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Estimating the effects of competition in the hinterland of European primary airports

Annika Paul[1] and Benny Mantin[2]

Abstract

Past developments such as the amplified presence of low cost carriers in Europe and the accompanying growth of airports in the hinterland have spurred the discussion whether competitive constraints for primary airports are sufficient to render economic regulation obsolete. There is consensus that a detailed analysis is required for each airport. The level of competition faced by European airports has hence been evaluated, for example, by analysing airline countervailing power, the number of accessible airports for passengers within a distinct catchment area and, in particular, the overlap in transfer connections. This paper focuses on competition for primary airports in their local market by empirically testing for the effects of market concentration on the density of routes at these airports. The estimation of a fixed-effect model, accounting for route-specific and time-specific effects, yields insight into the reaction of primary airports. The number of seats and frequencies offered per route decreases with increasing market concentration, implying the restriction of output due to market power. Furthermore, the results also show that the presence of low cost carriers in the primary airports' catchments leads to a higher route density suggesting that primary airports are opening up to these particular carriers and thus meeting the overall growth of this market segment.

1.1 Introduction

Since airports have traditionally been considered as natural monopolies due to their cost structure and locational specifics, economic regulation has been established to keep these airports from abusing their market power. However, with the deregulation of the European airline market and the increasing presence of multiple (low cost) airlines, additional airports have been emerging and providing a range of destinations to European passengers (Müller-Rostin *et al.*, 2010). These developments have been fostering the discussion on the increasing competitive constraints faced by European airports. Competition authorities have established frameworks to assess the level of competition for individual airports (e.g. Competition Commission, 2009; Civil Aviation Authority, 2016) and to implement tailored economic regulation accordingly. A range of studies has been assessing the different areas in which an airport might face competition such as the potential of airlines to switch their operations between airports and the associated costs (Thelle *et al.*, 2012; Maertens, 2012; Polk and Bilotkach, 2013; Müller *et al.*, 2010). Another aspect concerns the substitution potential passengers face and which factors determine their choice in selecting a particular airport, both for point-to-point and transfer flights (e.g. Starkie, 2008; Redondi, Malighetti and Paleari, 2011; Wiltshire, 2013; Burghouwt and Redondi, 2013; Malina, 2010; Mandel, 1998). An important aspect 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 primary airports (Thelle *et al.*, 2012; Dobruszkes, 2013; Burghouwt, Mendes de Leon and De Wit, 2015). Furthermore, welfare implications of increased competition have been assessed by Allroggen

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and Malina (2010), Lin (2006), or Brueckner and 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.

For this purpose, the 30 largest European primary airports and those within the respective hinterland (catchment areas) are considered (Section 1.2 and Section 1.3). Based on this, the development of both primary and secondary airports is analysed in terms of low cost carrier growth and its distribution across airports (Section 1.4). The analysis of traffic development at the airports shows an even distribution of low cost carrier growth. To see whether an overlap in routes between secondary and primary airports has an effect on the output at the primary airports, the level of route-specific market concentration is estimated. As a measure for this, the distance-weighted Herfindahl Hirschman Index is introduced highlighting the level of competitive constraints each of the considered primary airports has been facing in the period from 2000 to 2016. The Herfindahl Hirschman Index is applied as one measure to determine the concentration of an industry (Carlton and Perloff, 2005; Davis and Garcés, 2010) and has been used in the airport industry context as well (see Section 1.5 for more detail). To determine the effect of the level of market concentration on the network structure at the primary airport as well as on the density of each route in terms of seats offered, four different fixed-effect panel regression models are estimated. Within these models, it is controlled for a route-specific effect representing a particular market or airport pair and for a time-specific effect covering the period from 2000 to 2016 in four-year intervals. The distance-weighted Herfindahl Hirschman Index is applied as explanatory variable as is a variable accounting for growth effects of low cost carriers (Section 0 and Section 1.7). Section 1.8 discusses the findings and concludes the paper.

1.2 Airport data set and traffic development

For the purpose of obtaining a detailed overview of the development of the European airport market a set of 30 primary airports and their respective secondary airports in the catchment are defined. Those primary airports are selected which had the highest passenger numbers in 2016 (Airports Council International Europe, 2016) (see Table 1). The ranking of airports in terms of passenger numbers has changed over the considered period from 2000 to 2016 with Istanbul Atatürk Airport, for example, having a steep increase in passenger numbers from 14.7 million in 2000 to 60 million in 2016. Another main source of data is the OAG database which provides scheduled airline traffic. 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, data on ticket prices or airline revenues. Due to data availability a period of 16 years, from 2000 to 2016 in intervals of four years is considered. Further data sources employed within the next sections include urbanisation and population statistics taken from the United Nations database (United Nations / Department of Economic and Social Affairs, 2014) as well as data on the gross domestic product of different countries (The World Bank, 2017).

Table 1: Passenger volume at European primary airports[3]

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

1.3 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 (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 or routes offered. Catchment areas vary by travel purpose and distance of destination from the origin airport. Dobruszkes, Lennert and 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. Mandel (2014)

[3] Sources: Airports Council International Europe (2016); (Groupe ADP, 2017); (Ataturk Airport, 2017); (ISG, 2017); (Copenhagen Airports AS, 2000); (Zurich Airport, 2000); (Unique (Flughafen Zürich AG), 2004); (Eurostat, 2016)

emphasizes that for each passenger segment and trip purpose as well as route a unique catchment area exists which has to be taken into consideration. Staub (2014) analyses a range of criteria influencing airport and airline choice for selected airports area in Germany. The results confirm that catchment areas deviate from two-hour driving isochrones. Lieshout (2012) further shows that the size of the catchment area and hence the potential competition differs across destinations. The model is tested for Amsterdam Schiphol Airport and reveals that especially long-haul connections have a large catchment area and a different potentially competitive airport set than many short-haul connections.

Table 2: Catchment airports of European primary airports[4]

Airport	1h drive time	2h drive time
LHR	LTN, LGW, LCY, STN, SOU	BOH, BHX, GLO, BRS, EMA
CDG	ORY, BVA	XCR
AMS	RTM	EIN, NRN, ANR, GRQ, MST, BRU, DUS
FRA	MHG	HHN, CGN, SXB, SCN, FKB, ZQW, STR, DUS
IST	SAW	KCO
MAD	TOJ	SLM, RGS
BCN	REU	GRO, ILD, PGF
LGW	LHR, LCY	STN, LTN, SOU, BOH, BHX
MUC	AGB	FMM, NUE, SZG, INN, STR
FCO	CIA	
SVO	VKO	DME
ORY	CDG	BVA, XCR
SAW	IST	KCO
CPH	MMX	AGH ,KID, HAD
DME	VKO	SVO
DUB		BHD, BFS, WAT
ZRH	ACH	BSL, BRN, FDH, FMM, STR, SXB
MAN	LPL BLK	LBA, EMA, BHX, DAS, HUY, MME, GLO
OSL		RYG, TRF
ARN	BMA	NYO, NRK, ORB
STN	LCY, LTN	NWI, LHR, LGW
DUS	CGN, DTM, MST	EIN, FMO, PAD, BRU, ANR, FRA, AMS, RTM
VIE	BTS	GRZ, LNZ
BRU	ANR, CRL	EIN, MST, OST, LIL, RTM, DUS, AMS, LUX, CGN
TXL	SXF	LEJ, RLG, DRS, SZZ
MXP	LIN, BGY	LUG, TRN, VBS, PMF, GOA, VRN
AYT		ISE

Since no comprehensive data on all the primary airports in regard to the socio-economic characteristics of the passengers in the catchment is available, catchment areas are determined using both a one-hour and two-hour driving radius for each of the airports in Table 1. 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. This intermodal competition is not considered here, though, due to lack of comprehensive data for all airports.

[4] Not included in the analysis of catchment areas: PMI / LIS / ATH due to no other airports within 2h catchment

Table 2 outlines the number of airports within a one-hour and two-hour driving radius for each of the selected European primary airports. Those airports within the local catchment of an airport have been selected that have scheduled passenger traffic according to the OAG database. These secondary airports are therefore considered as potential substitutes for the traffic offered at the primary airports.

1.4 Primary vs. secondary airport development in Europe

This section provides an insight into the traffic development at both primary airports and their respective secondary airports, especially considering the growth of low cost traffic and its distribution across the different airport types. Table 3 outlines the number of seats and frequencies in 2000 and 2016 for both incumbent and low cost carriers[5]. The absolute number of seats and frequencies offered by incumbent carriers (INC) 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). INC have also increased their seats within that period by 28 per cent; frequencies, however, have declined by 2 per cent, rationed by the use of larger aircraft with an average of 124 seats per flight in 2000 to 162 seats per flight in 2016.

Table 3: Change in seats and frequencies offered by LCC and INC (2000 and 2016)

	LCC 2000	LCC 2016	Change LCC	INC 2000	INC 2016	Change INC
Seats p.a. (in million)	28.54	210.62	638%	454.1	580.53	28%
Frequency p.a. (in thousands)	199	1237	522%	3671	3593	-2%
Average seats per flight	143	170	19%	124	162	31%

In terms of the distribution of traffic across primary and secondary airports, offered seats and frequencies by both incumbent and low cost carriers are higher at the primary airports, denoted by *LCC_prim* and *INC_prim* in Figure 1 and Figure 2, all variables have been logged. These figures also show that low cost carriers have been experiencing stronger growth between the years 2000 and 2016 (*LCC_prim, LCC_sec*), both in terms of seats and frequencies.

[5] An overview of low cost carriers within each region and year can be found in the Appendix, incumbent carriers are the remaining airlines.

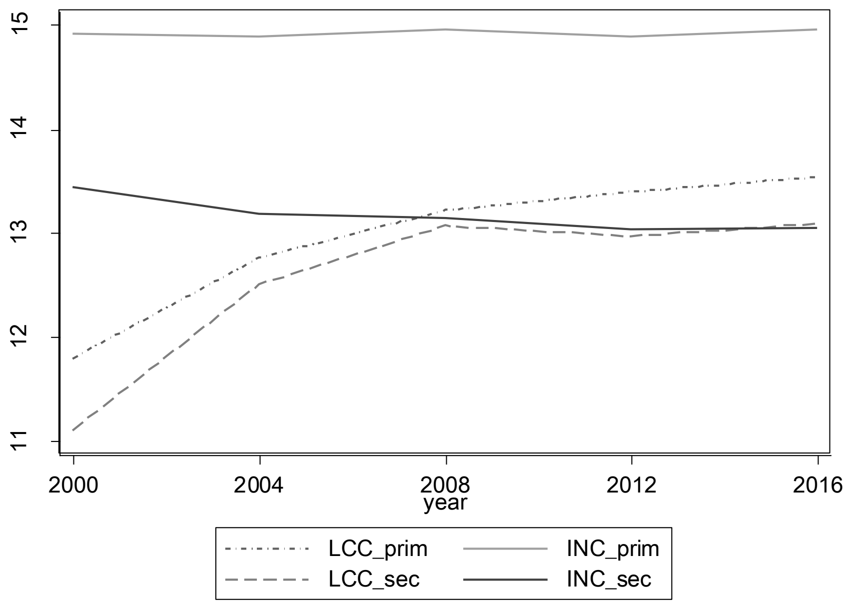


Figure 1: Distribution of frequencies across primary and secondary airports

The number of seats offered by low cost carriers has been growing from less than 20 million in 2000 to more than 130 million in 2016 at the primary airports and from less than 10 million in 2000 to almost 80 million in 2016 at the secondary airports (Table 4). The same holds for offered frequencies with an increase of 472 per cent and 621 per cent, at primary and at secondary airports respectively.

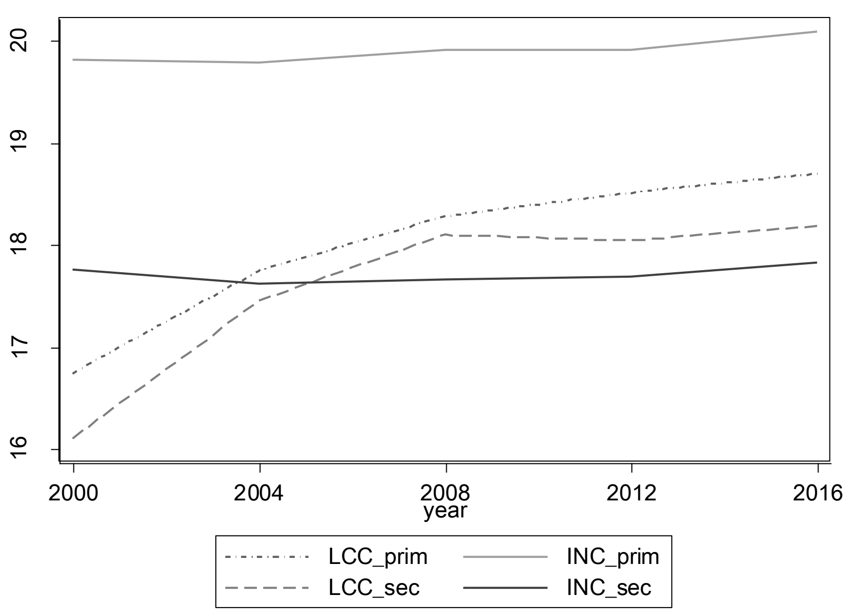


Figure 2: Distribution of seats across primary and secondary airports

However, Figure 1 and Figure 2 also show that low cost carrier traffic at secondary airports experienced a slight drop in seats and frequencies after 2008. At primary airports, a slowdown rather than a drop in growth can be observed in this period. This might imply that low cost carriers at secondary airports (*LCC_sec*) have been affected more severely by the financial crisis in 2008/2009 than those at primary airports (*LCC_prim*). Or that in a time of economic downturn, low cost carriers have been focusing their operations more strongly on primary airports due to sufficient demand at these nodes. Furthermore, incumbent carrier traffic has been growing at a much lower (or even declining) rate than low cost carrier traffic, with seats offered at primary airports increasing by 30 per cent and at secondary airports by only seven per cent. Incumbent carriers have even been cutting the total frequencies offered at secondary airports by 32 per cent from 2000 to 2016, however the average number of seats per flight increased from 75 to 118 which compensates for the reduction in frequencies and hence still leads to an increase in total seats over time.

Table 4: Change in offered seats and frequencies by airport type (2000, 2016)

	Airline type	Primary 2000	Primary 2016	Change primary	Secondary 2000	Secondary 2016	Change secondary
Seats p.a. (in million)	INC	403.00	525.86	30%	51.09	54.67	7%
	LCC	18.66	131.85	607%	9.90	78.77	696%
Frequency p.a. (in thousands)	INC	2990	3131	5%	680	462	-32%
	LCC	132	755	472%	67	483	621%
Average seats per flight	INC	135	168	24%	75	118	57%
	LCC	141	175	24%	148	163	10%

This initial overview shows that both primary and secondary airports in Europe have been experiencing growth in terms of total offered seats and frequencies between the period of 2000 and 2016. Furthermore, low cost carrier traffic growth has not been concentrated at secondary airports but has been spread across the different types of airports. In terms of competition, primary 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 primary airports, the following section analyses the level of market concentration primary airports face.

1.5 Measuring aggregated market concentration

Bel and Fageda (2009), Papatheodorou (2010) and Rodrigues Pacheco, Estrada Braga and Fernandes (2015) all apply the Herfindahl Hirschman Index (HHI) in the airport context. Bel and Fageda (2009) use the HHI, inter alia, in their analysis of the concentration of intercontinental flights departing from European airports over time. It shows decreasing concentration levels across the considered airport data set due to an increasing importance of point-to-point intercontinental traffic offered at other airports than the incumbent hub airports. The authors emphasize that American or Asian network carriers increasingly use European airports for feeder flights to their hub airports and that this development fosters a slight decrease in the importance of European hubs. Papatheodorou (2010) applies the HHI to evaluate airport competition in Greece. The results show that especially the mainland airports reveal a high level of concentration, both for domestic and international traffic. Correlating the traffic levels with gross domestic product and population yields a strong relationship for the main urban centres of Athens and Thessaloniki. Rodrigues Pacheco, Estrada Braga and Fernandes (2015) investigate the concentration of international traffic across Brazilian airports. They find that a decline in the concentration of supplied seats in the considered period from 1999 to 2012 results from an increased presence of foreign airlines offering additional flights to the different regions. Borenstein (1992) analyses the impact of deregulation on the U.S. airline market network structure by applying the HHI for different distance segments. Lijesen, Nijkamp and Rietveld (2002) apply different indicators, also including the HHI, to determine the level of competition in civil aviation, highlighting that the inclusion of multiple indicators can yield a more comprehensive understanding of the factors influencing competition.

Table 5: HHI_c for European primary airports[6]

Airport	2000	2004	2008	2012	2016
DUS	0.25	0.26	0.24	0.25	0.24
LHR	0.38	0.31	0.26	0.29	0.25
BRU	0.29	0.28	0.27	0.25	0.25
MXP	0.41	0.31	0.28	0.26	0.26
LGW	0.40	0.34	0.29	0.32	0.28
MAN	0.34	0.29	0.25	0.29	0.31
STN	0.45	0.39	0.34	0.37	0.33
AMS	0.35	0.37	0.35	0.34	0.34
FRA	0.41	0.38	0.35	0.37	0.36
SVO	0.52	0.44	0.38	0.38	0.37
DME	0.52	0.44	0.38	0.38	0.37
ZRH	0.44	0.41	0.40	0.40	0.41
TXL	0.51	0.45	0.43	0.45	0.43
CDG	0.55	0.55	0.55	0.52	0.52
ORY	0.55	0.55	0.55	0.52	0.52
MUC	0.48	0.51	0.51	0.53	0.54
IST	1.00	0.99	0.84	0.66	0.57
SAW	n/a	0.99	0.84	0.66	0.57
DUB	0.60	0.55	0.56	0.57	0.62
ARN	0.82	0.72	0.66	0.65	0.71
VIE	0.79	0.77	0.73	0.81	0.80
FCO	0.98	0.86	0.80	0.81	0.81
OSL	0.90	0.87	0.83	0.74	0.83
CPH	0.78	0.83	0.84	0.82	0.83
BCN	0.94	0.79	0.71	0.81	0.89
AYT	0.99	1.00	1.00	1.00	0.99
MAD	1.00	1.00	1.00	1.00	1.00

Classifications regarding industry structure based on an HHI assessment vary and are rather arbitrary, i.e. there are no coherent application and limits at which an industry is characterized as a competitive

[6] The Herfindahl Hirschman Index for each catchment is calculated using a two-hour driving radius and the respective secondary airports within this; within a one-hour driving radius most primary airports in the dataset only face one secondary airport.

one. The U.S. Department of Justice (2010) states that HHI values 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.

In a first step, the aggregated Herfindahl Hirschman Index for each primary airport's catchment (HHI_c) is calculated taking into account the total seats offered at both the primary airport and the secondary airports within the catchment[7]. The purpose of using this particular index is to obtain an initial overview of the market concentration in each catchment. The results for each primary airport and the development of the HHI_c over time are displayed in Table 5 and arranged in descending order, thus showing the airport with the lowest Herfindahl Hirschman Index in its catchment for 2016 at the top. A HHI_c of less than 0.25 implies that the total catchment including the primary and its secondary airports is only moderately concentrated, i.e. total seats offered are distributed rather evenly across all airports in the catchment. This only applies to the airports of DUS, LHR, BRU and MXP. Airports with a significant change in HHI over the considered period are LHR, MXP, or LGW indicating that airports within these primary airports' catchment area have been growing in the considered period.

1.6 Route-level concentration at European primary airports

In the next step, for each destination *r* the Herfindahl Hirschman Index is determined using the number of seats offered at each airport in the catchment *i* ($SeatsDest_{ri}$) and the total seats to this destination in the entire catchment ($TotalSeatsDest_r$). To attain the level of market concentration from the perspective of the primary airport a weighting factor is introduced. Since the attractiveness of a secondary airport, i.e. the substitution potential for passengers, might decrease with distance from the primary airport, each secondary airport is weighted by the inverse share of the distance (w_{dj}), representing its distance from the primary airport and yielding the distance-weighted HHI (HHI_{di}):

$$\boldsymbol{HHI_{di} = \left(\frac{SeatsDest_{r1}}{TotalSeatsDest_r}\right)^2 * w_{d1} + \left(\frac{SeatsDest_{r2}}{TotalSeatsDest_r}\right)^2 * w_{d2} + \cdots + \left(\frac{SeatsDest_{ri}}{TotalSeatsDest_r}\right)^2 * w_{dj}}$$

Equation 1

The example in Table 6 exemplifies how the HHI_d for a generalized primary airport is calculated. In the left hand column the different airports within the catchment are stated, i.e. the primary airport and the respective secondary airports. Each of these airports offers a particular amount of seats per year to destination r ($SeatsDest_{ri}$) which is used to calculate the HHI_{ri} (third column). In order to obtain the weighting factor w_{dj} the distance in kilometres of each secondary airport *j* to the primary airport is

[7] Seats are used as variable since information on this available for all considered airports, both at the aggregated level (HHI_c and HHI_n) and at the disaggregated, route level (HHI_{di})

determined (*km*). Since secondary airports closer to the primary airport might be more feasible substitutes for passengers, these airports are assigned with a higher weight. This is done by using the inverse share of the distance: for Secondary 1 a weighting factor of w_{dj}=0.83 is obtained by calculating 1-0.7*(100/400). Furthermore, a threshold of 0.3 is introduced in order to avoid that the weight of the secondary airport furthest away from the primary or in case there is only one airport does not tend towards zero. As outlined in Equation 1 this factor is used to determine the distance-weighted Herfindahl Hirschman Index (HHI_{di}) for each route (airport pair).

Table 6: Example – calculating HHI_d

Airport	$seatsdest_r$	HHI_r	*km*	w_{dj}	HHI_d
Primary	55000	0.076	0		0.076
Secondary 1	20000	0.010	100	0.83	0.008
Secondary 2	15000	0.006	120	0.79	0.005
Secondary 3	110000	0.303	180	0.68	0.208
Sum	**200,000**	**0.395**	**400**		**0.297**

In the example, the value for the HHI_d is lower (0.297) than for the HHI_r (0.395) due to the furthest secondary airport (Secondary 3) having the most seats but the lowest weight, i.e. the potential competition imposed by this airport for the primary airport is assumed to be lower than that from Secondary 1 or Secondary 2. The intention of using a weighted Herfindahl Hirschman Index is to reflect the potential level of competition for the primary airport. Thus, a high HHI_r of e.g. 0.60 does not mean that the market *r* is concentrated at the primary airport. The latter might only a have small share in seats offered to this destination and a secondary airport in the catchment might have most seats on this route (see Table 6: Primary with 55,000 seats vs. Secondary 3 with 110,000 seats).

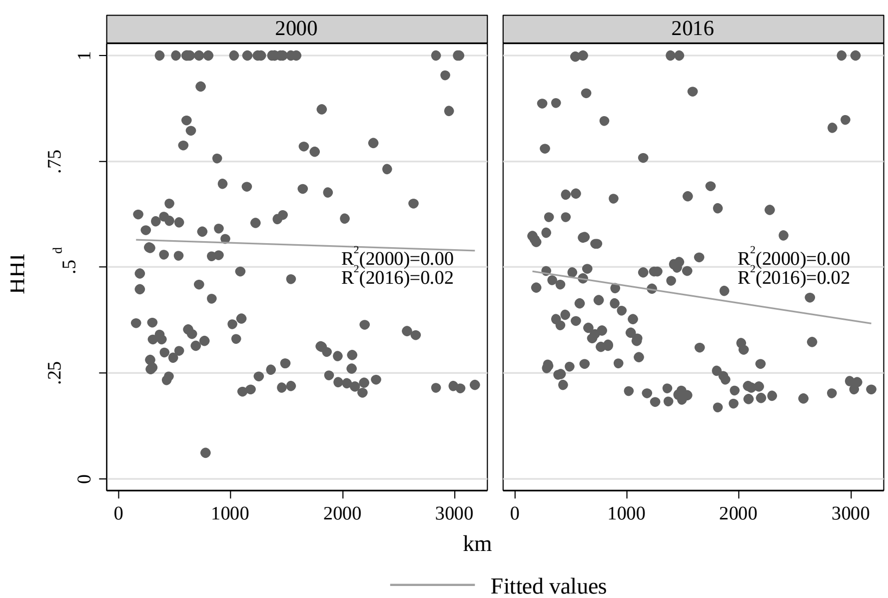
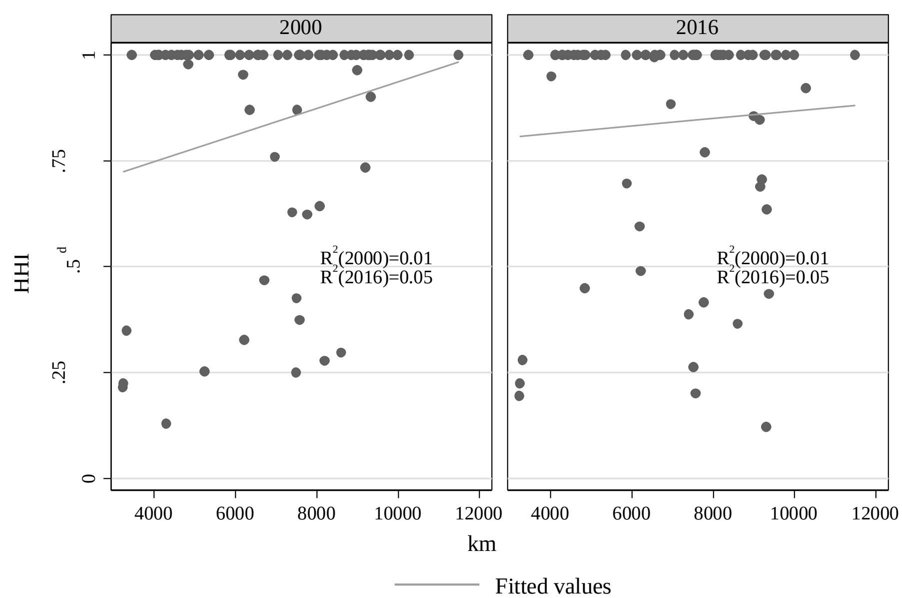


Figure 3: Correlation between HHI_d and km for FRA short-haul market

In order to illustrate the difference in HHI_d across destinations at a primary airport as well as the development of this index over time, London Heathrow Airport (LHR) and Frankfurt Airport (FRA) are discussed in more detail since they are the hubs of two of the largest airlines in Europe – Lufthansa and British Airways (as part of the International Airlines Group). As highlighted in Section 1.4, low cost carrier traffic both at European primary and secondary airports has increased steeply between 2000 and 2016. Low cost carriers are more focused on short-haul routes and hence on the European market whereas incumbent carriers offer both short-haul and long-destinations (see Dobruszkes (2013) for an overview of LCC network development). It might hence be assumed that competition on the short-haul market has intensified to a larger degree than that for long-haul routes with the emergence of low cost carriers in Europe. In order to analyse these markets separately routes are distinguished according to their great circle distance (in kilometres) from the primary airport, i.e. the short-haul market includes all destinations up to a distance of 3,200 kilometres[8].

Figure 3 shows the results for the short-haul market of FRA for the years 2000 and 2016. On the x-axis the destinations offered at FRA are plotted according to their distance from the primary airport. On the y-axis the distance-weighted Herfindahl Hirschman Index for each destination is shown (HHI_d). The short-haul market made up about 70 per cent of total offered seats in 2000 and about 67 per cent in 2016 at FRA. In 2000, a slightly positive correlation between the HHI_d and the distance can be observed whereas in 2016 the reverse is true and the HHI_d is decreasing with distance. The data also shows that the share of short-haul destinations with a low HHI_d, less than 0.25 and hence implying potential competition on this route from other airports, has increased from 17 per cent in 2000 to 25 per cent in 2016 (Table 7).



[8] The short-haul and long-haul range segments are defined rather arbitrarily since there is no comprehensive definition of stage length and their categorization; these are often based on flying time. The UK government defines different distance bands according to which airlines have to pay taxes: A – 0-2,000 miles (~3,200km), B – over 2,000 miles (HM Revenue & Customs, 2015).

Figure 4: Correlation between HHI_d and km for FRA long-haul market

In the long-haul market at Frankfurt Airport (Figure 4) there is a small positive correlation between distance and HHI_d. In regard to the amount of competitive routes, this segment lags behind the short-haul segment with only four and six per cent of destinations having a HHI_d of less than 0.25, respectively for 2000 and 2016 (Table 7). This means that the long-haul market at FRA is more concentrated than the short-haul market and thus verifying the assumption that more competitive pressure has been exerted over time on the short-haul market.

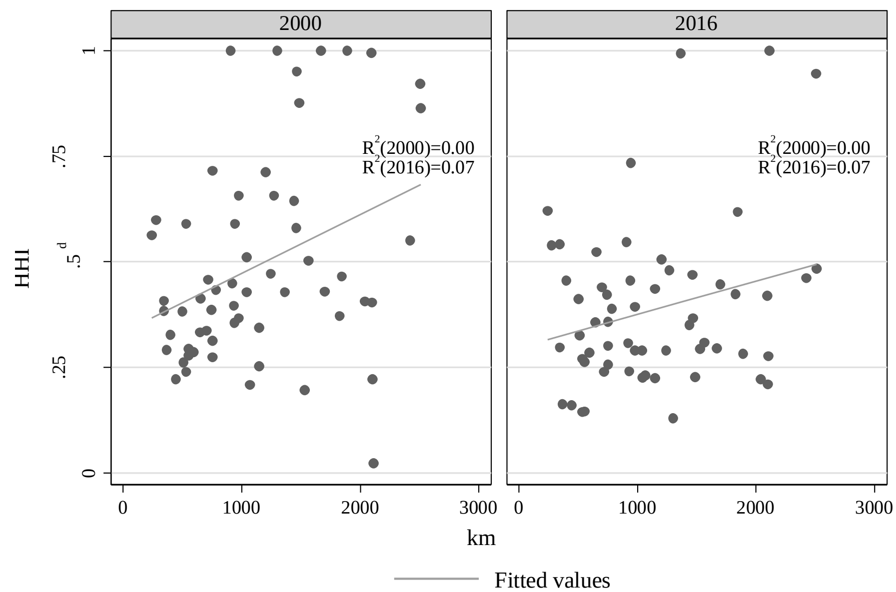


Figure 5: Correlation between HHI_d and km for LHR short-haul market

In comparison, Figure 5 shows the development of London Heathrow Airport's (LHR) short-haul market. This market segment accounted for about 60 per cent of total offered seats in 2000 and for about 48 per cent in 2016 at LHR (Table 7), illustrating a shift from short-haul to long-haul operations over time. However, inferring from the share of short-haul destinations with an HHI_d smaller than 0.25, LHR also experienced an increase in competition with 10 per cent in 2000 and 22 per cent in 2016 (Table 7).

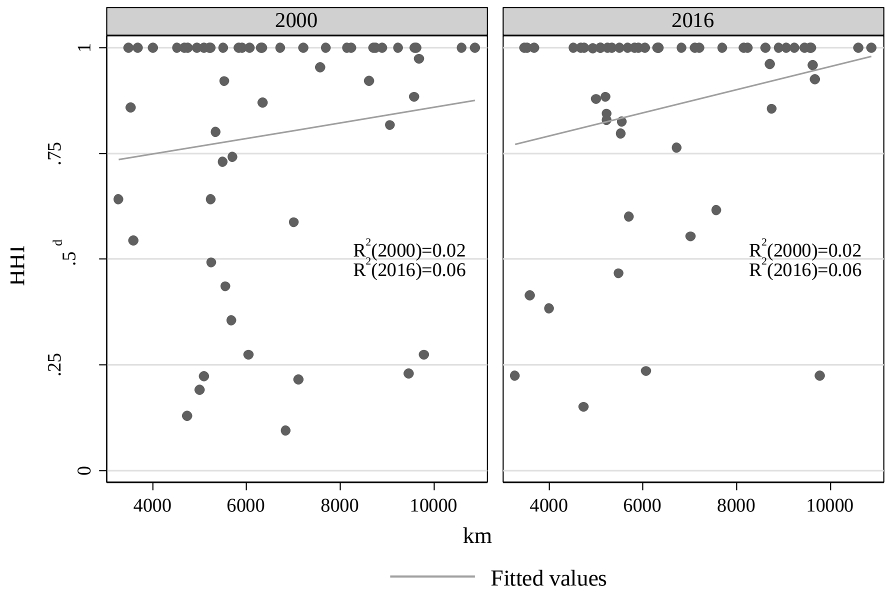


Figure 6: Correlation between *HHI*$_d$ and km for LHR long-haul market

Contrasting this development is the long-haul market segment at LHR which has seen a decrease in competitive constraints: the share of destinations with a HHI_d below or equal to 0.25 has declined from nine per cent in 2000 to seven per cent in 2016 (Table 7). And along with the previously outlined shift of seat capacities from the short- to the long-haul segment this might imply that the airport and its respective airlines are moving to less concentrated markets, i.e. primary and secondary airports are focusing on different markets (destinations).

Table 7 provides an overview of all considered primary airports in Europe, the share of the short-haul market in total seats offered as well as the share of destinations facing some degree of competition, i.e. those with a low Herfindahl Hirschman Index. Overall, LHR is the only airport in the sample that has a larger long-haul market in terms of total seats offered than the short-haul segment. All other primary airports have a stronger focus on the short-haul segment with some airports such as BCN, SAW, OSL, ARN, STN, VIE, TXL, or AYT almost entirely focusing on destinations up to 3,200 kilometres. This also implies that long-haul flights out of Europe are concentrated at only a few primary airports.

Table 7: Market concentration for short- and long-haul segments

	Short-haul market				**Long-haul market**	
	Share of seats		*Share destinations with HHI_d < 0.25*		*Share destinations with HHI_d < 0.25*	
Airport	2000	2016	2000	2016	2000	2016
LHR	60%	48%	10%	22%	9%	7%
CDG	70%	61%	25%	20%	5%	4%
AMS	70%	71%	31%	20%	11%	11%
FRA	70%	67%	17%	25%	4%	6%
IST	93%	84%	0%	11%	0%	0%
MAD	87%	77%	0%	0%	0%	0%
BCN	99%	94%	1%	4%	0%	0%
LGW	59%	84%	24%	25%	21%	23%
MUC	91%	84%	7%	8%	2%	2%
FCO	89%	85%	1%	13%	0%	0%
SVO	79%	79%	10%	30%	5%	15%
ORY	88%	87%	20%	31%	40%	63%
SAW	n/a	99%	n/a	64%	n/a	100%
CPH	92%	89%	0%	1%	0%	0%
DME	71%	87%	29%	31%	17%	38%
DUB	94%	86%	6%	4%	0%	7%
ZRH	82%	80%	9%	24%	0%	2%
PMI	n/a	n/a	n/a	n/a	n/a	n/a
MAN	83%	79%	17%	17%	0%	2%
OSL	99%	94%	1%	2%	0%	0%
ARN	96%	91%	1%	6%	0%	0%
STN	99%	99%	30%	27%	13%	75%
DUS	93%	88%	56%	63%	54%	58%
VIE	90%	90%	2%	3%	4%	0%
LIS	n/a	n/a	n/a	n/a	n/a	n/a
BRU	87%	85%	37%	59%	38%	34%
TXL	99%	94%	23%	16%	56%	22%
ATH	n/a	n/a	n/a	n/a	n/a	n/a
MXP	85%	78%	6%	24%	2%	4%
AYT	100%	99%	0%	1%	0%	0%

Furthermore, there is no unique pattern across European primary airports in regard to the share of destinations with a low HHI_d, neither in the short-haul nor the long-haul market. SAW and DUS, for example face potential competition for more than 60 per cent of their short-haul routes whereas CPH, AYT, or MAD have only very few or none destinations with low market concentration in both their short-haul and long-haul segments. The change in the share of destinations with low market concentration from 2000 to 2016 yields interesting insight into the effect of increasing traffic at secondary airports as outlined in Section 1.4. At MXP, for example, six per cent of the routes in the short-haul segment faced potential competition (an HHI_d below 0.25) in 2000 whereas this figure amounted to 24 per cent in 2016. 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 competitive constraints on MXP. The same effect might apply for the case of BRU which saw an increase in routes with low concentration from 37 per cent in 2000 to 59 per cent in 2016. Ryanair also opened a base at a nearby airport (CRL) in 2001 (Brussels South Charleroi Airport, 2017) and has been expanding operations quickly. Section 1.7 analyses the aggregated effects of increasing (decreasing) market concentration on the primary airports' output in more detail.

1.7 Effects of market concentration on primary airport output

Several studies investigate the effect of market concentration by applying the Herfindahl Hirschman Index as a proxy for competition. Fageda (2013), for example, focuses on the analysis of the Spanish airline market and whether liberalization 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 (HHI). The results show that an increase in concentration at the airport level leads to a decrease in frequencies offered. Using the HHI to determine market concentration as a proxy for the level of competition is also applied by Lieshout *et al.* (2016) in the analysis of airline and airport competition for different regions. Bel and Fageda (2009) apply different concentration indices, including the Herfindahl Hirschman Index, to evaluate the change in concentration of international traffic across European airports. The findings show that the concentration of international traffic has been decreasing over time. Dobruszkes, Lennert and Hamme (2011) provide an analysis of different factors influencing the degree of air traffic concentration within Europe. Factors include, inter alia, the population and the gross domestic product (GDP) of a country, the level of tourism within a country, or the distance to the destination. The results of the regression analysis show that GDP is the main determinant of the number of air services offered within a country. Kluge *et al.* (2017) also give an overview of different studies investigating factors that have a potential influence on the level of air transport demand. This study also confirms the results by Dobruszkes, Lennert and Hamme (2011) that GDP per capita is the main driver of air trips per capita, in this case for selected EU28 and EFTA countries. The Herfindahl Hirschman Index is also integrated in the empirical analysis by Givoni and Rietveld (2009) who identify the determinants of an airline's choice of aircraft size. Using a range of explanatory variables accounting for route and airport characteristics, the HHI is applied to account for market concentration on the route level. The results indicate that increasing concentration has a positive effect on aircraft size.

Within the following analysis, the effect of expanding (low cost) traffic on the network structure at the primary airports is investigated (Section 1.7.1). Here, the Herfindahl Hirschman Index on the network level (HHI_n) is used as the dependent variable. In a second step (Section 1.7.2), the effects of market concentration on the primary airports' output are estimated using the distance-weighted Herfindahl Hirschman Index (HHI_d) as explanatory variable. Table 8 gives an overview of the variables applied in the estimated models in Section 1.7.1 and Section 1.7.2.

1.7.1 Low cost carrier traffic and primary airports' network

Using the Herfindahl Hirschman Index on the network level (HHI_n) gives insight into the primary airports' network structure and how the number and density of destinations offered at have changed over the period from 2000 to 2016. Opposed to the HHI_c the HHI_n only considers the primary airport and the respective distribution of seats across routes and does not include the secondary airports. A high HHI_n might imply that an airport has few high density destinations, i.e. large number of frequencies and/or seats offered to these destinations and a high amount of destinations with low density. This index is below 0.10 for all airports which implies that seats are rather evenly distributed across all destinations offered at each primary airport.

Table 8: Variables for regression analysis, panel data (2000, 2004, 2008, 2012, 2016)

Variable	description
Seats	number of seats offered at primary airport (depairport) between specific airport pair (route) per year
AvgSeats	average number of seats per flight between a specific airport pair
HHI	HHI on an airport-airport market level in 2-hour drive time catchment of hub airport, using seats offered by all airports within catchment between specific airport pair, lagged variable
HHI_d	HHI weighted by distance of catchment airports to primary airport, lagged variable
HHI_n	HHI on airport network level, using share of seats offered at the primary to each of its destinations in total seats offered at the primary airport
ShareLcc	share of offered seats by low cost carriers out of total seats in the catchment (not including primary airport)
LccCatch	number of low cost carriers offering airport pair at one of the catchment airports (only if carrier is different from low cost carrier operating at primary airport), lagged variable
PopGdp	population in the urban area at destination (United Nations / Department of Economic and Social Affairs, 2014) times the gross domestic product per capita in the arrival country (The World Bank, 2017)

However, some airports show a decline in HHI_n (e.g. OSL, LIS, or TXL) or peaks during the observed time period (e.g. AYT, BRU, or SVO). To analyse these changes in HHI_n, the effect of the share of low cost carrier traffic at secondary airports on the network structure at the primary airport is estimated. Due to the equal dispersion of low cost traffic across the different airport types, it is expected that an increasing share of low cost traffic has a negative effect on the HHI_n, implying that airlines at primary airports either extend their network by adding new destinations, i.e. duplicating those offered in the catchment, or increasing the density of exisiting destinations, i.e. increasing seats offered if the destination is also offered in the catchment. To test these assumptions, a fixed-effect regression with control variables for both primary airport *i* and time-specific *t* effects is estimated:

$$\boldsymbol{HHI_{n,t}^{i} = \alpha_0 + \alpha_1 ShareLcc_t^i + \beta_t^i + \gamma_t^i + \varepsilon_t^i} \qquad \textbf{Equation 2}$$

with $t \in \{2000, 2004, 2008, 2012, 2016\}$ and $i \in n$ representing the number of primary airports in the dataset (N=26), β_t^i is the time fixed effect, γ_t^i is the primary airport fixed effect, and ε_t^i is the error term. The independent variable *ShareLcc* depicts the share of seats offered by low cost carriers in the catchment (not including the primary airport)[9]. The estimation results show that an increase in the share of low cost traffic in the primary airport's catchment leads to a decrease in the degree of network concentration at the primary airport[10]. The initial assumption that the Herfindahl Hirschman Index on the network level is decreasing in the share of low cost traffic in catchment is thus confirmed. However, in order to understand in more detail how changes in market concentration and an increasing share of low cost traffic in the catchment affect the primary airports, a more thorough analysis on the destination level is required. The following section hence estimates these effects for specific routes (airport pairs).

1.7.2 Effects of market concentration at the destination level

The empirical estimation in this section looks into the potential competition for a specific destination a primary 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. Testing empirically for the effects of the latter on the density of routes at these primary airports is the focus of the following section. Since no comprehensive data is available on ticket prices on a route level, the output of the primary airports in terms of seats per year (*Seats*) and the average seats per flight (*AvgSeats*) are used to measure the density of a route and are hence set as dependent variables. The impact of market concentration on these is then assessed, using both the unweighted (*HHI*) and the weighted Herfindahl Hirschman Index (HHI_d) which have been introduced in the previous section. The initial assumption is that the primary airports restrict their output if the destination is concentrated at this airport, i.e. if there is no or only little competition in the local catchment. Therefore, a negative impact of the explanatory variables *HHI* and HHI_d on the seats offered to a destination is expected. In order to better understand how changing market concentration in a primary airport's catchment affects its output decisions, four fixed-effect models are estimated. In the first part, the following equations are estimated, using *Seats* and *AvgSeats* as dependent variables[11], respectively, and control variables for the market-specific effects *i*, i.e. the destination or airport pair, and the time-specific effects *t*:

$$\boldsymbol{Seats_t^i = \alpha_0 + \alpha_1 PopGdp_t^i + \alpha_2 HHI_{d,t-1}^i + \beta_t^i + \gamma_t^i + \varepsilon_t^i} \qquad \text{Equation 3}$$

with $t \in \{2000, 2004, 2008, 2012, 2016\}$ and $i \in n$ representing the number of destinations offered at each primary airport, β_t^i is the time fixed effect, γ_t^i is the market fixed effect, and ε_t^i is the error term. $HHI_{d,t-1}^i$ is the destination-specific and distance-weighted Herfindahl Hirschman Index analysed in

[9] In this estimation ATH, LIS, PMI are not included since there are no secondary airports within the two-hour driving catchment. SAW is also not included since operations commenced in 2004 and hence the values for this airport might bias the estimation results.

[10] α_1 with a value of -0.0084, p-value <0.01, standard error 0.0029

[11] Only the weighted HHI_d is depicted in the model, the same estimations are conducted using the unweighted *HHI* as an explanatory variable.

Section 0. This variable affects the dependent variable with a lag which means that the HHI_d from the previous period (*t-1*) is included in the equation since it is assumed that a certain degree of market concentration in the catchment has a delayed or lagged impact on the seats or frequencies offered at the primary airport. The variable $PopGdp_t^i$ represents the purchasing power of population in period *t* at the urban region of destination *i*. This variable is expected to have a positive coefficient and hence accounting for demand effects.

The same is estimated using *AvgSeats* as dependent variable. The results of these two estimations are shown in Table 9 in columns 2 and 4. The coefficient of the *PopGdp* variable is positive in both models, implying that an increase in population in the urban region of the destination leads to an increase in seats, both in terms of total seats offered per year as well as average seats per flights (although the latter effect is very small). The lagged distance-weighted Herfindahl Hirschman Index has a negative impact on the seats offered to a particular destination *i*. This result confirms the initial assumption that output to a specific destination *i* is restricted at the primary airport if this market *i* is concentrated at the primary airport in the previous period.

Table 9: Results fixed-effect regression assessing the impact of route-level market concentration

	(1) seats (unweighted)	*(2) avg_seats (unweighted)*	*(3) seats (weighted)*	*(4) avg_seats (weighted)*
PopGdp	0.30***	0.0001***	0.30***	0.0001***
	(0.0274)	(0.000009)	(0.027)	(0.000009)
HHI	-61824.9***	-19.09***		
	(9396.41)	(3.21)		
HHI_d			-37577.62***	-13.34***
			(8032.52)	(2.75)
LccCatch	5903.72**	5.12***	7631.32**	5.53***
	(2229.95)	(0.76)	(2206.89)	(0.76)
const	222137.5***	169.27***	201409.70***	164.20***
	(8149.80)	(2.79)	(6903.17)	(2.36)
N	6924	6924	6924	6924
R^2 (within)	0.0383	0.0531	0.0344	0.0510

Notes. Standard error in parentheses. $^{**}p<0.01$ $^{***}p<0.001$.

In the second step, the effect of a low cost carrier in the catchment offering seats and frequencies per week to a particular destination (*LccCatch*) is estimated (Equation 4). Here, a lagged variable is also applied with *i* denoting the destination and *t-1* the previous time period. This variable captures whether a destination has been offered in the previous period at a secondary airport by a low cost carrier other than those operating at the primary airport. The approach in determining whether a particular route is offered by a potentially competing carrier at a different airport than the primary one is based on the work in Brueckner, Lee and Singer (2013) and Brueckner, Lee and Singer (2014) and exemplified in Figure 7.

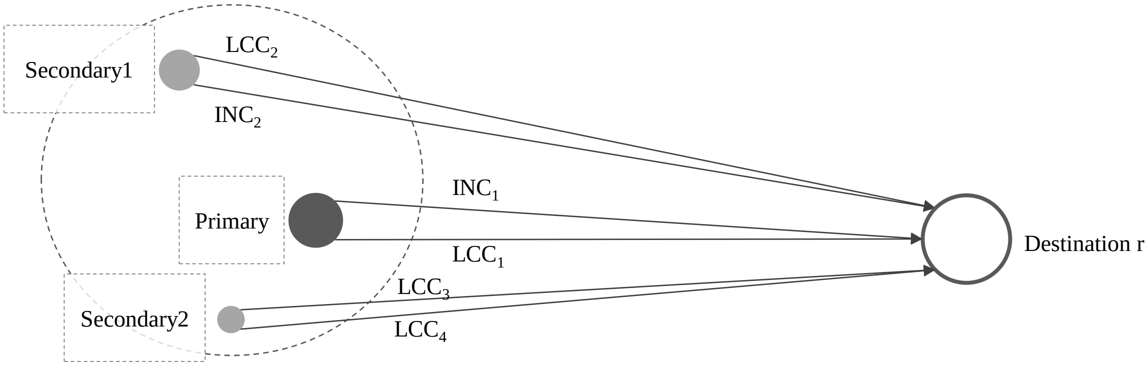


Figure 7: Low cost carrier competition in the primary airport's catchment

At the primary airport ("Primary") an incumbent airline offers seats to destination *r* (INC_1) as does a low cost carrier (LCC_1). At another airport in the catchment ("Secondary1") a different incumbent carrier offers seats to the same destination (INC_2) as does a different low cost carrier (LCC_2). These carriers have to be different from the carriers operating at the primary airport in order to be counted, e.g. if Ryanair is operating at the primary airport and at one of the secondary airports, the seats offered by Ryanair are only counted at the primary airport. There can also be a second secondary airport in the catchment ("Secondary2") that offers seats to destination *r*, in this case by two low cost carriers (LCC_3 and LCC_4) which are again different carriers from LCC_1 and LCC_2. In this particular example, the variable *LccCatch* has a value of 3, i.e. each individual low cost carrier offering seats in the catchment (not including the primary airport) is counted. Integrating this variable in the fixed-effect regression estimation previously outlined yields the following equation:

$$\boldsymbol{Seats_t^i = \alpha_0 + \alpha_1 PopGdp_t^i + \alpha_2 lHHI_{d,t}^i + \alpha_3 LccCatch_{t-1}^i + \beta_t^i + \gamma_t^i + \varepsilon_t^i} \qquad \textbf{Equation 4}$$

with $t \in \{2000, 2004, 2008, 2012, 2016\}$ and $i \in n$ representing the number of destinations offered at each primary airport, β_t^i is the time fixed effect, γ_t^i is the market fixed effect, and ε_t^i is the error term. The same estimation is also conducted using *AvgSeats* as dependent variable. Table 9 shows the results for the impact of *LccCatch* on the seats offered at the primary airports in the sample. The results are statistically significant and show a positive coefficient, meaning 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 primary airport. This also confirms the assumption and findings of the regression analysis in Section 1.7.1 that the increased presence of low cost carriers leads to a positive effect regarding the seats offered at the primary airport.

1.8 Conclusion

The initial analysis of applying the distance-weighted Herfindahl Hirschman Index shows that for most airports the share of routes exposed to potential competition has risen over time, implying a potential overlap between the routes offered at the primary airports and those at the airports in the catchment. Further, the estimation of a fixed-effect regression model, in which the distance-weighted Herfindahl Hirschman Index is applied as an explanatory variable, shows that the number of seats and frequencies offered per route decrease with increasing market concentration. This means that a route with high market concentration at the primary airport in the previous period experiences a decrease in both frequencies per week and seats per year in the current period. Contributing to the discussion on the extent of European airport competition, the findings within this paper give a first insight into negative effects of increasing market concentration on primary airports' route density. Furthermore, the results also show that the presence of low cost carriers in the primary airports' catchments leads to a higher route density suggesting that primary airports have been opening up to these particular carriers and thus meeting the overall growth of this market segment.

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