, an overview of the countries included in each region can be found in Appendix 8.9: (1) North America (NA), (2) Middle East (ME), (3) Europe (EU), (4) Asia (AS), (5) Latin America (LA), and (6) Africa (AF). The approach taken here is similar to the calculation of the $HHI_{connect}$, and yields the following formula:

$$HHI_{region} = \sum_{i=1}^{N} s_{region,i}^2 \quad (24)$$

Where $s_{region,i} = Q_{region,i}/Q_{region}$ represents the share of hub airport i's seats $Q_{region,i}$ in total seats offered on a transfer connection to or from a particular region (Q_{region}), with i = *1, ..., N*. The total seats offered on a transfer connection to or from a particular region are hence depicted by Q_{region}, which is the sum of all hub airportss seats on this transfer connection $Q_{region,i}$. Calculating the HHI_{region} therefore yields a single value for each region offered via the hub airport.

Determining this particular index gives a more detailed insight into the regions the network carriers at their respective hubs are focusing on, and to derive implications for the potential competition faced in the different market segments. Figure 37 illustrates the North American market as an example and shows the development of the HHI_{region} for this particular region.

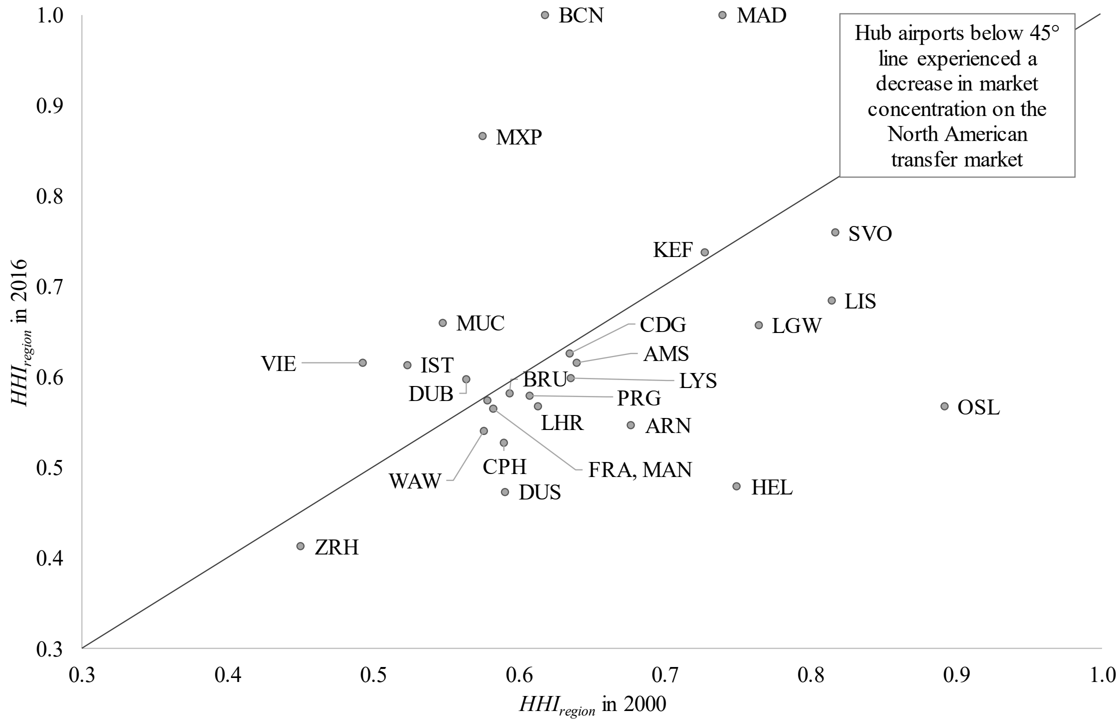

Figure 37: HHI_{region} for North America (2000 and 2016)

Source: own depiction

North America has been selected as an example since most European hubs in the sample offer connections to or from this market, other regions such as Latin America or Asia are served via less airports. Since the focus is on the development of the HHI_{region} only those airports are depicted which have been serving the North American market both in 2000 and 2016. Budapest (BUD) and Athens as disappearing hubs have been offering connections only in 2000, whereas Berlin Tegel (TXL) and Rome Fiumicino (FCO) as emerging or new hubs have been active in this market in 2016 only.

For all hub airports the HHI_{region} for North America for 2000 and 2016 is plotted in Figure 37. For those airports above the 45° line an increase in the HHI_{region} can be observed between the two time periods. Above this line, the further away an airport is from the line, the higher the increase in market concentration. Among these, BCN and MXP belong to the category of disappearing hubs, which means that the transfer market at these airports is becoming less important over the observed time period. On the contrary, airports below this line faced a decrease in market concentration, the further away the higher. As can be seen in the figure, the majority of European hub airports falls into this category.

Regarding the level of the HHI_{region} in 2016, it is lower for all airports but MAD, DUS, and MXP, than the mean $HHI_{connect}$ in this year. Frankfurt Airport (FRA), for example, has a HHI_{region} of 0.57 in 2016 whereas the mean $HHI_{connect}$ in this year is 0.72. This observations suggests that on the North American transfer market the duplication of transfer connections across multiple hub airports is higher than for other regional transfer markets. However, the North American market is also one of high demand due to economic and political ties between the U.S. and the European economies. Therefore, a high overlap and hence a low degree of market concentration does not necessarily imply that airport market power is constrained. Comparing the absolute value of the HHI_{region} for different hub airports in Figure 37, Zurich (ZRH) exhibits the lowest level of market concentration in regard to transfer connections to and from North America, and Madrid Airport (MAD) the highest level in 2016.

Table 35: HHI_{region} for all regions (2000 and 2016)

#	Hub	North America		Middle East		Europe		Asia		Latin America		Africa	
		2000	2016	2000	2016	2000	2016	2000	2016	2000	2016	2000	2016
1	IST	0.52	0.61	0.74	0.82	**0.87**	**0.88**	0.70	**0.74**	-	0.66	0.78	0.81
2	CDG	**0.63**	**0.63**	0.64	0.61	**0.75**	**0.74**	0.63	0.60	0.78	0.67	**0.80**	**0.81**
3	FRA	**0.58**	**0.57**	0.61	0.55	**0.76**	**0.75**	0.65	0.56	0.64	0.55	0.58	0.63
4	AMS	**0.64**	**0.62**	0.66	0.65	**0.75**	**0.80**	0.63	0.58	0.77	0.72	0.71	0.65
5	LHR	**0.61**	**0.57**	0.62	0.59	**0.74**	**0.72**	0.61	0.57	0.47	0.50	0.64	0.57
6	SVO	0.82	0.76	0.70	0.69	**0.91**	**0.85**	**0.90**	**0.83**	0.92	0.88	0.86	-
7	MUC	**0.55**	**0.66**	0.60	0.52	**0.75**	**0.73**	0.43	0.50	0.59	0.50	0.62	0.46
8	MAD	0.74	1.00	-	0.72	**0.86**	**0.85**	-	0.55	**0.80**	**0.75**	0.71	0.79
9	HEL	0.75	0.48	-	0.51	**0.92**	**0.71**	0.68	**0.61**	-	-	-	-
10	FCO	-	0.49	-	0.66	-	**0.78**	-	0.49	-	0.57	-	0.68
11	DME	-	-	-	0.95	-	**0.96**	-	**0.95**	-	-	-	-
12	LIS	0.81	0.68	-	-	**0.85**	**0.86**	-	-	**0.86**	**0.86**	0.89	**0.83**
13	VIE	**0.49**	**0.61**	0.63	0.74	**0.70**	**0.74**	0.55	0.51	-	-	0.48	0.67
14	ZRH	**0.45**	**0.41**	0.50	0.58	**0.65**	**0.57**	0.45	**0.36**	0.51	0.35	0.56	0.46
15	BRU	**0.59**	**0.58**	0.57	0.70	**0.76**	**0.72**	0.70	0.48	-	-	**0.69**	**0.73**
16	CPH	0.59	**0.53**	0.60	-	**0.82**	**0.69**	0.60	0.45	-	-	-	0.57
17	SAW	-	-	-	**0.83**	-	**0.92**	-	-	-	-	-	-
18	DUB	**0.56**	**0.60**	-	-	**0.62**	**0.65**	-	-	-	-	-	-
19	KEF	**0.73**	**0.74**	-	-	**0.72**	**0.75**	-	-	-	-	-	-
20	ARN	0.68	0.55	-	-	**0.95**	**0.8**	0.43	0.51	-	-	-	-
21	LGW	**0.76**	0.66	0.79	-	**0.84**	**0.90**	0.80	0.65	0.78	**0.89**	0.86	0.90
22	WAW	**0.58**	**0.54**	0.50	0.58	**0.75**	**0.69**	-	0.42	-	-	-	-
23	TXL	-	0.53	-	**0.77**	**0.94**	**0.77**	-	-	-	-	-	0.93
24	ORY	-	0.87	-	-	**0.99**	**0.97**	-	-	0.99	**1.00**	0.98	**1.00**
25	OSL	**0.89**	0.57	-	-	**0.92**	**0.89**	-	0.43	-	-	-	-
26	PRG	**0.61**	0.58	**0.58**	0.64	**0.77**	**0.65**	-	**0.49**	-	-	0.65	-
27	ATH	0.68	-	**0.69**	-	**0.86**	**1.00**	0.67	-	-	-	0.75	-
28	PMI	-	-	-	-	-	**0.95**	-	-	-	-	-	-
29	DUS	**0.59**	**0.47**	-	-	**0.75**	**0.45**	-	0.32	-	-	-	-
30	MXP	**0.57**	0.87	0.60	**0.31**	**0.80**	**0.55**	0.56	**0.22**	0.62	-	0.63	-
31	BCN	0.62	**1.00**	0.71	1.00	**0.91**	**1.00**	-	-	-	-	0.79	-
32	MAN	**0.58**	**0.57**	-	**0.51**	**0.74**	0.64	-	-	-	-	-	-
33	LYS	0.64	-	-	-	**0.88**	-	-	-	-	-	0.67	-
34	BUD	0.40	-	0.56	-	**0.69**	-	0.44	-	-	-	0.69	-
35	AYT	-	-	-	-	-	-	-	-	-	-	-	-

Note. HHI_{region} values in bold depict that this market accounts for at least 20 per cent of the respective hub airport's offered seat capacities in its total transfer market. (-) indicates that this market is not offered via the hub airport.

Source: own depiction

However, in order to assess the impact of the degree of market concentration on the North American market on each hub, the market share of this particular regional market in the total connections of each hub airport has to be considered. In the case of ZRH, for example, the North American market accounted for about 30 per cent of total offered seats in both 2000 and 2016, and thus transfer connections to and from North America are exposed to an increasing degree of overlapping connections via other hub airports. Frankfurt's (FRA) and London Heathrow's (LHR) transfer connections to and from this particular region account for about between 25 and 30 per cent of their respective transfer markets, and both airports have seen a decrease in the level of market concentration over the observed period (see Table 35).

The development of market concentration for each European airport in the sample and across the different regions is depicted in Table 35. Here, figures in bold indicate that a market accounts for at least 20 per cent of the airport's total transfer connections. Based on this, it is apparent that all airports have a focus on connections from and to Europe, with differences across airports, however. Amsterdam (AMS), London Heathrow (LHR), Frankfurt (FRA), and Paris Charles de Gaulle (CDG) have shares between about 20 and 30 per cent, whereas Stockholm (ARN), Oslo (OSL), or Helsinki (HEL) have shares of more than 50 per cent in 2016 (Table 55 in Appendix 8.11). With the latter airports facing a high level of market concentration in terms of their European connections and having a high share of traffic volume on this market, this potentially implies that there is only limited competition for these airports on this market. Notably, however, is the decrease in HHI_{region} over the considered period for HEL and DUB but not for ARN.

From the analysis of these regional transfer markets, it is also apparent that some of the considered airports focus on particular niche markets such as Lisbon (LIS) and Madrid (MAD) offering between about 25 and 30 per cent of its seats to and from Latin America, Paris Charles de Gaulle (CDG) directing more than 20 per cent of connections to the African market in 2016, or Berlin Tegel (TXL) and Istanbul Sabiha Gökcen (SAW) having shares of slightly less than 30 per cent in the Middle Eastern market in 2016. The latter is due to the geographical location, and the former has special ties to this market since Etihad is one of the main shareholders in Air Berlin (AB).

Chapter 5.3 focused on the analysis of market concentration on the transfer market at European hub airports. Having established the methodology to identify feasible transfer connections based on scheduled airline data, the number of transfer connections offered by each hub airport in a predefined week for the years 2000, 2004, 2008, 2012, and 2016 was determined. Categorising the hub airports according to their amount of total transfer connections, their development over time, and the predominant range segments being offered yielded a high-level differentiation between airports. According to this classification it becomes apparent that European hub airports seem to be focusing on different market segments. This initial assumption was confirmed by the subsequent analysis of market concentration for each transfer connection using the Herfindahl Hirschman Index ($HHI_{connect}$). The mean values across transfer connections are relatively high for all European hub airports, compared to the minimum feasible values at each airport, implying that transfer connections are rather concentrated at these hub airports. However, this does not necessarily imply that market power is being abused by increasing prices or decreasing output. To shine more light on this particular issue, the following chapter therefore focuses on the effects of a degree of high market concentration on the seats provided per transfer connection.

5.4 Empirical analysis

Having analysed the development of market concentration on the transfer market at European hub airports, the next step involves the empirical analysis of the effects of this level of market concentration on the amount of seats offered on transfer connections at European hub airports. The following research question will therefore be in the focus of Chapter 5.4:

(6) What is the impact of market concentration on the output decisions, in terms of seats offered on a transfer connection, at European hub airports? As a measure for market concentration, the Herfindahl Hirschman Index for each available transfer connection ($HHI_{connect}$) will be employed as explanatory variable in the regression analysis. A transfer connection is a route offered from origin A to destination B via a hub airport H, which is comprised of the European hub airports considered in this thesis.

According to this research question, Chapter 5.4 consist of three main parts. The first part of the analysis (Chapter 5.4.1) focuses on the description of the applied variables. The following Chapter 5.4.2 defines the empirical model and provides the respective theoretical background. Chapter 5.4.3 discusses the findings of the estimation and assesses the impact of market concentration on seats being offered on different transfer connections.

5.4.1 Selection of variables

The effect of market concentration on the transfer connections offered via the different European hub airports is tested by using as dependent variables the overall number of seats per week offered on a transfer connection, *log(Connect)*, the mean number of seats per flight on this connection, *log(MeanConnect)*, and the total frequencies, *log(FreqWeek)* on a particular connection during the observed weeks. These dependent as well as the various independent variables are outlined in Table 36.

Table 36: Variables considered in empirical analysis

Variable	Description
log(Connect)	The total number of seats offered on a transfer connection via a hub airport (during a particular week, as specified in Chapter 5.3.1, logarithmic variable).
log(MeanConnect)	The mean number of seats offered per flight on a transfer connection via a hub airport (during a particular week, as specified in Chapter 5.3.1, logarithmic variable), proxy for the aircraft size employed on a transfer connection.
log(FreqWeek)	The total frequencies offered on a transfer connection via a hub airport (during a particular week, as specified in Chapter 5.3.1, logarithmic variable).
log(Demand)	The average of the gross domestic product per capita in the departure and the arrival country, weighted by the population in the urban regions of the departure and arrival airports (logarithmic variable).
$HHI_{connect}$	The Herfindahl Hirschman Index for a particular transfer connection, considering all other transfer connections between points A and B
log(Distance)	The distance between the origin and the hub airport plus the distance between the hub airport and the destination, logarithmic variable.
AirlineGroup	Dummy variable which is 1 if the transfer connection is also offered via another hub airport of the same airline or airline group.
Year	Categorical variable indicating the year of the observation (reference year = 2000).

Source: own depiction

Within the empirical analysis, a variable is introduced which controls for the potential passenger demand between two destinations, *log(Demand)*. This is done by using the weighted average of the gross domestic product (GDP) per capita of both the origin and destination region, the weights are based on the population of the urban regions in which the origin and the destination airports are located. The variable therefore depicts the mean purchasing power of the two urban regions connected by the transfer flight via the hub. This approach is similar to the one taken by Albalate, Bel & Fageda (2015), who investigate the impact of competition from high-speed rail on the number of seats supplied at airports. The weighted GDP per capita serves a proxy to account for the demand on a particular route. Here, data on the population of urban regions, for all years considered, is extracted from United Nations / Department of Economic and Social Affairs (2014) and the GDP per capita stems from the database of The World Bank (2017). Since a high GDP per capita as well as large urban agglomerations are assumed to induce a higher demand for mobility, it is expected that the explanatory variable *log(Demand)* exhibits a positive coefficient. This variable hence accounts for the fact that flights between two cities with a high level of demand can be offered via several hub airports without imposing competitive constraints on either of these hubs.

The Herfindahl Hirschman Index on the connection level ($HHI_{connect}$) is applied as a proxy for the level of market concentration on a connection, it thus represents whether this connection via a particular hub is also offered by another hub airport and to what degree. In line with the argumentation in Chapter 2, a negative coefficient of this variable is expected since a firm operating in a monopolistic market is assumed to restrict output.

Another explanatory variable is included which accounts for the distance between the origin and the destination, including the transfer at the hub airport, *log(Distance)*, and is measured in kilometres. The distance between two points is reported in the OAG database. Contrary to the assumptions in Chapter 4.3, a positive effect of the *Distance* coefficient on the seats offered is expected. It is expected that with increasing distance between two points, less direct connections between these are available, solely due to being outside the range of current aircraft types. Therefore, for long-haul to long-haul connections a transfer stop is required. Also, in case of mean seats per flight (*log(MeanConnect)*) as dependent variable, a positive coefficient is expected since long-haul destinations are served by larger aircraft, in line with the argumentation for the O&D market investigated in Chapter 4.3.

Table 37: Hub airports of airline groups

Hub airports (year of same airline ownership)[36]	Airline group	Reference
LHR, MAD, BCN, LGW, MAN	International Airlines Group (IAG) (2011)	International Airlines Group (2017)
FRA, MUC, ZRH (2007), DUS, VIE (2009)	Lufthansa Group (LHG)	Lufthansa Group (2017)
CDG, AMS, ORY, LYS	Air France-KLM (2004)	Air France-KLM (2017)
CPH, OSL, ARN	SAS	SAS (2017)

Source: own depiction

An additional variable accounts for the fact that a connection offered by one hub is also offered via another hub, and both these hub airports are the base of either the same airline or part of the same airline group (*AirlineGroup*). Table 37 shows that airlines within the Lufthansa Group, for example, have been operating five distinct hub airports in the observed period. In regard to the discussion on airline countervailing power in Chapter 5.1, the empirical analysis gives more insight into the network structure of the network carriers engaging in some form of multi-hub strategy. It is therefore interesting to see whether airlines might strategically build up their connecting traffic via their different hubs in a way not to engage in competition, or that they duplicate some of their network via other hubs in order to be able to exert buyer power on the respective airports.

Table 38 shows the degree of overlap between the different hubs of the same airline group, and reveals distinct behaviour across the four airline groups. In the Lufthansa Group, the secondary hub airports next to Frankfurt (FRA) exhibit a high share of overlapping connections with the Lufthansa's (LH) main hub. Especially at Zurich (ZRH), almost half of the connections are duplicated at another hub airport of the airline group. Munich (MUC), which has been growing as secondary hub airport in Lufthansa's multi-hub strategy, has been duplicating between 20 and 30 per cent of the connections offered via other hubs of the airline group in the years 2012 and 2016.

[36] Only those airlines and respective hub airports are included which have the same ownership either over the entire or part of the considered time period from 2000 to 2016. Therefore, Brussels Airlines (SN) is excluded from the Lufthansa Group here since it will be fully integrated from 2018 onwards (Lufthansa Group, 2016).

Table 38: Degree of overlap between hubs of the same airline group

Group	hub	2000	2004	2008	2012	2016
AF-KLM	AMS	n/a	14%	11%	11%	12%
	CDG	n/a	9%	6%	8%	8%
	ORY	n/a	4%	0%	0%	2%
	LYS	n/a	9%	8%	7%	n/a
LH Group	FRA	2%	4%	8%	9%	11%
	MUC	12%	12%	19%	21%	28%
	ZRH	n/a	n/a	35%	45%	45%
	VIE	n/a	n/a	n/a	18%	22%
	DUS	19%	18%	23%	31%	23%
IAG	LHR	n/a	n/a	n/a	3%	2%
	MAD	n/a	n/a	n/a	7%	4%
	LGW	n/a	n/a	n/a	1%	3%
	MAN	n/a	n/a	n/a	0%	0%
	BCN	n/a	n/a	n/a	9%	n/a
SAS	CPH	1%	1%	1%	1%	1%
	ARN	3%	2%	2%	2%	1%
	OSL	0%	0%	0%	0%	0%

Source: own calculation based on OAG data

Pursuing a duplication strategy across its different hub airports may imply that the Lufthansa Group has a greater leverage than other network carriers to potentially switch connections between its multiple hubs. London Heathrow (LHR), being one of the largest European hub airports, has only a very low share of duplicated connections within its airline group, although this only applies to the years 2012 and 2016. Within the network of the carrier SAS (SK), only a very low level of overlapping connections exists, implying that this carrier has a complementary hub strategy across its three main airports. The coefficient of *AirlineGroup* gives hence an indication to the airline group's strategy by either avoiding overlap or duplicating operations across their different hub airports. A negative coefficient of this variable in the empirical analysis would therefore imply that hub airport A reduces the number of seats or frequencies offered on a connection if this is also offered by hub airport B. The descriptive statistics of the variables are outlined in Table 39.

Table 39: Descriptive statistics of variables (values at the transfer connection level)

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Connect	5100	1590	829	136	8701
MeanConnect	5100	242	61	48	474
FreqWeek	5100	7	3	1	33
Demand (in '000)	882	136000	99900	1630	598000
$HHI_{connect}$	5100	0.56	0.32	0.06	1
AirlineGroup	5100	0.13	0.34	0	1
Distance	5100	12951	2843	4523	20714

Source: own depiction

In order to test for the effect of these variables on the output, i.e. seats being offered on transfer connections at European hub airports, the following chapter specifies the empirical model applied for this analysis.

5.4.2 Model specification

In the empirical analysis, the effect of market concentration on the seats offered on transfer connections via European hub airports is the main causal relationship investigated in this chapter. The model applied in this chapter is analogous to (19) in Chapter 4.3.2, with a least squares dummy estimation, with the dummy variable γ_t representing the time fixed effect in the regression model. Furthermore, a balanced panel is used, which means that only those transfer connections are considered that are offered in each time period. The following equation is estimated, using *log(Connect)*, *log(MeanConnect)* and *log(FreqWeek)* subsequently as dependent variables:

$$\begin{aligned} log(Connect_{ct}) &= \beta_0 + \beta_1 log(Demand_{ct}) + \beta_2 HHI_{connect,ct} \\ &+ \beta_3 log(Distance_{ct}) + \beta_4 AirlineGroup_{ct} + \gamma_t \\ &+ u_{ct} \end{aligned} \quad (25)$$

with $t \in \{2000, 2004, 2008, 2012, 2016\}$ and c = 1, …, K, representing the transfer connections offered via each hub airport, γ_t is treated as the unknown intercept which is to be estimated for each time period, and u_{ct} is the error term. The results of the estimation are displayed in Table 41 in Chapter 5.4.3.

The dependent variables as well as the continuous explanatory variables *log(Demand)* and *log(Distance)* are in logarithmic form since a non-linear relationship between these variables is expected, see Chapter 4.3.2 for a more detailed discussion of these relationships. In addition, Table 40 displays the Pearson correlation coefficient for the continuous variables in the model.

Table 40: Pearson correlation coefficient for selected variables

	log(Connect)	*Connect*	*log(MeanConnect)*	*MeanConnect*	*log(FreqWeek)*	*FreqWeek*	*log(Demand)*	*Demand*	*$HHI_{connect}$*	*log(Distance)*	*Distance*
log(Connect)	1.00										
Connect	0.91	1.00									
log(MeanConnect)	0.57	0.50	1.00								
MeanConnect	0.57	0.53	0.97	1.00							
log(FreqWeek)	0.83	0.76	0.02	0.04	1.00						
FreqWeek	0.75	0.83	0.01	0.03	0.91	1.00					
log(Demand)	0.30	0.28	0.27	0.28	0.20	0.19	1.00				
Demand	0.22	0.25	0.25	0.26	0.11	0.13	0.84	1.00			
$HHI_{connect}$	-0.34	-0.30	-0.22	-0.22	-0.27	-0.22	-0.41	-0.33	1.00		
log(Distance)	0.37	0.34	0.59	0.58	0.58	0.03	0.49	0.44	-0.25	1.00	
Distance	0.38	0.36	0.57	0.58	0.58	0.06	0.49	0.46	-0.25	0.98	1.00

Source: own depiction

Having defined the empirical model as well as the variables to be estimated, the following chapter will address the research question highlighted at the beginning of Chapter 5.4 and discuss the respective findings.

5.4.3 Effects of market concentration on connectivity levels

Coming back to the research question whether market concentration on the transfer market affects output decisions (by a network carrier and its partners) at hub airports, this chapter focuses on the empirical estimation of this specific causal relationship. The variables specified in Chapter 5.4.1 are employed in model (25). The results of this estimation are displayed in Table 41, all models exhibit no multicollinearity and standard errors are robust to heteroskedasticity.

Table 41: Results of OLS estimation with time fixed effects

Variable	(10a) *log(Connect)*	(10b) *log(MeanConnect)*	(10c) *log(FreqWeek)*
log(Demand)	0.06**	-0.009	0.06**
	(0.02)	(0.10)	(0.02)
$HHI_{connect}$	-0.38***	-0.08**	-0.29***
	(0.06)	(0.03)	(0.05)
log(Distance)	0.74***	0.65***	0.09
	(0.08)	(0.04)	(0.07)
AirlineGroup	-0.009	-0.01	-0.001
	(0.07)	(0.03)	(0.06)
$Year^{2004}$	0.25***	0.05*	0.20***
	(0.06)	(0.02)	(0.05)
$Year^{2008}$	0.26***	0.03	0.24***
	(0.05)	(0.03)	(0.04)
$Year^{2012}$	0.25***	0.02	0.24***
	(0.06)	(0.03)	(0.05)
$Year^{2016}$	0.31***	0.09***	0.22***
	(0.04)	(0.02)	(0.03)
Intercept	-0.73***	-0.48	-0.25***
	(0.71)	(0.34)	(0.64)
Observations	882	882	882
R^2	0.2712	0.3351	0.1395
SER	0.4742	0.2255	0.4260

Notes: Standard errors in parenthesis (robust to heteroskedasticity).
*** Significance at 0.1%. ** Significance at 1%. * Significance at 5%

Source: own depiction

In models (10a) and (10c) in Table 41, the variable *log(Demand)* is positive and statistically significant. Since both the dependent variable and the independent variable are in logarithmic form, the coefficient of the latter represents the elasticity of demand with respect to the dependent variables (see Table 22). This implies that a one per cent increase in the level of demand leads to a 0.06 per cent increase in both the seats and frequencies offered per week. These results confirm the assumption that a high level of demand on particular routes leads to an increase in capacities offered on these. In model (10b), however, with *log(MeanSeats)* as dependent variable, this coefficient has a negative sign and is not statistically significant. It can be assumed that a higher number of total seats is offered by increasing the frequencies instead of employing larger aircraft (mean seats per flight being a proxy for the latter). This finding is interesting since it suggests that a high value is placed on having more frequencies, and thus also resulting in a higher level of flexibility for passengers.

The coefficient of the explanatory variable *AirlineGroup* is negative, and thus implying that in case a transfer connection is also offered via a hub of the same airline (group), the number of seats on this connection is reduced. However, this effect is not statistically significant in any of the models.

In terms of the *log(Distance)* variable, the coefficients are statistically significant and positive in models (10a) and (10b), no statistically significant effect can be observed in regard to *log(FreqWeek)* as dependent variable. Considering the first two models, a one per cent increase in distance leads to an increase in total seats offered on a transfer connection by 0.74 per cent, and by 0.65 per cent regarding the mean number of seats being offered per flight. Therefore, it can be deduced that aircraft size increases with distance as does the total number of seats being offered. As outlined in Chapter 5.4.1, the reason for this observation might be that no or only little direct connections exist on long-haul to long-haul connections. On shorter transfer connections, the competition from direct connections may therefore constrain offered seat capacities.

In addition to this, the categorical variables for each year exhibit a positive and statistically significant coefficient for all years in models (10a) and (10c), but only for the years 2004 and 2016 in model (10b). In terms of the dependent variables *log(Connect)* and *log(FreqWeek)* a positive effect on the total number of seats, and the frequencies being offered can be observed. The strongest increase in total seats can be observed in 2016.

The proxy variable for market concentration, $HHI_{connect}$, is statistically significant and has a negative coefficient in all three models. This variable and its effects represent the main causal relationship investigated in this chapter. Confirming the assumption outlined in Chapter 5.4.1, an increase in the market concentration on a particular transfer connection leads to a decrease in total seats, mean seats per flights, and frequencies being offered. This finding is in line with that of the local catchment where an increase of market concentration also leads to the reduction of seats on an origin-destination pair (Chapter 4.3.3). If a transfer connection is concentrated at a particular hub airport, the network carrier operating at this airport restricts the output being offered on that connection. If the $HHI_{connect}$ increases by one unit, the total number of seats decreases by 38 per cent, the mean number of seats by eight per cent, and the frequency per week by 29 per cent. Controlling for other parameters influencing the number of seats being offered on a transfer connection, it can thus be concluded that transfer connections with a high degree of market concentration are more prone to restrictive behaviour than those routes which are less concentrated, i.e. the latter face more competition from other airports and network carrier offering the same transfer connections.

Based on these findings, the following chapter discusses the implications of the effects of the level of the $HHI_{connect}$ in terms of the identified degree of market concentration on transfer connections at European hub airports in Chapter 5.3. This discussion provides a detailed insight into which airports may exhibit market power and may be prone to abuse this.

5.5 Assessing potential competition on the transfer market at European hub airports

The constraints imposed on hub airports' market power on the transfer market by other hub airports has been the main research focus within this chapter. Since this particular market is determined by airlines organising their network in a hub-and-spoke structure, and using hub airports as their nodes, the chapter started with a short analysis of the position of these network carriers at their respective hub airports. Based on this, the amount of transfer connections offered at each European hub airport during a predefined week in each considered time period has been identified. This analysis already provides insight into the different types of hub airports in terms of the importance of the transfer market. The degree of overlap between each hub's transfer connections with other hub airports was investigated by applying the Herfindahl Hirschman Index, yielding the level of market concentration for each individual transfer connection at all European hub airports. Using this indicator as explanatory variable in the empirical estimation of the effects of market concentration on seat capacities offered on transfer connections, complements the findings on potential competition on the transfer market.

Concerning the interlinkage between hub airports and their respective network carriers, the latter have a share in total seats offered of about 40 per cent or more at the majority of the European hub airports. Coming back to the discussion on this vertical relationship in Chapter 3, a dominant carrier at an airport may be able to exercise some degree of bargaining power over the airport regarding the terms and conditions of operations. Furthermore, in the case of hub-and-spoke operations, these carriers are prone to charge a hub premium in the form of higher ticket prices for passengers. On the other hand, many hub airports play an important role in the network of a carrier, and the limited ability of the latter to easily relocate operations to another airport therefore strengthens the dominant position of the hub airport. However, cooperation between the airline and airport may also aim at fostering the competitive position on the market for transfer connections, and thus deriving benefits for passengers. Eventually, the implications for the hub airport depend on the importance of the transfer market in its total operations.

The amount of transfer connections offered during the investigated week therefore provide a good indication of the role the transfer market is playing in the airport's total operations. By analysing these as well as the different range segments covered by these connections, the different European hub airports can be categorised accordingly. The transfer market constitutes a significant part in airport operations at both the incumbent and emerging hub airports, including AMS, CDG, LHR, FRA, IST, MAD, MUC, SVO, VIE, DUB, HEL, KEF, LIS, WAW, ARN, and OSL. The other investigated hub airports either only have a very small amount of transfer connections, or none at all anymore in 2016. The competitive constraints imposed by this particular market is therefore stronger for the airports with a high amount of connections.

In order to analyse these potential constraints, the degree of overlap between transfer connections, measured by the Herfindahl Hirschman Index, shows that most airports in the sample face decreasing market concentration levels (Figure 38). Some of those experiencing an increase are of the category declining or disappearing hub airports, in which case the transfer market does not play a major role in the assessment of competitive constraints. Others such as DME, FCO, PMI, and SAW are in the category of new hubs, with only a small amount of transfer connections being offered. This market is therefore currently of minor importance at these, it might increase over time, though, and therefore has to be observed closely.

Considering the decrease in market concentration at the other hub airports, including most of the major hub airports in Europe, both in terms of total passengers numbers and regarding the amount of transfer connections offered per week, implies that these have seen an increasing overlap of their transfer connections. This suggests that passengers have more choice available when selecting their most feasible connection, thus putting increasing competitive pressure on these hub airports.

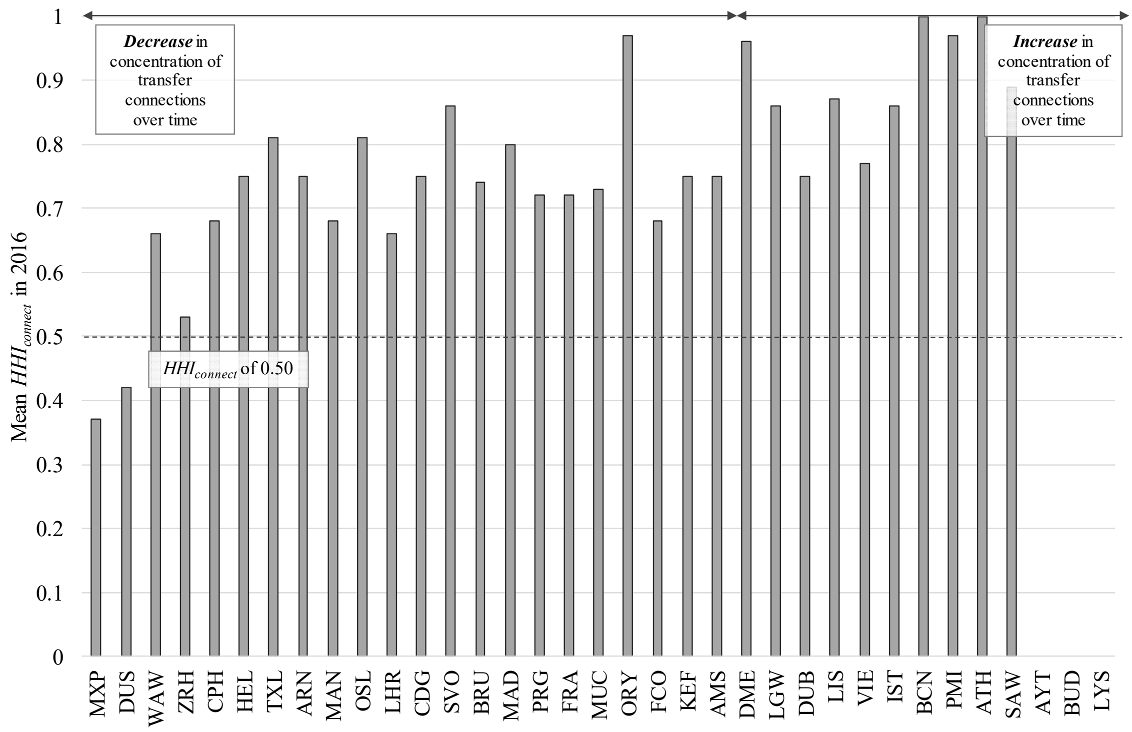

Figure 38: Development of market concentration on the transfer market

Source: own depiction

Regarding the level of market concentration, however, for most of these airports a rather high Herfindahl Hirschman Index can be observed. Applying the same threshold as in Chapter 4, most hub airports have a mean index of well above 0.50, implying that a high share of transfer connections offered at these hubs is relatively concentrated, i.e. only little or no competing transfer connections are provided. Comparing the four incumbent airports LHR, CDG, AMS, and FRA shows that LHR faces the highest degree of overlap in terms of its transfer connections, and AMS the least.

Providing further insight into the potential competition on the transfer market is the regional analysis of transfer connections. On the North American market, for example, which accounts for a large share of transfer connections at all airports, concentration levels have been decreasing over time for the majority of airports, and are lower than the above highlighted mean concentration level. This suggests that passengers are able to choose from a range of alternatives when travelling to and from the North American market. Furthermore, the regional analysis also reveals at that some airports, such as Lisbon (LIS) or Istanbul Sabiha Gökcen (SAW), the network carriers focus a large share of their connecting traffic on a niche market segment, e.g. Latin America, or the Middle East. For these markets only a limited degree of overlapping connections exist, thus endowing these hub airports with a dominant position on these markets.

Looking further into the effects of market concentration in regard to transfer connections, the complementary empirical analysis confirms the findings from Chapter 4. An increase in market concentration on the transfer connection level has a negative effect on the output level at the hub airport, i.e. the number of seats and frequencies offered per week are reduced. This implies that the output on transfer connections exposed to high market concentration is restricted. Again, as in Chapter 4, translating this to the analysis of market concentration on the transfer market at European hub airports suggests that a high amount of transfer connections at these airports may be subject to output restrictions, in the form of frequency reductions and/ or decreases in total seats. Carefully analysing this development over time, and whether trends of decreasing market concentration on the transfer market are continuing, further contributes to a detailed assessment of competition on this particular market.

Although the mean level of concentration appears to be relatively high in Figure 38, the regional analysis suggests that markets which contribute a high share of these airports' overall operations face some degree of overlap, such as the North American transfer market, for example. LHR, CDG, AMS, and FRA have more than 20 per cent of their transfer traffic to and from this market in 2016, and all face a Herfindahl Hirschman Index of around 0.60 on this market, suggesting that there is higher overlap with other hub airports than on most of the other markets. Considering the development of market concentration on markets with a high share of traffic therefore provides a further criterion in the assessment of overall competition.

The complementary implications of the findings of market concentration in both the local catchment and on the transfer market for the competitive constraints imposed on European hub airports are discussed in the following chapter.

6 Conclusion

Focusing on the assessment of competitive constraints faced by European hub airports over a period of 16 years, both in the local catchment and on the transfer market, the initial research questions formulated in Chapter 1 have established the structural framework of this thesis. Competitive constraints in this case refer to the availability of substitute airports, to what degree the hub airports' destinations are also offered at these, and deducing from this the choice passengers have to switch between different airports, both in the local catchment and on transfer connections. This potential to substitute between airports has been considered as one of the reasons why the assumed market power in the airport industry is being restrained, and thus this increased competition should foster a rethinking of current regulatory frameworks in place at European (hub) airports. The debate on the existence and degree of market power in the airport industry has been a long and controversial one, though, with the different sides delivering evidence supporting both strands of arguments. The research in this thesis provides a structured and empirically funded approach to assess some of these competitive constraints on the origin-destination market in the local catchment and on the transfer market at European hub airports. To provide a comprehensive overview of the specific characteristics of the airport industry, and to evaluate potential competition on both markets, the thesis has been structured into four main parts.

Since airports have long been considered as (natural) monopolies with significant market power, the first part discusses the theoretical background of this particular market structure. The associated behaviour of firms often makes economic regulation in industries with monopolistic bottlenecks essential, especially in the case of public utilities, in order to reduce overall welfare losses. Potential entry barriers for new competitors may strengthen the dominant position of an incumbent firm in the market, the efficacy of these barriers, however, is controversially discussed. Economies of scale, for example, are, on the one hand, considered as an entry barrier since incumbents have an advantage producing at a large scale, and potential entrants may incur losses due to producing at a lower scale. On the other hand, opposing arguments highlight that a new competitor can charge lower prices and therefore redirect demand to its own products. This discussion in Chapter 2 shows that market power, the efficacy of entry barriers, and the resulting implications for firm behaviour are often not clear-cut, thus requiring a detailed assessment of each firm assumed to engage in abusive behaviour.

The approaches in determining an industry's degree of market power and subsequently deciding on required measures which constrain abusive behaviour have also all seen its respective opponents and advocates. In the first part of this thesis, the discussion of the direct and indirect approaches to assess market power hence highlights the benefits and drawbacks of the different methodologies. The application of the indirect approach in antitrust law, and its associated assumptions, was often criticised as imposing too strict rules on concentrated industries. This was often due to the reason that market power was directly inferred from the existence of high market shares. This ruling potentially ignored the superior efficiency of large firms in the market and the respective increase in overall welfare. However, over time this strict interpretation of market shares or concentration measures changed, and these are rather regarded as providing a good insight into the structure of a market. In combination with the analysis of new firms' ease of entry into an industry, this indirect approach is currently often applied in European and U.S. competition policy when assessing mergers between firms or market power within an industry. Salop (2015) also highlights that "… various theories of oligopoly conduct … are consistent with the view that competition with fewer significant firms on average is associated with higher prices" (p.276). The change in an index measuring market concentration, for example, is hence often applied to evaluate whether a firm's dominant position in a market has been manifesting over time. In comparison, the direct approach often focuses on demand and price analysis, and deduces the degree of a firm's market power from this assessment. This particular method requires detailed firm-level data in order to draw a picture of the firm's behaviour. This sort of disaggregated data on a firm's prices and costs is often not available, though, and therefore antitrust analysis resorts to indirect measures of market power. In line with this, the pursued research methodology within this thesis also applies elements from the indirect assessment of market power in an industry.

When assessing the potential competition European hub airports face, the two different markets considered in this analysis are distinct to hub airports. The second part of the analysis in this thesis, Chapter 3, therefore focuses on the discussion of airport market structure. Some airlines organise their network in a hub-and-spoke structure, with a particular airport representing the node. These network carriers bundle their flights within this node in order to realise economies of scale, scope, and density. Due to this network structure, these airlines often contribute a high share of the airport's overall operations. On the other hand, the airlines are dependent on their nodes as well, since the relocation of network carrier operations proves to be rather difficult, oftentimes these are associated with high investment in respective airport infrastructure. Depending on this specific interlinkage, the network carrier is able to earn a significant hub premium, for example, and, due to contractual long-term agreements with the airport and mutual investment, has the ability to restrict other carriers' access to essential facilities at the airport. But this relationship between network carrier and hub airport may also bear benefits for passengers in terms of higher travel frequencies, and more travel destinations available. Furthermore, since network carriers benefit from offering transfer connections, this leads to competition with other airports also offering these connections. In order to persist in this competitive market, network carriers and hub airports may decide to engage in a closer relationship with each other to strengthen their overall position.

Concerning the previously addressed substitution potential between airports as well as the vertical relationship between network carriers and hub airports, this particular part of the thesis furthermore highlights factors that influence passengers' decision for a specific airline or airport. In regard to the origin-destination market in the local catchment of a hub airport, it is often assumed that passengers make their decision regarding airport and airline choice jointly, and that airports compete for passengers through the airlines (Suzuki, 2007; D'Alfonso & Nastasi, 2012). In terms of the transfer market at European hub airports, the close relationship between these airports and their respective network carriers leads to the inference that competition between network carriers for passengers on transfer connections also implies competition the hub airport is exposed to. Different approaches to measure competition between airports are discussed in Chapter 3, highlighting the various areas airports may compete in – the competition for airlines, competition on both the origin-destination and transfer market, and the constraints arising from the two-sided nature of the airport business.

Building on this current research landscape in the field of airport competition, this thesis considers both the origin-destination and the transfer market for 36 European hub airports over a time span of 16 years, and the degree of competition these markets have been exposed to. Most other studies in this area mainly focus on only a subset of these airports, and also cover shorter time periods. The structure and research methodology applied is the same for the origin-destination and the transfer market. For the analysis of potential market power of European hub airports, the first step of the analysis of each market hence comprises an assessment of the level of market concentration as well as its development over time. The Herfindahl Hirschman Index is employed as a measure for this, and, as highlighted before, this method is taken from the indirect approach to assess market power. Regarding the substitution potential passengers are exposed to in terms of switching between airports, determining the degree of market concentration for each of these airports provides a good first approximation to the overlap in destinations between airports, and thus the choice passengers have when planning their journey. It therefore constitutes a first detailed insight into the position of European hub airports on both the origin-destination and the transfer market.

A high degree of market concentration does not necessarily imply that an airport is abusing its market power by restricting output and increasing prices. In the second step of the analysis, the effect of market concentration on the output offered at each hub airport is therefore empirically estimated, again for both the origin-destination as well as the transfer market. Output in this case is denoted by the flight frequencies or total seats offered to a particular destination per year. Using airport output as the dependent variable in regression analysis, and employing the Herfindahl Hirschman Index as explanatory variable, as a measure for market concentration, is in line with previous research in the field of airport competition, including Burghouwt & Veldhuis (2006); Givoni & Rietveld (2009); Fageda (2013); Albalate, Bel & Fageda (2015). The lack of demand data for the disaggregated analysis on the destination level over a period of 16 years has been another reason to resort to supply data, and derive implications for the market power of European hub airports. Furthermore, especially in regard to the origin-destination market in the local catchment of European hub airports, other factors impacting the level of competition faced by a hub airport, are included in the empirical analysis. This two-step approach has been applied to both the origin-destination and the transfer market, thus contributing parts three and four of the thesis, respectively.

Investigating the degree and development of market concentration on the origin-destination market in the local catchment of European hub airports in the third part of the thesis (Chapter 4), thus addressing research question (1), shows that the majority of these experienced a decrease in market concentration in the period between 2000 and 2016. Since market concentration is measured on the individual route level, this development suggests that secondary airports in the hub airports' catchment areas have been providing a larger overlap with the hub airport over time. As initially stated, a higher degree of overlap between destinations provides passengers with more alternatives when selecting their location of arrival and departure. This may subsequently impose increasing competitive constraints on hub airports since passengers may be more likely to switch to other airports in the catchment if these offer better conditions in the form of ticket prices, for example.

However, in regard to the level of market concentration, expressed by the value of the Herfindahl Hirschman Index, a rather highly concentrated market at most of the European hub airports can be observed. Although there is no predefined threshold at which an industry is said to exhibit high market concentration, some properties of this index allow for the deduction of a value each airport can be benchmarked against. If firms in a market are of equal size, the minimum value this index can take is the inverse of the number of firms. With two equally sized firms in the market, the minimum value of the Herfindahl Hirschman Index is 0.50. In the local catchment, all airports but Brussels Airport and Dusseldorf Airport exceed this value by far, implying that the routes offered at the hub airports exhibit a rather high degree of market concentration, and thus only limited overlap with other airports in the catchment. This means that the airports within a catchment, including hub and secondary airports, potentially focus on distinct market segments. These findings are complemented with the empirical estimation of the effect of market concentration on airport output, addressing research question (2). The statistically significant results show that an increase in market concentration, i.e. the value of the Herfindahl Hirschman Index, leads to a decrease in the total offered seats on a route, a reduction in the aircraft size employed, and to less frequencies being offered. This also means that in case of increasing competition, i.e.

decreasing Herfindahl Hirschman Index values, a rise in frequencies can be observed. Competition between airports may therefore take place by raising the flight frequencies to particular destinations, thus providing more flexibility to passengers.

Another observation to be made on the origin-destination market is the effect of the presence of low cost carriers at secondary airports in the catchment, referring to research question (3). In case a route at the hub airport is also offered by a low cost carrier in the catchment, the total seats offered per year as well as the flight frequency are increasing at the hub airport. This means that airlines at these react to the offer of low cost carriers by increasing their output to these specific destinations. Furthermore, an effect on air services at hub airports by the quality of a rail network can be noticed, thus answering to research question (4). In case this quality increases, measured in the available rail-kilometres per square kilometre in a country, the number of total seats as well as frequencies offered to a destination decreases. The reasons for this may be twofold: Either the attractiveness of offering the same route decreases due to not being able to compete with rail prices, or the rail network is used as a complement for air traffic, hence replacing air routes. In case a hub airport is well connected to the rail network, airlines may substitute feeder flights in its hub-and-spoke network by cooperating with rail providers.

The analysis of the transfer market at European hub airports, which is analysed in the fourth part of the thesis (Chapter 5), reveals similar results to that of the origin-destination market. However, first, it can be observed that this particular market is of different importance across the sample of hub airports. The calculation of feasible transfer connections within a predefined week within each year shows that at some airports only a very small number of connections is offered. The significance of the transfer market at these airports may therefore be only limited, and competitive constraints imposed on this market may thus not apply. Investigating the degree and development of market concentration on this particular market, referring to research question (5), also measured by applying the Herfindahl Hirschman Index, points to an increasing overlap between transfer connections at most airports in the dataset over the considered period. Especially for connections to and from the North American market passengers faced an increasing choice of transfer flights in the period from 2000 to 2016. Other regional markets, such as connections to and from Latin America, for example, are more concentrated since only a rather small share of airports focuses on these markets. Considering the market share each hub airport has in a region and the respective market concentration on the connections to and from this region, therefore provides further insight into the degree of overlap a hub airport faces on its transfer market.

Comparing the overall level of market concentration on the transfer market at the airports, applying the same threshold as for the origin-destination market, shows that all but three airports exhibit a value of at least 0.60, implying a rather concentrated market for transfer connections at European hub airports. The effect of a decrease in airport output on routes with increasing market concentration can also be observed on this particular market, answering to research question (6). The statistically significant results show that an increase in the Herfindahl Hirschman Index leads to a decrease in the amount of total seats offered, the mean aircraft size, and the flight frequencies per week. On transfer connections with high overlap, i.e. those with low market concentration, the airports, and in this regard the network carriers, compete via increasing their frequencies, for example. Passengers selecting a transfer connection may therefore be more willing to choose a connection with higher frequencies, thus accounting for potential delays of a connection and having another one available in due time.

Bringing together the assessment of the origin-destination and the transfer market at the considered European hub airports yields a high-level overview of the degree of market concentration each of these airports faces on both markets. Figure 39 depicts the mean values for the Herfindahl Hirschman Index in 2016 for both these markets as well as the number of transfer connections offered at each airport within this period. The latter is an indication to the importance of the transfer market when assessing the potential competition on this. In evaluating the potential competition for an airport, it is important to consider the different markets in which an airport might be exposed to some degree of competition and investigate these in more detail. The transfer market hence plays only a minor role at those airports which offer a very small amount of transfer connections during the investigated week. For these airports, the degree of competition on the origin-destination market therefore has a higher impact on the airport's output decisions and pricing behaviour than the transfer market.

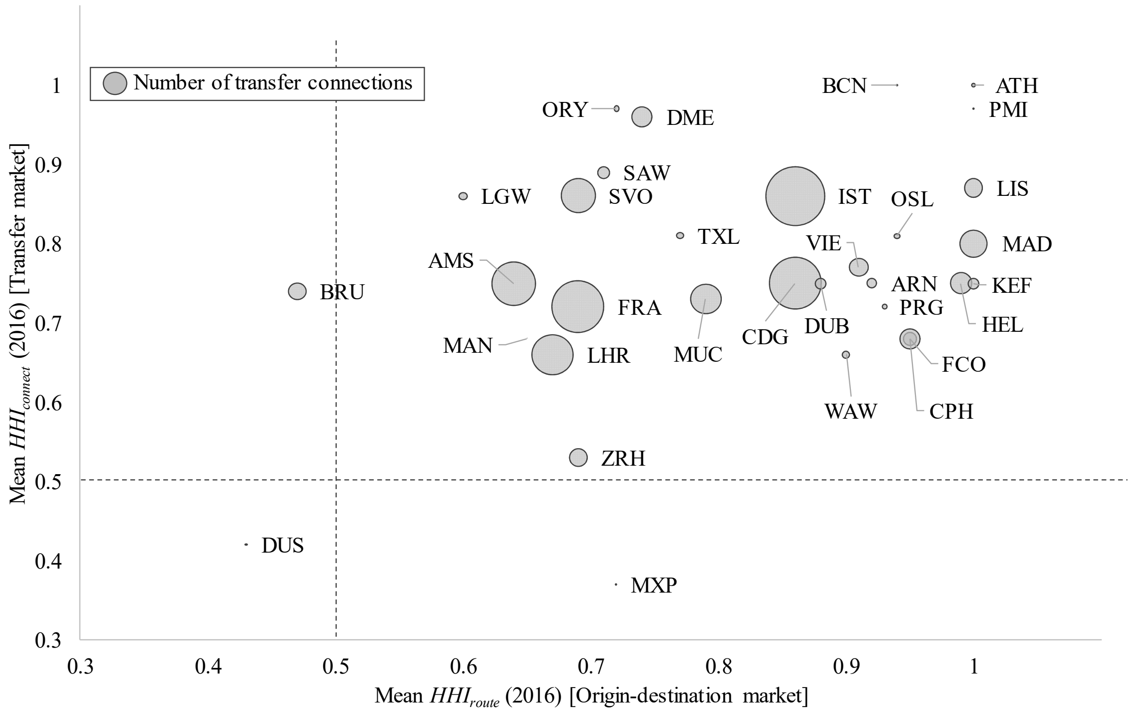

Figure 39: Market concentration on the origin-destination and transfer market

Source: own depiction

This overview shows that the majority of hub airports in Europe has a dominant position both on the origin-destination and on the transfer market. In general, this implies that the overlap in routes offered on these markets with other airports is rather limited. Using a Herfindahl Hirschman Index with a value of 0.50 as a rough threshold illustrates that all but three airports in the dataset exceed this limit on both the transfer and the origin-destination market. As the results of the empirical estimation have shown, an increase in the level of the Herfindahl Hirschman Index leads to a decrease in output offered on the respective origin-destination route or transfer connection. Having an airport with a high share of routes on both the origin-destination and transfer market with a high level of market concentration therefore implies that this airport has a dominant position, and is likely to restrict output accordingly. However, the second observation for these markets shows that market concentration has been decreasing steadily for the majority of European hub airports. The analyses in Chapter 4 and 5 reveal that only Dublin Airport (DUB) and Sabiha Gökcen Airport (SAW) faced an increase in market concentration on both markets across the observed period from 2000 to

2016. This development shows, on the other hand, that most airports in the sample have been exposed to an increasing overlap of their destinations, i.e. a decrease in market concentration. This implies that origin-destination routes and transfer connections which face more overlap are offered with higher frequencies and a higher amount of total seats, thus providing more choice to passengers. Another implication, not investigated in this thesis but shown in other studies such as Fageda (2013), is the negative effect a decreasing level of market concentration has on the ticket price on a route. With the majority of European hub airports experiencing a decrease in market concentration, it can be assumed that the individual routes particularly exposed to this are subject to an increase in output and a reduction in ticket prices. European hub airports are thus exposed to an increasing level of competition considering the period between 2000 and 2016.

Of the large hub airports in Europe in terms of total passenger volume, London Heathrow Airport (LHR) exhibits the lowest degree of market concentration on the transfer market, and ranks in second place in terms of low market concentration on the origin-destination market. Furthermore, for both markets a decrease of market concentration from 2000 to 2016 can be observed. The competitors on the origin-destination market in the local catchment of London Heathrow are strong in terms of offering similar destinations as the hub airport, thus providing a high degree of substitution potential for passengers. In addition to that, a high share of transfer connections via London Heathrow are to or from the North American market, which has been outlined as being the most competitive transfer market in Chapter 5. Considering only these developments, London Heathrow can be considered as facing competition on a rather high share of routes and transfer connections, thus limiting its ability to exert market power on its customers, the airlines and passengers.

As a guideline to approach the assessment of the degree of competition faced by an airport, in this case especially hub airports, the following criteria analysed throughout this thesis have to be considered:

- The degree and development of market concentration on the origin-destination market in the local catchment of an airport; assuming that an increase in market concentration on the individual route level leads to a decrease in the output offered on this route.

- Investigation of the strength of low cost carriers in the catchment of a hub airport; the empirical analysis suggests that airlines at hub airports compete with these carriers, which often focus on holiday destinations and thus leisure passengers.
- Analysis of the availability and quality of the rail network on the short-haul market at hub airports, usually only focusing on a distance of up to 800 kilometres, and assessment of the degree of cooperation or competition between rail and air services; the empirical results imply that the availability of rail connections leads to a decrease of air services, thus suggesting a substitution or complementary effect between transport modes.
- The degree of interlinkage between hub airports and their network carriers, in terms of the airline's traffic shares at the hub airport as well as potential contractual agreements between these; the discussion of the vertical relationship between an airport and airline shows that there might be potential drawbacks of a dominant airline, such as charging a hub premium, but also benefits derived for passengers, including higher flight frequencies.
- The degree and development of market concentration on the transfer market of an airport; assuming that an increase in market concentration on the individual transfer connection level leads to a decrease in the output offered on this route.

This list is not exhaustive and there are additional aspects that have to be taken into consideration when assessing the degree of competition an airport faces. However, the listed criteria provide an insight into the airport's position in the origin-destination market in the local catchment and on the transfer market. To exemplify this, these aspects are discussed for the case of Frankfurt Airport (FRA).

In terms of overall passenger volume per year, FRA has been in third or fourth place in Europe in between 2000 and 2016. In its local catchment area, defined as a two-hour driving radius, there are nine different secondary airports with scheduled airline traffic, which may impose some degree of competition on FRA in terms of the overlap in origin-destination routes. In this regard, market concentration in this local catchment decreased steadily over the observed period but is still relatively high compared to the threshold of 0.50 discussed above, with 0.73 in 2000 and 0.69 in 2016. However, the decreasing level of market concentration suggests that secondary airports in the catchment have been catching up and providing more routes, and respective total seats or frequencies, which are equivalent to the offer at FRA. Cologne Airport (CGN) has been a strong base of Germanwings as well as Stuttgart Airport (STR), thus these airports can be considered as drivers of the increased overlap in destinations available to passengers. Furthermore, Ryanair opened a base at Frankfurt Hahn Airport (HHN) in 2002, and increased its offered capacities to various destinations over the considered period. Dusseldorf Airport (DUS), as being one of the other hub airports considered in this thesis, also contributed to this development. Having strong counterparts in its local catchment therefore provides more choice available for passengers when selecting their arrival or departure airport.

Frankfurt Airport is also well connected to the rail network, with a high-speed rail connection being provided in close vicinity to the terminals. The results from the empirical estimation in Chapter 4 show that a better connected rail network leads to a decrease in the seat capacities offered on a route. Since the main carrier at Frankfurt Airport, Lufthansa, has a close cooperation with the German rail provider, Deutsche Bahn, it can be assumed that the airline replaces some of its routes with rail services and feeding passengers into its node by rail (Lufthansa, n.d.).

The transfer market at Frankfurt Airport exhibits a similar development as its origin-destination market regarding the degree and development of market concentration. With a Herfindahl Hirschman Index of around 0.70 and a decrease of this over the observed time period, more transfer connections offered via this airport face an overlap with connections via other hub airports. The analysis in Chapter 5 illustrates that the transfer markets on which Frankfurt Airport offers its highest shares of seat capacities, North America and Asia, face a lower degree of market concentration than on other regional markets, and it has also been decreasing over time. This finding suggests that these regional markets are exposed to competition from other hub airports and their respective network carriers. And since these contribute a large share of transfer traffic at this particular airport, it can be inferred that this market is exposed to competition.

The conclusion to be drawn from this high-level insight into the degree of competition faced by Frankfurt Airport is the development towards more competitive markets, both for origin-destination and transfer traffic. Resulting in lower ticket prices for passengers as well as higher quality of air services, in terms of more flight frequencies being offered, for example, leads to an increase in consumer welfare. It is therefore important to further foster this development towards a more competitive market in the future.

However, some aspects have to be noted which were not considered in this analysis but may influence the degree of airport competition in the future. First, as already discussed in Chapter 4, low cost carriers are making a move towards hub airports, as observed in the case of Ryanair and Frankfurt Airport. Questions arising in this context concern the growth of low cost carriers and whether this will still be equally distributed across hub airports and their secondary counterparts, or whether this will be at the expense of the latter. Having more low cost carriers relocating their operations to large or hub airports may therefore lead to an increase in market concentration again, thus offering less alternatives to passengers.

Another aspect addresses the competition on the transfer market hub airports are exposed to. In this thesis only those transfer connections are considered which are offered by a network carrier and its respective alliance partners. Not in the scope of the analysis was the concept of self-hubbing which means that passengers organise their transfer connections by themselves or use online portals that match flights according to available flight schedules. Currently, this does not include single ticketing or baggage through handling. However, with online platforms advancing into more businesses areas, providing this single ticket for passengers and taking over liabilities in case of delays or cancellations might only be a matter of time. Thus, the availability of this type of transfer connections adds another dimension to the competition hub airports face. This development is further fostered by the rise of the long-haul low cost business model such as Eurowings or Norwegian. Integrating these connections into the assessment of competition on the transfer market should therefore be within the scope of future research.

This thesis has considered a particular aspect regarding the degree of competition faced by European hub airports, namely the overlap in destinations and respective seat capacities across airports for the origin-destination market in the local catchment and on the transfer market. This analysis thus provides insight into the structure of the European hub airport market, and gives an indication across considered airports as to the level of market concentration they face, and the resulting implications for competition. This approach and the respective findings in this thesis serve as further guidance to policy makers deciding on the extent of economic regulation feasible for individual hub airports in Europe. From an airport and airline standpoint these results can, of course, also be applied to gain insight as to which airports are their main competitors, and which routes face a high overlap with other airports and airlines, thus designing their network structure accordingly.

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8 Appendix

8.1 Catchment areas of European hub airports

Table 42: Catchment airports of European primary airports

Rank	Airport	1h drive time	2h drive time
1	LHR	LTN, LGW, LCY, STN, SOU	BOH, BHX, GLO, BRS, EMA
2	CDG	ORY, BVA	XCR
3	AMS	RTM	EIN, NRN, ANR, GRQ, MST, BRU, DUS
4	FRA	MHG	HHN, CGN, SXB, SCN, FKB, ZQW, STR, DUS
5	IST	SAW	KCO
6	MAD	TOJ	SLM, RGS
7	BCN	REU	GRO, ILD, PGF
8	LGW	LHR, LCY	STN, LTN, SOU, BOH, BHX
9	MUC	AGB	FMM, NUE, SZG, INN, STR
10	FCO	CIA	n/a
11	SVO	VKO	DME
12	ORY	CDG	BVA, XCR
13	SAW	IST	KCO
14	CPH	MMX	AGH ,KID, HAD
15	DME	VKO	SVO
16	DUB	n/a	BHD, BFS, WAT
17	ZRH	ACH	BSL, BRN, FDH, FMM, STR, SXB
18	PMI	n/a	n/a
19	MAN	LPL, BLK	LBA, EMA, BHX, DSA, HUY, MME, GLO
20	OSL		RYG, TRF
21	ARN	BMA	NYO, NRK, ORB
22	STN	LCY, LTN, LHR	NWI, LGW
23	DUS	CGN, DTM, MST	EIN, FMO, PAD, BRU, ANR, FRA, AMS, RTM
24	VIE	BTS	GRZ, LNZ
25	LIS	n/a	n/a
26	BRU	ANR, CRL	EIN, MST, OST, LIL, RTM, DUS, AMS, LUX, CGN
27	TXL	SXF	LEJ, RLG, DRS, SZZ
28	ATH	n/a	n/a
29	MXP	LIN, BGY	LUG, TRN, VBS, PMF, GOA, VRN
30	AYT	n/a	ISE
31	HEL	HEM	TKU
32	PRG	n/a	KLV, DRS
33	WAW	WMI	LCJ
34	BUD	n/a	n/a
35	LYS	LYN, GNB	GVA, CFE
36	KEF	REK	n/a

Source: own calculation based on Google (2017)

8.2 Mean HHI_{route} for European hub airports

Table 43: Development of mean HHI_{route} for European hub airports over time

Hub airport	2000	2004	2008	2012	2016
DUS	0.44	0.44	0.41	0.40	0.43
BRU	0.57	0.53	0.51	0.48	0.47
LGW	0.70	0.68	0.68	0.63	0.60
AMS	0.69	0.71	0.68	0.66	0.64
MAN	0.72	0.67	0.68	0.63	0.65
STN	0.69	0.73	0.73	0.67	0.66
LHR	0.71	0.74	0.70	0.72	0.67
FRA	0.73	0.72	0.70	0.70	0.69
SVO	0.90	0.78	0.70	0.64	0.69
ZRH	0.81	0.79	0.73	0.71	0.69
SAW	n/a	0.68	0.78	0.74	0.71
LYS	0.66	0.72	0.73	0.75	0.71
MXP	0.85	0.87	0.82	0.76	0.72
ORY	0.80	0.81	0.80	0.80	0.72
DME	0.79	0.78	0.75	0.71	0.74
TXL	0.72	0.72	0.77	0.78	0.77
MUC	0.75	0.78	0.75	0.75	0.79
IST	1.00	0.99	0.95	0.89	0.86
CDG	0.90	0.90	0.89	0.88	0.86
DUB	0.87	0.88	0.86	0.87	0.88
WAW	1.00	1.00	0.97	0.89	0.90
VIE	0.94	0.92	0.91	0.93	0.91
ARN	0.97	0.96	0.93	0.89	0.92
PRG	0.92	0.96	0.94	0.92	0.93
OSL	0.97	0.98	0.94	0.88	0.94
BCN	0.98	0.94	0.92	0.92	0.94
FCO	1.00	0.97	0.97	0.95	0.95
CPH	0.97	0.98	0.97	0.96	0.95
HEL	0.98	0.99	0.99	0.99	0.99
AYT	1.00	1.00	1.00	1.00	1.00
MAD	1.00	1.00	1.00	1.00	1.00
KEF	1.00	1.00	1.00	1.00	1.00
ATH	1.00	1.00	1.00	1.00	1.00
BUD	1.00	1.00	1.00	1.00	1.00
PMI	1.00	1.00	1.00	1.00	1.00
LIS	1.00	1.00	1.00	1.00	1.00

Source: own calculation based on OAG data

8.3 Overview low cost carriers

Table 44: Low cost carriers by year

Year	Low cost carriers
2000	0B, 5D, 5J, 6A, 7R, 8Q, AK, B6, BC, BE, BL, BV, C6, DE, DG, DH, DI, DS, DY, F9, FF, FL, FR, G4, GO, H9, HD, HV, IG, IT, JN, JR, JT, KF, LF, N7, NB, NJ, NK, P9, QZ, RE, SG, SH, SJ, SY, TV, TV, TZ, U2, VA, VQ, WN, WS, XQ, YX, Z2, ZA
2004	0B, 2L, 3J, 3K, 3L, 4P, 4U, 5D, 5J, 5P, 6A, 7G, 7R, 8A, 8I, 8Q, 9C, 9X, AK, B6, BC, BE, BL, BV, C0, C6, DD, DE, DG, DH, DI, DJ, DS, DY, F7, F9, FD, FL, FR, G3, G4, G9, GX, H2, H9, HC, HD, HG, HQ, HV, IG, IT, IV, IX, JN, JQ, JR, JT, KF, KI, KK, LF, LQ, LS, MN, NB, NE, NK, NZ, OX, PA, QG, QZ, RE, SG, SG, SH, SJ, ST, SX, SY, T6, TR, TV, TW, TZ, U2, U5, UO, VA, VE, VF, VQ, VY, W6, WN, WO, WS, WW, X3, XQ, Y2, YX, Z2, Z4, ZB, ZE
2008	0B, 2L, 2P, 3K, 3L, 4O, 4U, 5J, 5K, 5P, 6A, 6E, 7C, 7G, 7H, 8A, 8I, 8J, 8Q, 8Z, 9C, 9X, AD, AK, B6, BC, BE, BL, BV, C0, C4, C6, D7, DD, DE, DG, DJ, DJ, DS, DY, EF, F7, F9, FD, FL, FR, FZ, G3, G4, G8, G9, H2, H9, HC, HD, HG, HV, IG, IT, IV, IX, J9, JE, JN, JQ, JR, JT, KF, KI, KK, LF, LJ, LQ, LS, LZ, MJ, MN, NB, NE, NK, NM, NZ, O8, PA, QA, QG, QS, QZ, RE, SG, SJ, SX, SY, T6, TO, TR, TT, TW, TZ, U2, U5, UO, V5, VA, VB, VF, VX, VY, W6, WG, WH, WN, WO, WS, WU, WW, X3, XG, XQ, XW, XY, Y2, Y4, YV, YX, Z2, Z4, ZB, ZE, ZG, ZS
2012	0B, 2L, 2P, 3K, 3L, 3O, 4O, 4U, 5J, 5K, 5P, 6E, 7C, 7G, 7H, 8J, 8Q, 9C, AD, AK, B6, BC, BE, BL, BV, C6, D7, DD, DE, DG, DJ, DS, DY, E5, EF, F9, FD, FL, FN, FR, FZ, G3, G4, G8, G9, GK, H2, H9, HC, HD, HG, HV, IG, IV, IX, J9, JE, JQ, JT, JW, KF, KK, LJ, LQ, LS, LZ, MJ, MM, MN, NK, NM, NZ, O6, OD, PA, PQ, QG, QS, QZ, RE, RI, SG, SY, T6, TO, TR, TT, TW, U2, U5, UO, V7, VA, VB, VF, VJ, VX, VY, W6, WG, WH, WN, WS, WU, WW, X3, XQ, XY, Y4, YV, Z2, ZB, ZE
2016	0B, 2L, 2P, 3K, 3L, 3O, 4O, 4U, 5J, 5K, 5P, 6E, 7C, 7G, 7H, 8Q, 9C, AD, AK, B6, BC, BE, BL, BV, C6, D7, DD, DE, DG, DJ, DS, DY, E5, EF, F9, FD, FL, FN, FR, FZ, G3, G4, G8, G9, GK, H2, H9, HD, HG, HV, IG, IX, J9, JE, JQ, JT, KF, KK, LJ, LQ, LS, MJ, MM, MN, NK, NZ, O6, OD, PA, PQ, QG, QS, QZ, RE, RI, SG, SY, TO, TR, TT, TW, U2, UO, V7, VA, VB, VF, VJ, VX, VY, W6, WG, WN, WS, WU, WW, X3, XQ, XY, Y4, YV, Z2, ZB, ZE

Source: ICAO (2017)

Table 45: Airline IATA codes and full name (low cost carrier)

Code	Carrier name	Code	Carrier name	Code	Carrier name	Code	Carrier name
E5	Air Arabia Egypt	Z2	Air Asia Zest	BV	Blue Panorama	EF	Easy Fly
JX	Jambojet	5J	Cebu Pacific Air	9X	ItAli Airlines	O6	VivaColumbia
3O	Air Arabia Maroc	2P	PAL Express	IG	Meridiana	JR	AeroCalifornia
8A	Atlas Blue	PQ	Philippines Air Asia	8I	MyAir (MyWay Airlines)	C4	Alma de Mexico
8J	Jet4you	DG	Tigerair Philippines	VA	V Australia	6A	Aviacsa
T6	1time Airline	DJ	Pacific Blue	IV	Wind Jet	V5	Avolar
MN	kulula.com	3K	Jetstar Asia Airways	5D	Dutchbird	4O	Interjet
JE	Mango Airlines	TR	Tiger Airways	HV	Transavia.com	ZE	Eastar Jet
FN	Fastjet	VF	ValuAir	DY	Norwegian Air Shuttle	QA	Mexicana Click
VQ	Impulse Air	ZE	Eastar Jet	4P	Air Polonia	VB	VivaAerobus
JQ	Jetstar	7C	Jeju Air	C0	Centralwings	Y4	Volaris
TT	Tiger Airways Australia	LJ	Jin Air	5K	Hifly	J9	Jazeera Airways
VA	V Australia	TW	T'way Airlines	0B	Blue Air	XY	Flynas
9C	Spring Airlines	MJ	Mihin Lanka	XW	SkyExpress	ZS	Sama
UO	Hong Kong Express Airways	DD	Nok Air	NE	Sky Europe Airlines	G9	Air Arabia
O8	Oasis Hong Kong Airlines	OX	ONE-two-GO	XG	Clickair	FZ	flyDubai
ZG	Viva Macau	FD	Thai AirAsia	V7	Volotea	C6	CanJet Airlines
IX	Air India Express	SL	Thai Lion Air	VY	Vueling	HQ	Harmony Airways
G8	GoAir	BL	Jetstar Pacific Airlines	SH	Aeris	SG	SpiceJet
6E	IndiGo	VJ	VietJet Air	LF	FlyNordic	WG	Sunwing
IT	Kingfisher Red	LZ	Belle Air	DS	Easyjet Switzerland	WS	Westjet Airlines
SG	SpiceJet	3L	InterSky	F7	Flybaboo	3J	ZIP
KI	Adam Air	HG	Niki	2L	Helvetic Aiways	Z4	Zoom Airlines
QG	Citilink	TV	Virgin Express	KK	Atlasjet Airlines	ZA	Access Air
QZ	Indonesia Air Asia	8Z	Wizz Air Bulgaria	7H	Corendon Airlines	FL	Air Tran Airways
JT	Lion Air	QS	SmartWings	8Q	Onur Air	G4	Allegiant Air
RI	Tigerair Mandala	NB	Sterling	H9	Pegasus Airlines	TZ	ATA Airlines
JW	Air Asia Japan	KF	Blue1	XQ	SunExpress	F9	Frontier Airlines
HD	Air Do	SH	Aeris	WU	Wizz Air Ukraine	YV	Go!
GK	Jetstar Japan	TO	Transavia France	WO	Air Southwest	DH	Independance Air
MM	Peach Aviation	DE	Condor Flugdienst	WW	WOW Air	B6	JetBlue Airways
BC	Skymark Airlines	DI	DBA	U2	easyJet	YX	Midwest Airlines
LQ	Solaseed Air	ST	Germania Express	BE	Flybe	N7	National Airlines
7G	StarFlyer	4U	Germanwings	Y2	FlyGlobespan	P9	Pro Air
JW	Air Asia Japan	X3	TUIFly	GO	GO	SX	Skybus Airlines
AK	Air Asia	5P	SkyEurope Hungary	LS	Jet2.com	WN	Southwest Airlines
D7	Air Asia X	W6	Wizz Air	NM	Manx2	NK	Spirit Airlines
OD	Malindo Air	HC	Iceland Express	ZB	Monarch scheduled	SY	Sun Country Airlines
Y5	Golden Myanmar Airlines	WW	WOW Air	JN	XL Airways	FF	Tower Air
SJ	Freedom Air	RE	Aer Arann	AD	Azul Linheas Aereas Brazileiras	U5	USA 3000
DJ	Pacific Blue	VE	Eujet	7R	BRA Transportes Aereos	NJ	Vanguard
NZ	Tasman Express	GX	JetMagic	G3	GOL Linheas Aereas	VX	Virgin America
E4	Aero Asia International	FR	Ryanair	WH	Webjet Linheas Aereas		
PA	Air Blue	TV	Virgin Express	H2	Sky Airline		

Source: IATA (2017)

8.4 Sensitivity analysis of threshold in HHI_{dist} calculation

Table 46: Analysis of different thresholds in regard to HHI_{dist}

Hub airport	HHI_{route}	HHI_{dist} with different thresholds 0.1	0.2	0.3	0.4
AMS	0.74	0.43	0.47	0.50	0.54
ARN	0.94	0.84	0.85	0.86	0.87
AYT	1.00	0.99	1.00	1.00	1.00
BCN	0.94	0.86	0.87	0.88	0.89
BRU	0.70	0.23	0.28	0.33	0.38
CDG	0.90	0.81	0.82	0.83	0.84
CPH	0.96	0.95	0.95	0.95	0.95
DME	0.82	0.57	0.59	0.62	0.65
DUB	0.88	0.88	0.88	0.88	0.88
DUS	0.65	0.16	0.22	0.27	0.33
FCO	0.97	0.93	0.94	0.94	0.94
FRA	0.74	0.57	0.59	0.61	0.63
HEL	0.99	0.98	0.98	0.98	0.98
IST	0.92	0.91	0.91	0.91	0.91
KEF	0.99	0.99	0.99	0.99	0.99
LGW	0.78	0.55	0.58	0.60	0.63
LHR	0.75	0.57	0.59	0.61	0.63
LYS	0.84	0.49	0.53	0.57	0.61
MAD	1.00	1.00	1.00	1.00	1.00
MAN	0.69	0.57	0.58	0.60	0.61
MUC	0.79	0.65	0.66	0.68	0.70
MXP	0.83	0.69	0.71	0.72	0.74
ORY	0.90	0.68	0.71	0.73	0.76
OSL	0.94	0.87	0.87	0.88	0.89
PRG	0.94	0.82	0.83	0.85	0.86
SAW	0.92	0.77	0.79	0.80	0.82
STN	0.82	0.52	0.55	0.58	0.62
SVO	0.82	0.55	0.58	0.61	0.64
TXL	0.81	0.69	0.70	0.71	0.73
VIE	0.92	0.89	0.89	0.89	0.90
WAW	0.95	0.91	0.92	0.92	0.92
ZRH	0.79	0.51	0.54	0.57	0.60
ATH	1.00	1.00	1.00	1.00	1.00
BUD	1.00	1.00	1.00	1.00	1.00
LIS	1.00	1.00	1.00	1.00	1.00
PMI	1.00	1.00	1.00	1.00	1.00

Source: own depiction

8.5 Network carrier at European hub airports

Table 47: European hub airports and respective network carriers

Rank	Airport	2000	2004	2008	2012	2016
1	London Heathrow Airport (LHR)	BA	BA	BA	BA	BA
2	Paris Charles de Gaulle (CDG)	AF	AF	AF	AF	AF
3	Amsterdam Schiphol Airport (AMS)	KL	KL	KL	KL	KL
4	Frankfurt Airport (FRA)	LH	LH	LH	LH	LH
5	Istanbul Atatürk Airport (IST)	TK	TK	TK	TK	TK
6	Madrid Barajas International Airport (MAD)	IB	IB	IB	IB	IB
7	Barcelona Airport – El Prat (BCN)	IB	IB	IB	IB	IB
8	London Gatwick Airport (LGW)	BA	BA	BA	BA	BA
9	Munich Airport (MUC)	LH	LH	LH	LH	LH
10	Rome Fiumicino (FCO)	AZ	AZ	AZ	AZ	AZ
11	Moscow Sheremetyevo International Airport (SVO)	SU	SU	SU	SU	SU
12	Paris Orly Airport (ORY)	AF	AF	AF	AF	AF
13	Istanbul Sabiha Gökcen (SAW)	n/a	n/a	TK	TK	TK
14	Copenhagen Airport (CPH)	SK	SK	SK	SK	SK
15	Moscow Domodedovo Airport (DME)	n/a	S7	S7	S7	S7
16	Dublin Airport (DUB)	EI	EI	EI	EI	EI
17	Zurich Airport (ZRH)	SR	LX	LX	LX	LX
18	Palma de Mallorca Airport (PMI)	IB	AB	AB	AB	AB
19	Manchester Airport (MAN)	BA	BA	BA	BA	BA
20	Oslo Airport (OSL)	SK	SK	SK	SK	SK
21	Stockholm Arlanda Airport (ARN)	SK	SK	SK	SK	SK
22	London Stansted Airport (STN)	FR	FR	FR	FR	FR
23	Düsseldorf Airport (DUS)	LH	LH	LH	LH	LH
24	Vienna International Airport (VIE)	OS	OS	OS	OS	OS
25	Lisbon Airport (LIS)	TP	TP	TP	TP	TP
26	Brussels Airport (BRU)	SN	SN	SN	SN	SN
27	Berlin Tegel Airport (TXL)	LH	LH	AB	AB	AB
28	Athens International Airport (ATH)	OA	OA	OA	OA	OA
29	Milan Malpensa Airport (MXP)	AZ	AZ	AZ	AZ	AZ
30	Antalya Airport (AYT)	TK	TK	TK	TK	TK
31	Helsinki (HEL)	AY	AY	AY	AY	AY
32	Vaclav Havel Airport Prague (PRG)	OK	OK	OK	OK	OK
33	Warsaw (WAW)	LO	LO	LO	LO	LO
34	Budapest (BUD)	MA	MA	MA	MA	n/a
35	Lyons Airport (LYS)	AF	AF	AF	AF	AF
36	Keflavik (KEF)	FI	FI	FI	FI	FI

Source: own depiction

Table 48: Network carrier share (in total seats) at European hub airports

Rank	Airport	2000	2004	2008	2012	2016
1	London Heathrow Airport (LHR)	42%	41%	39%	46%	48%
2	Paris Charles de Gaulle (CDG)	55%	57%	56%	55%	51%
3	Amsterdam Schiphol Airport (AMS)	43%	49%	50%	51%	48%
4	Frankfurt Airport (FRA)	60%	59%	60%	63%	65%
5	Istanbul Atatürk Airport (IST)	66%	71%	73%	74%	76%
6	Madrid Barajas International Airport (MAD)	55%	56%	48%	47%	44%
7	Barcelona Airport – El Prat (BCN)	52%	47%	15%	0.1%	0.1%
8	London Gatwick Airport (LGW)	59%	40%	26%	17%	15%
9	Munich Airport (MUC)	51%	56%	57%	62%	55%
10	Rome Fiumicino (FCO)	52%	44%	40%	45%	41%
11	Moscow Sheremetyevo International Airport (SVO)	47%	57%	63%	74%	90%
12	Paris Orly Airport (ORY)	50%	57%	50%	41%	35%
13	Istanbul Sabiha Gökcen (SAW)	n/a	n/a	47%	14%	31%
14	Copenhagen Airport (CPH)	60%	55%	49%	43%	39%
15	Moscow Domodedovo Airport (DME)	n/a	24%	25%	28%	41%
16	Dublin Airport (DUB)	48%	37%	36%	45%	36%
17	Zurich Airport (ZRH)	60%	51%	56%	54%	52%
18	Palma de Mallorca Airport (PMI)	0.1%	24%	34%	30%	19%
19	Manchester Airport (MAN)	38%	26%	0.1%	0.1%	0.1%
20	Oslo Airport (OSL)	48%	40%	51%	42%	41%
21	Stockholm Arlanda Airport (ARN)	57%	51%	42%	42%	42%
22	London Stansted Airport (STN)	n/a	n/a	n/a	n/a	n/a
23	Düsseldorf Airport (DUS)	34%	31%	31%	35%	0.1%
24	Vienna International Airport (VIE)	41%	54%	49%	49%	46%
25	Lisbon Airport (LIS)	48%	54%	60%	62%	52%
26	Brussels Airport (BRU)	55%	27%	34%	36%	36%
27	Berlin Tegel Airport (TXL)	48%	37%	37%	45%	45%
28	Athens International Airport (ATH)	48%	40%	36%	23%	13%
29	Milan Malpensa Airport (MXP)	57%	55%	28%	0.1%	0.1%
30	Antalya Airport (AYT)	30%	18%	29%	20%	20%
31	Helsinki (HEL)	73%	67%	59%	60%	67%
32	Vaclav Havel Airport Prague (PRG)	54%	52%	47%	32%	19%
33	Warsaw (WAW)	60%	58%	45%	58%	49%
34	Budapest (BUD)	53%	49%	43%	n/a	n/a
35	Lyons Airport (LYS)	56%	62%	57%	40%	0.1%
36	Keflavik (KEF)	97%	82%	75%	75%	59%

Source: own calculation based on OAG data

8.6 Common ownership within the catchment

Table 49: Common ownership of airports within a catchment

Hub airport	Periods of common ownership with airports in the catchment (2000, 2004, 2008, 2012, 2016)
LHR	LGW (2000-2008); STN (2000-2012), SOU (2000-2016)
CDG	ORY (2000-2016); BVA (2000-2004)
AMS	RTM (2000-2016); EIN (2000-2016); MST (2000)
FRA	HHN (2000-2016); SCN (2000-2004)
MAD	TOJ (2000-2016); SLM (2000-2016); RGS (2000-2016)
BCN	REU (2000-2016); GRO (2000-2016)
LGW	LHR (2000-2008); LCY (2012); STN (2000-2008), SOU (2000-2012)
MUC	NUE (2000-2016)
FCO	CIA (2000-2016)
SVO	VKO (2000-2016)
ORY	CDG (2000-2016)
SAW	KCO (2004)
MAN	EMA (2004-2016); HUY (2000-2008)
ARN	BMA (2000-2016)
STN	LHR (2000-2012); LGW (2000-2008)
TXL	SXF (2000-2016)
MXP	LIN (2000-2016); BGY (2000-2016)
AYT	ISE (2000-2016)
HEL	TKU (2000-2016); HEM (2000-2016)
KEF	REK (2000-2016); RKV (2000-2016)

Sources: (Airports Council International Europe, 2016c, 2010; Royal Schiphol Group, n.d.; Flughafen Bern AG, n.d.; Groupe ADP, n.d.; Copenhagen Airports AS, n.d.; Fraport, n.d.; TAV Airports, n.d.; Heathrow Airport Limited, n.d.; Vienna International Airport, n.d.; Schiphol Group, 2012; LFV, n.d.; Manchester Airports Group, n.d.; ifm investors, n.d.) (BBC News, 2008, 2012, Aena, 2016, n.d.; Handelsblatt, 2015; Aeroporti di Roma, n.d.; British Airport Authority (BAA), 2006; Athens International Airport, n.d.; TAV Airports, n.d.; Flughafen Berlin Brandenbrug, n.d.; General Directorate of State Airports Authority, n.d.; Ferrovial, n.d.; Gatwick Airport, n.d.; Orio al Serio International Airport, 2017; Paris Aéroport, n.d.) (RP Online, 2014; Istanbul Sabiha Gokcen International Airport, 2017; SEA, n.d., n.d., n.d.; Klingelschmitt, 2009; Aéroport Paris-Beauvais, n.d.; Brussels Airport, n.d.; Finavia, n.d.; Airport Saarbrücken, n.d.; Zurich Airport, n.d.) (Isavia, n.d.)

8.7 Airline countervailing power

Table 50: Countervailing Power Index

hub	2000	2004	2008	2012	2016
AMS	0.08	0.08	0.08	0.08	0.08
ARN	0.11	0.12	0.12	0.11	0.11
ATH	0.08	0.08	0.07	0.06	0.03
AYT	0.19	0.10	0.17	0.12	0.18
BCN	0.12	0.12	0.08	0.04	0.03
BRU	0.07	0.04	0.05	0.06	0.06
BUD	0.06	0.06	0.06	0.01	n/a
CDG	0.10	0.11	0.11	0.11	0.10
CPH	0.12	0.12	0.12	0.11	0.10
DME	n/a	0.10	0.08	0.09	0.10
DUB	0.07	0.06	0.05	0.06	0.05
DUS	0.11	0.09	0.07	0.08	0.02
FCO	0.12	0.10	0.09	0.09	0.08
FRA	0.12	0.12	0.12	0.13	0.12
HEL	0.09	0.09	0.08	0.08	0.08
IST	0.10	0.10	0.10	0.11	0.12
KEF	0.13	0.10	0.09	0.09	0.09
LGW	0.16	0.16	0.14	0.13	0.12
LHR	0.10	0.09	0.09	0.09	0.09
LIS	0.08	0.08	0.09	0.09	0.08
LYS	0.14	0.14	0.15	0.12	0.05
MAD	0.11	0.11	0.09	0.08	0.07
MAN	0.12	0.11	0.05	0.04	0.02
MUC	0.14	0.14	0.12	0.13	0.12
MXP	0.12	0.11	0.09	0.03	0.03
ORY	0.14	0.15	0.15	0.15	0.15
OSL	0.13	0.13	0.13	0.13	0.13
PMI	0.12	0.10	0.13	0.10	0.08
PRG	0.07	0.07	0.07	0.05	0.04
SAW	n/a	0.14	0.20	0.20	0.19
STN	0.11	0.08	0.16	0.18	0.18
SVO	0.08	0.10	0.08	0.09	0.12
TXL	0.13	0.07	0.08	0.08	0.09
VIE	0.06	0.07	0.07	0.07	0.07
WAW	0.07	0.08	0.07	0.07	0.07
ZRH	n/a	n/a	0.08	0.08	0.08

Source: own depiction

8.8 Airline alliance members

Table 51: Airline alliances member airlines

Year	Star Alliance
2000	AC, NZ, NH, OS, LH, SK, SQ, TG, UA, RG, AN, VO, NG, BM, MX, JK, AA, BA, CX, AY, IB, LA/JJ, QF, EI, CP, MA, AM
2004	JP, AC, NZ, NH, OZ, OS, OU, LO, LH, SK, SQ, TG, UA, RG, VO, NG, BM, JK, US, KF
2008	JP, AC, NZ, NH, OZ, OS, OU, MS, LO, LH, SK, SQ, SA, LX, TP, TG, TK, UA, VO, NG, BM, JK, US, KF
2012	JP, A3, AC, CA, NZ, NH, OZ, OS, AV, SN, CM, OU, MS, ET, LO, LH, SK, ZH, SQ, SA, LX, TP, TG, TK, UA, VO, NG, BM, JK, US, KF, FM, CO, JJ, TA
2016	JP, A3, AC, CA, AI, NZ, NH, OZ, OS, AV, SN, CM, OU, MS, ET, BR, LO, LH, SK, ZH, SQ, SA, LX,TP, TG, TK , UA
Year	**One World**
2000	AA, BA, CX, AY, IB, LA/JJ, QF, EI, CP, MA
2004	AA, BA, CX, AY, IB, LA/JJ, QF, EI, MA
2008	AA, BA, CX, AY, IB, LA/JJ, QF, EI, MA
2012	AB, AA, BA, CX, AY, IB, JL, LA/JJ, QF, RJ, S7, MA
2016	NG, BM, AB, AA, BA, CX, AY, IB, JL, LA/JJ, QR, MH, QF, UL, RJ, S7, MA
Year	**Sky Team**
2000	AM, AF, DL, KE
2004	AM, AF, AZ, OK, DL, KL, KE
2008	SU, AM, UX, AF, AZ, CZ, OK, DL, KQ, KL, KE
2012	SU, AR, AM, UX, AF, AZ, CI, MU, CZ, OK, DL, KQ, KL, KE, ME, SV, RO, VN, MF
2016	SU, AR, AM, UX, AF, AZ, CI, MU, CZ, OK, DL , GA, KQ, KL, KE, ME, SV, RO, VN, MF

Source: Star Alliance, n.d.; SkyTeam, n.d.; oneworld, n.d.

Table 52: Airline IATA codes and full name (alliance airlines)

Code	Carrier name	Code	Carrier name
A3	aegean	MA	Malév
AA	American Airlines	ME	MEA
AB	airberlin	MF	XiamenAir
AC	Air Canada	MH	Malaysia Airlines
AF	AirFrance	MS	EgyptAir
AI	Air India	MU	China Eastern
AM	AeroMExico	MX	Mexicana Airlines
AN	Ansett Australia	MX	Mexicana de Aviacion
AR	AerolineasArgentinas	NG	Lauda Air
AV	Avianca	NH	ANA
AY	Finnair	NZ	Air New Zealnd
AZ	Alitalia	OK	Czech Airlines
BA	British Airways	OS	Austrian
BM	BMI	OU	Croatia Airlines
BR	Eva Air	OZ	Asiana Airlines
CA	Air China	QF	Qantas
CI	China Airlines	QR	Qatar Airways
CM	Copa Airlines	RG	VARIG
CO	Continental	RJ	Royal Jordanien
CP	Canadian Airlines	RO	Tarom
CX	Cathay Pacific	S7	S7 Airlines
CZ	China Southern	SA	South African Airlines
DL	Delta	SK	Scandinavian Airlines
EI	Aer Lingus	SN	Brussels Airlines
ET	Ethiopian	SQ	Singapore Airlines
FM	Shanghai Airlines	SU	Aeroflot
GA	Garuda Indonesia	SV	Saudia
IB	Iberia	TA	TACA Airlines
JJ	TAM Airlines	TG	Thai
JK	Spanair	TK	Turkish Airlines
JL	Japan Airlines	TP	TAP Portugal
JP	Adria	UA	United
KE	Korean Air	UL	SriLankan Airlines
KF	Blue1	US	US Airways
KL	KLM	US	US Airways
KQ	Kenya Airways	UX	AirEuropa
LA/JJ	LATAM	VN	Vietnam Airlines
LH	Lufthansa	VO	Tyrolean Airways
LO	LOT Polish Airlines	ZH	Shenzhen Airlines
LX	Swiss		
A3	aegean		
AA	American Airlines		
AB	airberlin		
AC	Air Canada		

Source: IATA (2017)

8.9 Overview OAG regions

Table 53: Regional differentiation according to OAG

Region	Countries
AF1	Algeria, Egypt, Libya, Morocco, Sudan, Tunisia
AF2	Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe
AF3	Benin, Burkina Faso, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Congo Democratic Republic of, Cote D'Ivoire, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Mayotte, Niger, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, Togo
AF4	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Reunion, Rwanda, Seychelles, Somalia, South Sudan, Tanzania United Republic of, Uganda
AS1	Afghanistan, Bangladesh, India, Maldives, Nepal, Pakistan, Sri Lanka
AS2	Bhutan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
AS3	Brunei Darussalam, Cambodia, Cocos (keeling) Islands, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-leste, Viet Nam
AS4	China, Chinese Taipei, Hong Kong (sar) China, Japan, Korea Democratic People's Republic of, Korea Republic of, Macao (sar) China, Mongolia, Russian Federation
LA1	Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Bermuda, Bonaire, Cayman Islands, Cuba, Curacao, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, Saint Barthelemy, Saint Kitts and Nevis, Saint Lucia, Saint Martin, St Maarten (dutch Part), St Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands, Virgin Islands (British and US)
LA2	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
LA3	Bolivia, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela
LA4	Argentina, Brazil, Chile, Falkland Islands, Paraguay, Uruguay
ME1	Bahrain, Iran Islamic Republic of, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen
NA1	Canada, Greenland, Saint Pierre and Miquelon, USA
EU1	Austria, Belgium, Cyprus, Denmark, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Iceland, Ireland Republic of, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom
EU2	Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Macedonia Former Yugoslav Republic of, Moldova Republic of, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Ukraine
SW1	American Samoa, Australia, Christmas Island, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Micronesia Federated States of, Nauru, New Caledonia, New Zealand, Niue, Norfolk Island, Northern Mariana Islands (except Guam), Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Wallis and Futuna Islands

Source: OAG database

8.10 Number of transfer connections at European hub airports

Table 54: Number of and change in transfer connections at European hub airports

Hub airport	2000	2004	2008	2012	2016	Change in transfer connections 2000-2004	2004-2008	2008-2012	2012-2016	2000-2016
MXP	1238	1087	98	14	9	-12%	-91%	-86%	-36%	-99%
BCN	208	194	72	34	4	-7%	-63%	-53%	-88%	-98%
MAN	45	64	4	5	3	42%	-94%	25%	-40%	-93%
ATH	408	283	267	56	30	-31%	-6%	-79%	-46%	-93%
LGW	1619	398	239	169	157	-75%	-40%	-29%	-7%	-90%
DUS	37	44	223	238	13	19%	407%	7%	-95%	-65%
PRG	139	390	336	134	69	181%	-14%	-60%	-49%	-50%
ZRH	1410	461	768	722	714	-67%	67%	-6%	-1%	-49%
ORY	154	136	137	80	82	-12%	1%	-42%	2%	-47%
BRU	912	137	171	515	662	-85%	25%	201%	29%	-27%
CPH	454	352	384	352	424	-22%	9%	-8%	20%	-7%
VIE	813	1020	1485	850	772	25%	46%	-43%	-9%	-5%
CDG	3434	4996	5838	5460	5646	45%	17%	-6%	3%	64%
AMS	2255	3150	3145	3956	4029	40%	0%	26%	2%	79%
FRA	3118	3395	4899	4919	5623	9%	44%	0%	14%	80%
ARN	112	152	171	159	231	36%	13%	-7%	45%	106%
SVO	1207	1154	1412	1504	2506	-4%	22%	7%	67%	108%
WAW	70	191	97	137	146	173%	-49%	41%	7%	109%
LHR	1597	2336	1993	2952	3464	46%	-15%	48%	17%	117%
MAD	710	938	1583	1145	1705	32%	69%	-28%	49%	140%
OSL	28	15	70	57	77	-46%	367%	-19%	35%	175%
DUB	76	86	124	169	278	13%	44%	36%	64%	266%
KEF	66	51	88	215	270	-23%	73%	144%	26%	309%
MUC	473	1116	1470	1915	1979	136%	32%	30%	3%	318%
HEL	201	250	560	462	1007	24%	124%	-18%	118%	401%
IST	1120	1044	2627	4608	7250	-7%	152%	75%	57%	547%
LIS	117	176	558	659	781	50%	217%	18%	19%	568%
TXL	7	0	29	158	113	-100%	n/a	445%	-28%	1514%
DME	0	282	610	656	937	n/a	116%	8%	43%	n/a
FCO	0	442	874	912	946	n/a	98%	4%	4%	n/a
PMI	0	12	85	37	15	n/a	608%	-56%	-59%	n/a
SAW	0	0	0	0	323	n/a	n/a	n/a	n/a	n/a
AYT	0	0	2	0	0	n/a	n/a	-100%	n/a	n/a
BUD	97	176	148	0	0	81%	-16%	-100%	n/a	-100%
LYS	129	93	125	46	0	-28%	34%	-63%	-100%	-100%

Source: own depiction

8.11 Regional shares on the transfer market

Table 55: Regional shares of transfer markets at European hub airports

Hub airport	AF 2000	AF 2016	AS 2000	AS 2016	LA 2000	LA 2016	EU 2000	EU 2016	NA 2000	NA 2016	ME 2000	ME 2016
AMS	15%	13%	15%	13%	12%	11%	24%	33%	23%	24%	12%	6%
ARN	-	-	2%	13%	-	-	88%	72%	9%	14%	-	-
ATH	15%	-	3%	-	-	-	53%	100%	9%	-	20%	-
BCN	4%	-	-	-	-	-	85%	26%	8%	60%	3%	14%
BRU	22%	24%	4%	4%	-	-	46%	45%	27%	23%	1%	5%
BUD	2%	-	10%	-	-	-	61%	-	13%	-	14%	-
CDG	20%	24%	12%	14%	12%	11%	29%	24%	21%	21%	5%	6%
CPH	-	1%	16%	17%	-	-	70%	59%	13%	22%	1%	-
DME	-	-	-	53%	-	-	-	43%	-	-	-	4%
DUB	-	-	-	-	-	-	73%	37%	27%	63%	-	-
DUS	-	-	-	14%	-	-	61%	48%	39%	38%	-	-
FCO	-	7%	-	10%	-	13%	-	46%	-	14%	-	11%
FRA	8%	9%	16%	18%	6%	5%	36%	33%	25%	25%	8%	9%
HEL	-	-	9%	36%	-	-	86%	59%	5%	5%	-	0%
IST	6%	15%	12%	28%	-	0%	61%	32%	6%	8%	16%	17%
KEF	-	-	-	-	-	-	38%	52%	62%	48%	-	-
LGW	18%	7%	2%	13%	15%	44%	33%	23%	27%	13%	4%	-
LHR	9%	10%	19%	15%	1%	6%	31%	28%	27%	29%	14%	11%
LIS	15%	23%	-	-	24%	25%	42%	39%	19%	13%	-	-
LYS	2%	-	-	-	-	-	88%	-	10%	-	-	-
MAD	5%	9%	-	2%	29%	34%	52%	38%	14%	14%	-	3%
MAN	-	-	-	-	-	-	64%	9%	36%	27%	-	64%
MUC	0%	3%	3%	16%	2%	3%	72%	53%	22%	23%	1%	2%
MXP	13%	-	8%	14%	4%	-	49%	57%	20%	6%	6%	23%
ORY	13%	20%	-	-	13%	24%	74%	45%	-	11%	-	-
OSL	-	-	-	8%	-	-	78%	80%	22%	12%	-	-
PMI	-	-	-	-	-	-	-	100%	-	-	-	-
PRG	5%	-	-	31%	-	-	51%	48%	21%	16%	24%	5%
SAW	-	-	-	-	-	-	-	74%	-	-	-	26%
SVO	2%	-	42%	52%	1%	2%	44%	39%	7%	4%	5%	3%
TXL	-	1%	-	-	-	-	100%	60%	-	10%	-	29%
VIE	4%	4%	11%	10%	-	-	48%	56%	23%	24%	15%	6%
WAW	-	-	-	9%	-	-	71%	61%	25%	25%	4%	5%
ZRH	13%	9%	13%	20%	4%	3%	30%	36%	30%	31%	10%	3%

Source: own calculation based on OAG data