UNIVERSITA' DEGLI STUDI DI BERGAMO
DIPARTIMENTO DI INGEGNERIA GESTIONALE
QUADERNI DEL DIPARTIMENTO[†]

Department of Economics and Technology Management

Working Paper

n. 10 – 2009

Hub competition and travel times in the worldwide airport network

by

Stefano Paleari, Renato Redondi, Paolo Malighetti

[†] Il Dipartimento ottempera agli obblighi previsti dall'art. 1 del D.L.L. 31.8.1945, n. 660 e successive modificazioni.

[§] L'accesso alla Collana dei Quaderni del Dipartimento di Ingegneria Gestionale è approvato dal Comitato di Redazione. I *Working Papers* della Collana costituiscono un servizio atto a fornire la tempestiva divulgazione dei risultati dell'attività di ricerca, siano essi in forma provvisoria o definitiva.

Hub competition and travel times in the worldwide airport network

Stefano Paleari[*], Renato Redondi[**], Paolo Malighetti[***]

[*] Department of Economics and Technology Management, University of Bergamo, Scientific Director of ICCSAI, Viale G.Marconi, 5 - 24044 Dalmine (BG) Italy

[**] Department of Mechanic Engineering, University on Brescia, Italy; Tel. +39 035 2052360 - Fax. +39 02 700423094

[***] Department of Economics and Technology Management, University of Bergamo, Italy

Abstract

The aim of this work is to measure the competition between hubs based on an analysis of travel times in the world-wide airport network. By considering the minimum travel time required to connect each pair of airports, it is possible to separate the effects of hub position and temporal coordination. This analysis was carried out at the global level, considering all 232 airports with more than 3 million seats yearly offered in departure flights, and also in relevant geographic markets. The results show a high level of competition among the most important world airports, but the major airports of Europe have an advantage over the major American and Asian airports. We also show that airports located in different continents often compete for the same origin-destination markets. Geographical position appears to be the most important variable explaining hub performance. In the last part of the empirical analysis, we apply this methodology to evaluate the impact of the US-EU open sky agreements on hub competition in that market.

Keywords: Hub competition, quickest travel times, open sky agreements

1. Introduction and literature review

The new open skies agreements between the U.S. and Europe and future liberalization of air markets foster the competition between major airports. In particular, the removal of entry barriers on intercontinental flights has increased competition between alliances and individual hubs. The need to attract new traffic has led airports to compete for indirect connections within individual O-D markets; passengers now have a meaningful choice of intermediate airports when planning their itineraries. The competitive structure of hubs is therefore of great interest to both operators and airport regulators at the national and international levels.

1.1 Competition between airports

Competition between airports can take different forms and may not be easy to measure, according to studies commissioned by the European Commission (ATG, 2002). On the one hand, neighboring airports compete to attract passengers whose travels originate or terminate in the region. The extent of an airport's catchment area can vary greatly, depending on several parameters such as accessibility. On the other hand, competition is influenced by the structure of the airport network. Following liberalization of the air transport market, carriers spread (see Spiller, 1989; Zhang, 1996; Oum et al., 1995) hub-and-spoke networks: flights from different origins to the same destination or from the same origin to different destinations are concentrated by passing through intermediate nodes defined as hubs. Borenstein (1989) discusses the economic factors and competitive dynamics that push carriers to opt for a hub-and-spoke structure (Caves et al., 1984; Oum et al., 1995).

Low-cost carriers are the exception to this rule, operating a decentralized network of point-to-point flights of short to medium length. When no direct flight is available between two specific airports, it is often possible to find several alternative routes involving intermediate airports. The major alliances generally offer to coordinate this indirect service for their clients. Alternatively, the passengers themselves can arrange a transfer between two independently operated flights. In the latter case, we speak of opportunities for "self-help hubbing" (see Malighetti et al., 2008). In both cases, the intermediate airport benefits from an increased number of passengers. For simplicity, in this paper the term "hub" refers to any intermediate airport employed by passengers to reach their final destinations, in both alliance-operated connections and self-help hubbing.

1.2 Hub competition

In a simple structure composed of two “spoke” airports, A and B, that connect to each other only through a third hub airport, H, the latter enjoys a monopoly on the A-B market. In reality, the pressure exerted by alliances and independent carriers tends to generate more than one option for the connection between any given airport pair.

Airports therefore have the opportunity to compete for hub roles. The literature shows that this form of competition has become very common in many parts of the world (Rietveld & Brons, 2001). Additional demand from transfer passengers could lead a hub airport to offer more destinations and higher frequencies, which would also benefit passengers originating in the region. From this perspective, hub competition is also relevant to local authorities and regulators. The present work focuses on this competition for indirect traffic.

To be convenient as an intermediate step, the hub airport should generate only a limited increase in terms of distance and travel time compared to a direct connection. These disadvantages are typically offset by higher frequency of service (Butler and Huston, 1990). A number of in-depth studies on location decisions are present in the literature, testifying to the importance of hub positions in the network (e.g. O'Kelly, 1987; Campbell, 1994).

Generally, the passenger's choice among paths operated by alternative carriers depends on frequency, price, and many other parameters related to quality (e.g. Bruinsma et al., 2000). However, their criteria can be summarized by three main factors. First is the connectivity offered by a specific path; the passenger desires to reach the final destination as speedily as possible. The literature confirms the central role of total travel times and route frequencies in identifying the market share captured by hubs (Hansen, 1990). The second factor is the total cost of travel, typically dominated by flight fares. The third aspect is quality of service, a concept which includes punctuality, the presence of ancillary services, and congestion in the intermediate airport.

1.3 Measures of Hub competition

With reference to hub competition, the literature has developed measures of hub attractiveness based on route frequencies and the number of destinations offered (Reynolds-Feighan and McLay 2006), the number of connections available within a given time window (Burghouwt and de Wit, 2005), and average waiting times (Rietveld and Browns, 2001; Lin, 2006). These various measures are useful for establishing benchmarks and comparing airports to each other, but do not indicate which hubs are potential stops for the same pair of origin-destination airports. In other words, existing measures do not determine which airports in the network are actually competing with each other in a given O-D market. Recent and ongoing research by Veldhuis and Burghouwt aims to overcome this shortcoming by developing a generalized cost for passengers, considering several economic factors (Burghouwt and Veldhuis, 2006; Burghouwt, 2007; Burghouwt et al., 2008). However, because vast amounts of data and specific assumptions are required to calibrate their model, this generalized cost function has only been applied to individual airports. Our present analysis relies on total travel times, including waiting time at the hub, to detect which intermediate airports can intercept the same origin-destination demand, regardless of the market shares of the different alternatives. We also consider paths involving more than one stop. The competitive positions of potential hubs are always analyzed with reference to a particular origin-destination pair. While simpler compared to the generalized cost model, this measure does not require calibration and can easily be applied to the entire network.

2. Methodology and data

The empirical analysis takes into account all scheduled flights between major airports worldwide. The sample is composed of all 232 airports offering more than 3 million seats in departure flights in 2008. The selected airports account for 75.4% of the total seats offered by more than three thousand airports worldwide, as covered by the Innovata dataset.

The research consists of two steps. Firstly, we calculate the minimum travel time for all possible pairs of origin-destination airports, including both flight time and waiting time at intermediate airports in case there is no direct connection. Secondly, in order to ensure that passengers can effectively use the indirect connections identified in step 1, we analyze all scheduled flights operating in a typical off-peak period of the autumn schedule, from 22 to 24 October 2008.

<Table 1 about here>

<Figure 1 about here>

The minimum travel time can be obtained using the dynamic approach of Miller-Hooks and Patterson (2004). This methodology calculates when a generic airport serves as an intermediate hub in the quickest paths (i.e., those with minimum travel time) between each O-D pair.

We account for flight frequency by considering *all* the quickest connections in the three-day period for a given O-D pair. The same analysis was applied to the European network over the course of a single day by Malighetti et al. (2008). Because this research concerns the worldwide network, the period is extended from one to three days.

We consider interline transfers only if they occur within the same alliance; otherwise, transfers must occur within the same carrier. We also require a minimum connecting time of 60 minutes for connections within the same country or integrated geographical entity such as the EU. Travel within the EU is considered akin to domestic travel, since people move freely without the need for immigration procedures. In the following, we use domestic (foreign) as related to airports (not) located in the same geographical entity as the intermediate airport. We extend the minimum connection time to 75 minutes for travel from a domestic airport to a foreign destination, including intercontinental airports. We extend the minimum connection time to 90 minutes for travel from a foreign airport to a domestic destination, because of the additional delay due to immigration procedures that take place at the connecting airport. The minimum connecting time of 90 minutes also applies to connections from foreign departures to foreign destinations. In our analysis, the average connecting time at an airport depends on the particular kind of connections it offers. For example, the average connecting time is higher at London Heathrow than at other European airports because Heathrow hosts a higher proportion of long-haul connections.

A hub is competitive when many connections passing through it have travel times close to the quickest alternative. Once we have determined the minimum travel time for each O-D pair, the second step is to compare travel times through a generic hub to the quickest alternative.

The connections considered are those whose travel times do not exceed the quickest alternative by a certain threshold. In this empirical analysis, we adopt a threshold of 20%. If the quickest path connecting airports A and B lasts 10 hours, an alternative path passing through hub H is considered only if its duration is less than or equal to 12 hours.

For each intermediate airport H, we identify all O-D connections meeting this criterion during the three-day study period. Then we calculate the average frequency, the average travel time, the average waiting time at H, and the average routing factor. We also report the average number of steps in the viable O-D connections. These averages are weighted as described in the next section.

In this manner, we identify all the hubs offering competitive O-D connections. We then compare the main competitors in terms of frequency of the O-D connection, travel times, waiting times and routing factors in order to come to a better understanding of their relative strengths and weaknesses.

3. Empirical analysis

The empirical analysis is composed of two sections. The first analyzes hub competition worldwide and on specific O-D markets. In the second section, we will show in detail how hub competition changed from October 2007 to October 2008 in the US-EU market. Our aim is to evaluate the impact of US-EU open sky agreements, which came into force in March 2008.

3.1 Hub competition on the major O-D markets

As remarked in the methodology section, this analysis takes into account only O-D connections whose total travel time is no more than 20% longer than the quickest alternative connection (which may or may not be direct). In all analysis, including the averaged performance indicators described below, we weight O-D connections by the total number of departing seats offered by the origin and destination airports. We identified a total of 53.592 viable O-D connections in the global network.

For reasons of space, we shall frequently refer to airports using their 3-digit IATA codes. Appendix A describes all the airports in the sample, indicating each one's extended name, country and city of reference.

In reference to the global network (see row 1 of Table 2), the Frankfurt airport (FRA) has the greatest share of O-D connections. Specifically, 34.1% of all viable connections, weighted by offered seats at the origin and destination airports, passes through this airport. The average frequency of the offered connections is 4.1 in the three-day period. This frequency means that O-D connections passing through FRA with travel times within 120% of the quickest alternative are offered more than once a day on average. The average number of steps per connection is 3.25. (One advantage of this methodology is that it does not limit the analysis to 2-step connections.) Most of the O-D connections available on a worldwide scale involve a three-step path. The average travel time is 1,193.3 minutes, including 105.7 minutes of waiting time at FRA. The average routing factor of the O-D pairs is 1.14.

Frankfurt’s most important direct competitor is Paris Charles de Gaulle (CDG), which provides alternative routes for 83.2% of its O-D connections. In other words, 83.2% of the O-D connections passing through Frankfurt may also be completed via CDG. For both airports, the travel times of these connections do not exceed those of the quickest alternatives by more than 20%. Note that neither airport necessarily offers the quickest connection for any given O-D pair.

Table 2 also describes the relative performance of the competitors. For example, among those O-D pairs offered by FRA and contested by CDG (the 83.2% of Frankfurt’s total), the Paris airport offers a higher average frequency. In fact, the ratio between the two airports’ average frequencies on these connections is 1.06, meaning that Paris connections occur about 6% more often on contested O-D pairs.

CDG connections are slightly less attractive in terms of travel times, with journeys lasting on average 1% longer than their Frankfurt equivalents (see the ‘tt ratio’ column of table 2). The main advantage of flying through Paris is that waiting times are about 7% lower. Frankfurt, on the other hand, is favored by a lower average routing factor that explains its quicker travel times. Table 2 also shows the percentage of O-D pairs contested by Frankfurt’s second and third competitors. Its second most important competitor is London Heathrow, which contests 82.1% of O-D pairs. Amsterdam comes in third, at 75.8%.

Interestingly, the first four airports in the ranking are all European. After Frankfurt, London Heathrow (LHR) serves as a potential hub for 33.6% of the O-D pairs worldwide. Then come Paris Charles de Gaulle and Amsterdam, with percentages of 32.9% and 30.5% respectively.

In fifth position is Atlanta, the first US airport, with a 27.9% share of O-D pairs. Its main strength is the low average waiting time: about 95 minutes, indicating strong coordination of incoming and outgoing flights. However, Atlanta also has one of the highest average routing factors, 1.17. This airport is simply not in an optimal location to offer worldwide O-D connections.

<Table 2 about here>

Those airports with the largest shares of O-D connections are often major competitors of other airports. Lower in the ranking, an increasing proportion of the O-D connections offered by a hub are contested by other airports. For example, Frankfurt services 95.4% of the O-D connections passing through Vienna.

Looking at table 2, the *lowest* percentage of O-D connections contested by any third competitor is 58.4%, referring to Beijing (PEK) connections contested by the Tokyo airport (NRT). This proportion is still very high, indicating that competition for O-D pairs is fierce worldwide.

Although table 2 offers a convenient global picture, deeper analysis shows that the hubs mainly compete over O-D pairs connecting different geographical regions. In appendix B, tables 7 through 10 report analogous statistics for O-D pairs between North America and Europe, Asia and Europe, Latin America and Europe and Asia and North America respectively.

London Heathrow dominates the market between North America and Europe (table 7), offering 64.7% of all O-D pairs. Its main competitor is Paris Charles de Gaulle, which contests 77.3% of those O-D pairs. Paris suffers from a lower average frequency and higher routing factors, but offers lower waiting times than London Heathrow. Overall, their travel times are similar. The two New York-based airports, Newark and J.F.K., come in third and sixth respectively. These hubs have the lowest average routing factors, below 1.10. London Heathrow is the first competitor of Newark and the second competitor of J.F.K. We will revisit this market in the next section of the empirical analysis, in order to evaluate the impact of the US-EU open sky agreements on hub competition.

In the market between Asia and Europe (table 8), Frankfurt returns to the top ranking, servicing 76.1% of weighted O-D pairs. Its first competitor is again Paris Charles de Gaulle with the SkyTeam alliance, but its share of the market is much less at 63.4%. The main advantage of CDG is lower waiting times; the airport seems to be better coordinated than other European airports. However, with respect to the Europe-Asia market, it has the drawback of lengthening the detour necessary to complete the connection. Its average routing factor is 1.15, where Frankfurt's is 1.13. The first Asian airport to appear in the ranking is Beijing, in sixth place with a share of 47.1%. Beijing offers the highest frequency of service over the three-day period, however, at 5.2 connections per O-D pair, together with Paris-Charles de Gaulle. Its main competitors are the European airports of Frankfurt, Paris-Charles de Gaulle and Amsterdam.

Table 9 reports on hub competition for the market from Latin America to Europe. This market provides a marked example of hub specialization in the Madrid airport. Madrid comes second in the ranking after CDG, with a market share of 66.1% compared to CDG's 67.2%. The Madrid airport has higher waiting times than CDG, by more than 10 minutes on average. The lowest average routing factor (1.07) belongs to Portugal's Lisbon, so this airport has a positioning advantage. However, Lisbon offers just 2.4 routes per O-D pair over the three-day period, while Paris Charles de Gaulle offers 4.5.

The last specific market considered is that between North America and Asia (table 10). The Los Angeles airport (LAX) services the largest share of O-D pairs, 65.7%. San Francisco and Tokyo are its main competitors. San Francisco occupies the fourth position and Tokyo is second, closely following LAX with a share of 65.5%. Tokyo enjoys lower routing factors and waiting times than its two main competitors. Note that two airports may compete as hubs for the same O-D pairs even if they are located in different continents.

The level of competition is uniformly high: even among the *third* competitors identified in all analyzed markets, the share of O-D pairs serviced is always well above 50%.

Figure 2 shows the share of O-D connections that can be intercepted as a function of airport ranking for the various O-D markets. A large share for the first airport and a rapidly decreasing curve indicate a concentrated market, where competition is restricted to just a few airports. A small share for the first airport followed by a gradual decrease reflects market fragmentation.

<Figure 2 about here>

The most dispersed markets for hub competition are the internal European (EU-EU) and North American (NA-NA) markets. The most important hubs service between 10% and 20% of their respective markets, again in terms of weighted O-D pairs.

There are two reasons for this low concentration. The first is that in intra-region markets, more airports are connected by direct flights, so the share of O-D pairs requiring an intermediate airport is reduced. Second, because O-D distances are much shorter in regional markets than in intercontinental markets, it is difficult to find more than one eligible hub that does not inordinately lengthen the detour. The choice of intermediate airport therefore depends mainly on the locations of the departure and arrival airports.

The most concentrated intercontinental market is that between Latin America and Europe. The share of the first hub, 67.2%, is not significantly larger than those of the other intercontinental markets, but the share decreases much more sharply after the first five airports (Paris Charles de Gaulle, Madrid, Frankfurt, London Heathrow and Amsterdam).

Figure 3 takes the thirty most important hubs of the world, as reported in table 2, and plots worldwide share against a factor describing the degree of specialization. We define the specialization of a hub as the ratio between its share in the most relevant market and its average share over all O-D markets for which the hub offers connections. For example, an airport with a share of 80% in its most relevant market, 50% in two other markets, and no presence in a fourth market would have a specialization ratio of 80/60 or 1.33.

All the major hubs (Frankfurt, London Heathrow, Paris Charles de Gaulle, Amsterdam and Atlanta) have specialization indexes below average, ranging between 1.4 and 1.8. All five offer connections on all major O-D markets, with minor specializations: the Asia-Europe market for Frankfurt and Amsterdam, the North America-Europe for Heathrow, the Latin America-Europe market for Paris Charles de Gaulle, and the Asia-North America market for Atlanta.

In the upper left of figure 3 are smaller hubs (in terms of worldwide O-D connection share) with a high degree of specialization. Los Angeles (LAX) has the highest specialization index, above 2.2, followed closely by Madrid. LAX specializes in the Asia-North America market, while Madrid specializes in the Latin America-Europe market. San Francisco (SFO), Seattle (SEA) and Vancouver (YVR) specialize in the Asia-North America market; Copenhagen (CPH), Rome Fiumicino (FCO) and Vienna (VIE) specialize in the Europe-Asia market. Finally, the Boston airport (BOS) specializes in the North America-Europe market.

<Figure 3 about here>

Table 3 shows whether waiting times or routing factors better explain the overall travel times observed in various markets[1]. In each market, we consider the relative performance of the 30 most important hubs and their main competitors, and report the percentages of airports for which waiting times and routing factors are coherent with overall travel times. That is, if an airport has higher waiting times but lower travel times than its main competitor, we presume that waiting times do not have a major impact on travel times for that airport. If an airport achieves better travel times than its main competitors despite having worse coordination between incoming and outgoing flights, its location *may* provide a competitive advantage instead (as seen in the average routing factor). Note that it is possible for travel times to be coherent with both factors, or with neither factor. Thus, in some cases the sum of the percentages will not be 100%.

On a global scale and considering only the first competitor, waiting times are coherent with travel times only for 10 of the 30 major hubs (33.3%). The percentage of hubs whose routing factors are

[1] We acknowledge that the total travel times for a given O-D market do not depend solely on waiting times spent in the intermediate airport and routing factors. The average cruising speed of the aircraft performing the connecting flights also plays an important role, as does the level of temporal coordination in other intermediate airports in cases where more than one stop is needed. However, the two factors considered here are both directly related to the analyzed airports.

coherent with travel times is 66.7%. Interestingly, for all geographical markets, routing factors better explain the overall travel times than waiting times. This result does not change when we compare the performance of each main hub to its first three and first five competitors.

<Table 3 about here>

Table 4 shows the percentage of hubs with at least one competitor located in a different continent. In the North America-EU market, 5 of the main 30 hubs (16.7%) have their main competitor in a different continent. That value increases to 17 out of 30 (56.7%) when considering the first three competitors. *All* of the major hubs on the North America – EU market have at least one airport located in a different continent among their first 5 competitors. The other geographical markets show similar figures, except for the last column. Thus, hub competition works on a wider scale than a single continent. This fact is an important result for policy-makers, since local policies such as regulations concerning airport charges may alter a hub's competitive position on broader markets.

<Table 4 about here>

3.2 Hub competition and the EU-US open sky agreements

This section compares hub competition on the EU-US market for the years 2007 and 2008, in order to estimate the impact of the EU-US open sky agreements that came into force in March 2008. For 2007, we analyze all scheduled flights operating in a typical off-peak, three-day period of the autumn schedule: Wednesday 24 to Friday 26 October. A corresponding period is analyzed in 2008, Wednesday 22 to Friday 24 October.

For the first thirty hubs in October 2007 and October 2008, table 5 compares several performance indicators: the O-D share, average frequency, average number of steps, average travel time, average waiting time, average routing factor, and the fraction of O-D pairs contested by its main competitor. We only consider O-D pairs between the United States and the EU, as only these connections are affected by the open sky agreements. (In table 4, we analyzed hub competition on the North America-EU market, including origins and destinations in Canada.)

The hub with the largest share of weighted O-D pairs in both years is London Heathrow, whose share increased from 60.7% in 2007 to 64.5% in 2008. After Heathrow in 2007, the three US airports of Newark, New York J.F.K., and Chicago follow with shares of 59.3%, 58.3% and 56.3% respectively. In 2008, those three airports lost ground with respect to other European airports. J.F.K dropped from 3rd to 4th place, with a reduced share of 55.3% in 2008. Chicago dropped from 4th to 7th place, with a reduced O-D share of 50.7%. Newark dropped from 2nd to 3rd place, with a reduced O-D share of 55.3%.

Indeed, most of the hubs served a smaller share of O-D pairs in 2008 than in 2007. Among the main European airports, aside from London Heathrow, only Paris Charles de Gaulle increased its O-D share; its 2008 value of 57.5% is slightly above its 2007 value of 56.0%. As a result, it advanced from 5th to 2nd place in the ranking. Among US hubs, only Atlanta increased its O-D share from 47.1% to 49.5%, advancing one position. Among other major airports, Frankfurt saw a decrease in its O-D share from 55.2% to 54.0%, Amsterdam from 54.9% to 53.7%, Munich from 34.6% to 31.3%, and Zurich from 29.7% to 26.3%. Thus, the open sky agreements appear to have concentrated the O-D market on its main player, London Heathrow, at the expense of the major airports.

Table 6 reports the change in each performance indicator for groups containing the top, middle, and bottom ten airports from 2007 to 2008. The *t*-test column shows whether the average values are statistically different. As observed above, O-D shares decreased on average. For the first ten hubs it passes from 54.3% to 52.4%, even if that reduction is not statistically significant. The reductions in O-D shares in the other two groups are statistically significant, at approximately the 95% confidence level.

<Table 5 about here>

The frequencies of O-D connections also decreased. This trend is most evident in the first ten airports, which go from 5.02 to 4.53 connections in the three-day period, a difference with minor statistical significance. Travel times and routing factors remain substantially unchanged among the first ten hubs, and very little changed in the other two groups. Waiting times for the last ten airports (21st to 30th) increased significantly, from 92.8 minutes to 97.6 minutes. Finally, the O-D share contended by the first competitor remained unchanged for all hubs.

Thus, the most significant consequence of the US-EU open sky agreements with respect to hub competition is a reduction in the O-D shares of most of the main airports. The noticeable exception is London Heathrow, which saw a strong increase in its O-D share. The market in 2008 is more fragmented, but competition did not significantly increase; the fraction of O-D pairs contested by the first competitor remained unchanged in all three groups.

These results appear to confirm our expectations, in that the open sky agreements allowed carriers to open new point-to-point routes to secondary airports in US and EU. The appearance of more direct connections explains why the indirect market share decreased for most of the main hubs. However, the open sky agreements also opened London Heathrow, formerly a stronghold of British Airways, to other carriers. Thus, the share of O-D connections mediated by this airport increased.

<Table 6 about here>

4. Conclusion

This work employs an innovative methodology based on minimum travel times to create new measures of hub competition. In particular, to the best of our knowledge, this analysis is the first to provide a comprehensive overview of competition among hubs both on a global scale and in the major origin-destination markets.

We find a high level of competition among major hubs, all of which have at least three other airports competing for more than 50% of their O-D market. The most common driver of performance (average travel time) for any given hub and its main competitors is geographical location, here expressed in terms of their average routing factors. Some hubs are highly specialized in a specific geographical market, for example, Madrid for O-D pairs between Europe and Latin America and Tokyo for O-D pairs between Asia and North America.

Competition among hubs is fierce even on the global scale, since airports located in different continents often compete for the same O-D pairs. Our analysis shows that the major European airports have higher shares of worldwide O-D pairs than their American and Asian competitors.

Finally, we used this methodology to evaluate the impact of the open sky agreements on hub competition between Europe and the US. We did not find any ground-breaking impact, even if most of the major hubs reduced their O-D share following the agreement. The exception is London Heathrow, which remains the main hub for the market and significantly increased its O-D share.

Acknowledgements

We wish to thank all participants at the ATRS 2009 conference in Abu Dhabi for their comments and ideas. The authors remain responsible for any remaining errors and inaccuracies.

References

ATG (Air Transport Group), 2002. Study on competition between airports and application of state aids rules, Final Report for the European Commission DG TREN, Vol. 1.

Borenstein, S., 1989. Hubs and High Fares: Dominance and Market Power in the U.S. Airline Industry. *RAND Journal of Economics* 20, 344 –365.

Bruinsma, F., Rietveld, P., Brons, M., 2000. Comparative Study of Hub Airports in Europe: Ticket Prices, Travel Time and Rescheduling Costs. *Journal of Economic and Social Geography* 91, 278–292.

Burghouwt, G., 2007. Airline Network Developments in Europe and its Implications for Airport Planning", England: Ashgate.

Burghouwt, G., Veldhuis, J., 2006. The Competitive Position of Hub Airports in the Transatlantic Market, *Journal of Air Transportation* 11(1),106–130.

Burghouwt, G., Lieshout, R., Veldhuis, J., 2008. Competition between hub airports: the case of Amsterdam Airport Schiphol, Paper presented ATRS conference 2008, Athens.

Burghouwt, G., deWit, J., 2005. Temporal configurations of European airline networks. *Journal of Air Transport Management* 11(3), 185–198.

Butler, R.V., Huston, J.H., 1990. Airline service to non-hub airports ten years after deregulation. *Logistics and Transportation Review* 26, 3–16.

Campbell, J., 1994. A survey of network hub location. *Locational Analysis* 6, 31–49.

Caves, D.W., Christensen, L.R., Tretheway, M.W., 1984. Economies of density versus economies of scale: why trunk and local service airline cost differ?. *Rand Journal of Economics* 15, 471–489.

Hansen, M., 1990. Airline competition in a hub-dominated environment: An application of noncooperative game theory. *Transportation Research B* 24 (1), 27–43.

Lin, M.H., 2006. Hub-airport competition: connecting time differentiation and concession consumption. *Australian Economic Papers* 45 (4), 299–317.

Malighetti, P., Paleari, S., Redondi, R., 2008. Connectivity of the European airport network: ''Self-help hubbing'' and business implications. *Journal of Air Transport Management* 14, 53–65.

Miller-Hooks E., Patterson S.S., 2004. On Solving Quickest Time Problems in Time-Dependent Dynamic Networks. *Journal of Mathematical Modelling and Algorithms* 3, 39–71.

O'Kelly, M.E., 1987. A quadratic Integer problem for the location of interacting hub facilities. *European Journal of Operational Research* 32, 393–404.

Oum, T.H., Zhang, A., Zhang, Y., 1995. Airline Network Rivalry. *Canadian Journal of Economics* 28, 836–857.

Reynolds-Feighan, A.J., McLay P., 2006. Accessibility and attractiveness of European airports: A simple small community perspective. *Journal of Air Transport Management* 12(6), 313-323.

Rietveld, P., Brons, M., 2001. Quality of Hub-and-spoke Networks: the Effects of Timetable Co-ordination on Waiting Time and Rescheduling Time. *Journal of Air Transport Management* 7, 241–249.

Spiller, P.T., 1989. A Note on Pricing of Hub and Spoke Networks. *Economics Letters* 30, 165–169.

Zhang, A., 1996. An Analysis of Fortress Hubs in Airline Networks. *Journal of Transport Economics and Policy* 30, 293–307.

Tables

Region	Code	Number of airports	Offered seats	Percentage of offered seats in the region
Africa	AF	6	36,868,643	41.0%
Asia-Oceania	AS-SW	64	663,642,065	75.3%
Europe	EU	62	671,112,872	72.8%
Latin America	LA	21	139,416,768	52.9%
Middle East	ME	11	80,017,036	74.2%
North America	NA	68	946,308,832	86.0%
Total		232	2,537,366,216	75.4%

Table 1. Airports included in the sample and their regional distribution.

	Worldwide O-D							1° competitor						2° competitor		3° competitor	
Rank	Code	O-D (%)	Freq. (f)	Average no. step	Travel Times (tt)	Waiting time (wt)	Routing Factors (rf)	code	O-D (%)	f ratio	tt ratio	wt ratio	rf ratio	code	O-D (%)	code	O-D (%)
1	FRA	34,1%	4,1	3,25	1.193,3	105,7	1,14	CDG	83,2%	1,06	1,01	0,93	1,01	LHR	82,1%	AMS	75,8%
2	LHR	33,6%	4,5	3,30	1.223,0	97,7	1,14	FRA	83,1%	0,85	0,99	1,07	0,99	CDG	82,6%	AMS	75,6%
3	CDG	32,9%	4,5	3,24	1.204,5	99,8	1,14	FRA	86,2%	0,93	1,00	1,06	0,99	LHR	84,4%	AMS	77,6%
4	AMS	30,5%	3,5	3,27	1.198,8	107,0	1,14	FRA	84,7%	1,24	0,99	0,98	1,00	CDG	83,8%	LHR	83,5%
5	ATL	27,9%	4,5	3,00	1.119,4	94,8	1,17	JFK	71,8%	0,99	0,99	1,12	0,96	ORD	71,5%	EWR	66,2%
6	JFK	27,0%	4,0	3,15	1.260,6	107,6	1,11	EWR	75,2%	0,79	1,01	0,98	1,00	ATL	74,3%	ORD	70,4%
7	ORD	26,4%	3,8	3,29	1.224,6	99,5	1,12	ATL	75,6%	1,10	1,00	0,93	1,03	JFK	72,0%	EWR	68,3%
8	EWR	24,3%	3,4	3,10	1.188,1	105,4	1,11	JFK	83,7%	1,27	0,99	1,01	1,00	ATL	76,1%	ORD	74,4%
9	YYZ	23,3%	2,9	3,34	1.238,4	101,3	1,12	JFK	77,2%	1,50	0,98	1,00	1,00	ORD	74,0%	ATL	71,8%
10	MUC	21,5%	3,3	3,50	1.253,8	97,5	1,15	FRA	91,9%	1,47	0,97	1,11	0,99	CDG	89,4%	LHR	86,4%
11	DTW	20,6%	3,2	3,45	1.262,5	101,7	1,12	ORD	80,7%	1,26	0,99	0,98	1,00	ATL	77,7%	JFK	72,8%
12	LAX	20,6%	3,8	3,42	1.389,9	108,9	1,16	ORD	62,9%	0,89	1,00	0,95	0,96	DFW	61,8%	SFO	61,7%
13	DFW	19,8%	3,9	3,16	1.144,0	98,7	1,16	ATL	78,7%	1,22	0,99	0,95	0,99	ORD	74,5%	IAH	69,6%
14	ICN	19,0%	2,7	3,55	1.399,5	111,3	1,13	NRT	74,4%	1,18	0,97	0,95	1,01	PVG	65,9%	PEK	63,3%
15	ZRH	19,0%	2,7	3,64	1.343,9	95,9	1,13	FRA	93,9%	1,72	0,97	1,12	0,99	CDG	92,6%	LHR	91,3%
16	NRT	19,0%	3,1	3,47	1.400,7	109,8	1,14	ICN	74,6%	0,83	1,02	0,98	0,98	LAX	61,2%	PVG	60,2%
17	IAH	17,5%	3,6	3,16	1.163,4	100,7	1,16	ATL	80,8%	1,40	0,98	0,95	0,97	DFW	78,6%	ORD	73,4%
18	PEK	17,4%	4,1	3,39	1.306,6	103,0	1,14	ICN	68,9%	0,80	1,00	1,03	1,00	PVG	68,7%	NRT	58,4%
19	PVG	16,2%	3,0	3,53	1.369,2	109,3	1,18	ICN	76,6%	1,04	0,99	0,95	0,97	PEK	73,8%	NRT	69,7%
20	MSP	15,0%	2,6	3,44	1.246,4	96,5	1,13	ORD	81,8%	1,64	0,98	1,06	0,99	ATL	77,2%	DTW	76,4%
21	HKG	14,9%	3,3	3,44	1.397,8	111,7	1,18	ICN	65,4%	0,71	0,99	1,03	0,96	PVG	63,2%	PEK	63,2%
22	SFO	14,5%	2,5	3,78	1.509,1	111,6	1,15	LAX	88,9%	1,59	0,97	0,96	1,01	NRT	67,6%	ORD	67,1%
23	BRU	14,5%	2,2	3,78	1.321,6	97,1	1,14	CDG	94,7%	2,38	0,96	1,04	1,00	FRA	94,6%	LHR	91,6%
24	DUS	14,4%	2,4	3,82	1.310,8	96,7	1,13	FRA	92,5%	2,06	0,96	1,09	1,00	CDG	92,2%	LHR	90,4%
25	BOS	14,3%	2,7	3,59	1.256,4	98,0	1,12	JFK	87,5%	1,75	0,96	1,06	0,99	EWR	82,2%	ORD	77,9%
26	SEA	13,9%	3,3	3,55	1.312,4	107,4	1,15	LAX	82,4%	1,58	0,97	0,94	1,03	SFO	67,0%	ORD	63,7%
27	FCO	13,6%	2,9	3,41	1.253,1	100,0	1,16	FRA	93,6%	1,86	0,97	1,03	0,97	CDG	93,6%	LHR	89,3%
28	VIE	13,6%	2,3	3,71	1.353,5	100,0	1,15	FRA	95,4%	2,14	0,96	1,12	0,99	CDG	91,6%	LHR	87,8%
29	YVR	12,9%	2,3	3,76	1.444,8	96,8	1,12	LAX	82,6%	1,97	0,97	1,10	1,03	SFO	69,9%	SEA	66,5%
30	CPH	12,8%	2,4	3,76	1.344,4	99,2	1,15	FRA	93,6%	2,02	0,97	1,09	1,00	AMS	90,6%	CDG	90,0%

Table 2. Top 30 hubs in worldwide O-D connections. For a given O-D pair, an airport counts as a hub if it offers at least one connection with a travel time <= 120% of the quickest alternative during the three-day period. The ranking is by percentage of worldwide O-D pairs served by the hub (3rd column), weighted by offered seats at the origin and destination airports. The percentages of these O-D pairs contested by the hub's top three competitors are reported in the 10th, 16th and 18th columns. The 'f ratio', 'tt ratio', 'wt ratio' and 'rf ratio' compare the first competitor (9th column) to the hub (3rd column) in terms of average frequency, travel time, waiting time, and routing factor respectively.

	World	NA-EU	LA-EU	AS-EU	AS-NA	EU-EU	NA-NA
First competitor							
Waiting Times	33,3%	46,7%	60,0%	23,3%	53,3%	46,7%	30,0%
Routing Factors	66,7%	76,7%	70,0%	66,7%	76,7%	70,0%	70,0%
First 3 competitors							
Waiting Times	40,0%	50,0%	36,7%	38,9%	48,9%	45,6%	38,9%
Routing Factors	58,9%	68,9%	60,0%	45,6%	68,9%	66,7%	71,1%
First 5 competitors							
Waiting Times	38,7%	43,3%	42,7%	34,0%	44,7%	49,3%	39,3%
Routing Factors	56,7%	67,3%	64,0%	46,0%	68,7%	68,0%	71,3%

Table 3. The coherence of waiting times and routing factors with total travel times in the 30 most important airports.

Market	% of main competitors in another continent	% of airports in another continent among the first 3 competitors	% of airports in another continent among the first 5 competitors
World	0,0%	6,7%	30,0%
NA-EU	16,7%	56,7%	100,0%
LA-EU	26,7%	43,3%	43,3%
AS-EU	23,3%	33,3%	33,3%
AS-NA	6,7%	50,0%	70,0%

Table 4. Percentage of airports located in different continents among the main competitors.

	United States - Europe O-D, year 2008								United States - Europe O-D, year 2007							
Rank	**Code**	**O-D (%)**	**Freq. (f)**	**Average no. step**	**Travel Times**	**Waiting time**	**Routing Factors**	**O-D by 1st competitor**	**C ode**	**O-D (%)**	**Freq. (f)**	**Average no. step**	**Travel Times**	**Waiting Time**	**Routing Factors**	**O-D by 1st competitor**
1	LHR	64,5%	5,6	3,20	1.012,4	92,1	1,11	78,3%	LHR	60,7%	6,1	3,30	1.009,1	87,1	1,11	77,4%
2	CDG	57,5%	5,4	3,11	1.013,1	91,9	1,12	87,9%	EWR	59,3%	4,6	2,93	969,3	96,7	1,09	81,6%
3	EWR	56,9%	4,4	2,89	965,3	99,9	1,08	79,4%	JFK	58,3%	5,0	2,99	981,4	93,4	1,09	82,9%
4	JFK	55,3%	4,7	2,90	981,5	101,0	1,09	81,8%	ORD	56,3%	6,0	3,11	1.003,8	89,7	1,13	84,5%
5	FRA	54,0%	4,9	3,11	1.014,4	97,1	1,12	88,6%	CDG	56,0%	5,8	3,13	1.001,7	89,9	1,11	83,8%
6	AMS	53,7%	4,5	3,09	1.014,2	99,7	1,12	87,2%	FRA	55,5%	6,0	3,14	1.007,0	95,4	1,12	84,6%
7	ORD	50,7%	4,6	3,13	1.011,0	96,1	1,13	82,5%	AMS	54,9%	4,6	3,19	1.011,2	97,7	1,12	82,3%
8	ATL	49,5%	4,9	2,90	1.007,7	93,7	1,15	87,3%	IAD	50,7%	3,8	3,14	986,9	93,9	1,11	84,7%
9	YYZ	44,2%	3,0	3,20	994,7	95,7	1,11	82,9%	ATL	47,1%	4,5	2,94	1.017,5	97,0	1,15	89,0%
10	BOS	38,0%	3,2	3,32	999,2	94,2	1,09	86,7%	PHL	44,6%	3,8	3,14	993,5	96,5	1,10	92,2%
11	DTW	34,5%	3,8	3,21	1.012,6	96,4	1,11	87,6%	BOS	44,5%	3,8	3,32	986,4	91,3	1,09	87,8%
12	MUC	31,3%	3,6	3,28	1.067,4	92,1	1,15	92,1%	YYZ	39,2%	3,0	3,26	1.010,4	93,4	1,11	85,4%
13	DUS	27,8%	2,8	3,44	1.068,1	94,2	1,12	92,9%	DTW	38,0%	4,2	3,27	1.012,9	92,0	1,11	89,0%
14	DUB	26,5%	2,6	3,39	1.017,2	98,1	1,09	85,3%	MUC	34,6%	4,4	3,23	1.051,8	89,5	1,14	95,1%
15	ZRH	26,3%	2,9	3,31	1.071,4	88,4	1,13	95,6%	LGW	29,8%	2,8	3,22	1.026,3	100,5	1,12	87,2%
16	BRU	25,2%	2,7	3,32	1.055,5	95,9	1,12	93,2%	ZRH	29,7%	3,2	3,32	1.055,8	90,9	1,12	95,2%
17	YUL	23,2%	2,4	3,44	1.020,5	98,2	1,10	81,3%	DUS	27,7%	2,6	3,51	1.081,1	92,9	1,12	91,1%
18	MSP	22,8%	3,4	3,35	1.098,1	95,1	1,14	90,5%	BRU	27,5%	2,8	3,36	1.045,0	96,5	1,11	92,8%
19	IAD	22,5%	2,5	3,47	1.079,9	96,0	1,13	89,0%	MAN	24,9%	2,4	3,51	1.034,7	90,6	1,11	82,1%
20	CVG	20,8%	2,6	3,29	1.053,2	89,3	1,12	91,0%	DUB	23,6%	2,4	3,46	1.019,5	99,7	1,09	85,0%
21	DFW	20,8%	4,8	3,26	1.108,1	95,0	1,15	91,9%	MSP	22,4%	3,4	3,39	1.087,1	94,4	1,14	91,6%
22	MAD	20,7%	4,4	3,20	1.045,4	96,0	1,15	87,3%	MAD	21,9%	4,7	3,23	1.037,7	92,0	1,14	88,8%
23	CPH	19,2%	2,7	3,34	1.074,0	97,1	1,17	94,5%	CPH	21,2%	2,9	3,37	1.060,8	96,3	1,16	92,2%
24	MAN	18,9%	2,5	3,55	1.048,2	88,4	1,11	87,6%	DEN	20,1%	4,5	3,35	1.118,9	96,2	1,13	94,6%
25	IAH	18,4%	4,4	3,16	1.104,2	97,5	1,17	92,3%	YUL	19,0%	2,6	3,47	1.017,1	94,5	1,10	86,8%
26	LGW	16,0%	2,4	3,30	1.056,6	97,0	1,13	88,6%	MXP	18,6%	3,0	3,31	1.073,3	98,3	1,10	97,6%
27	SEA	15,9%	5,2	3,31	1.154,2	105,4	1,17	85,9%	DFW	18,5%	4,1	3,26	1.111,3	92,4	1,14	93,9%
28	DEN	14,3%	3,4	3,51	1.155,5	112,8	1,13	93,6%	CVG	18,3%	2,7	3,40	1.060,4	86,7	1,12	95,1%
29	LAX	14,0%	4,9	3,23	1.155,6	99,8	1,16	87,6%	CLT	18,0%	2,7	3,36	1.028,8	90,0	1,13	92,7%
30	FCO	13,1%	4,8	3,19	1.062,9	87,4	1,11	97,7%	LAX	17,9%	7,2	3,25	1.120,3	87,2	1,16	92,6%

Table 5. The top 30 hubs for O-D connections between the US and Europe in 2007 and 2008, and various performance indicators. The airports are ranked by the fraction of O-D pairs serviced. All indicators are weighted by offered seats at the origin and destination airports. The fraction of an airport's O-D share contested by the first competitor is also reported. For further details on how these items are calculated, see the text.

	First 10 hubs			**From 11th to 20th**			**From 21st to 30th**		
	2008	**2007**	***t*-test**	**2008**	**2007**	***t*-test**	**2008**	**2007**	***t*-test**
O-D share	**52,4%**	**54,3%**	**51%**	**26,1%**	**32,0%**	**4%**	**17,1%**	**19,6%**	**3%**
Average Frequency	4,53	5,02	23%	2,93	3,16	41%	3,94	3,77	77%
Average Number of Steps	3,09	3,10	81%	3,35	3,35	94%	3,30	3,34	46%
Average Travel Times (min)	1.001,4	998,1	66%	1.054,4	1.032,4	10%	1.096,5	1.071,6	20%
Average Waiting times (min)	96,1	93,7	14%	94,4	93,7	69%	97,6	92,8	9%
Average Routing Factors	1,11	1,11	97%	1,12	1,11	26%	1,15	1,13	18%
O-D contented by the first competitor	84,3%	84,3%	97,7%	89,9%	89,1%	68,5%	90,7%	92,6%	24,7%

Table 6. Hub competition on the US-EU market in 2007 and 2008. The *t*-test column indicates the likelihood of the null hypothesis: that the 2007 and 2008 values are drawn from the same distribution. Thus, lower percentages indicate higher confidence that the performance indicators changed significantly.

	North America– Europe O-D							1° competitor						2° competitor		3° competitor	
Rank	**Code**	**O-D (%)**	**Freq. (f)**	**Average no. step**	**Travel Times (tt)**	**Waiting time (wt)**	**Routing Factors (rf)**	**code**	**O-D (%)**	**f ratio**	**tt ratio**	**wt ratio**	**rf ratio**	**code**	**O-D (%)**	**code**	**O-D (%)**
1	LHR	64,7%	5,5	3,15	998,8	92,8	1,11	CDG	77,3%	0,87	1,00	0,97	1,01	FRA	74,6%	AMS	72,9%
2	CDG	56,8%	5,4	3,09	1.000,5	91,8	1,12	LHR	88,2%	1,14	0,99	1,02	0,98	FRA	81,1%	AMS	78,5%
3	EWR	54,7%	4,4	2,88	961,8	99,8	1,09	LHR	79,2%	1,29	0,99	0,93	1,01	JFK	78,6%	ATL	74,6%
4	FRA	54,1%	4,8	3,07	1.001,3	97,4	1,12	LHR	89,1%	1,28	0,99	0,96	0,97	CDG	85,0%	AMS	78,1%
5	AMS	53,7%	4,4	3,07	1.005,7	99,8	1,12	LHR	87,7%	1,35	0,99	0,97	0,99	CDG	82,8%	FRA	78,7%
6	JFK	52,9%	4,7	2,90	979,7	100,9	1,09	EWR	81,3%	0,90	1,00	0,98	1,00	LHR	80,5%	CDG	74,8%
7	ORD	48,2%	4,6	3,13	1.010,3	96,1	1,13	EWR	82,3%	0,95	0,99	1,01	0,97	LHR	80,6%	JFK	78,3%
8	ATL	46,6%	4,9	2,90	1.007,7	93,7	1,15	EWR	87,3%	0,98	0,99	1,07	0,93	JFK	82,6%	LHR	80,4%
9	YYZ	43,2%	3,0	3,17	987,6	95,4	1,12	LHR	81,9%	1,87	0,98	0,96	1,00	EWR	80,9%	JFK	77,7%
10	BOS	36,2%	3,2	3,32	997,2	94,3	1,09	JFK	86,6%	1,76	0,97	1,01	1,00	EWR	84,6%	LHR	79,3%
11	DTW	32,5%	3,8	3,21	1.012,6	96,5	1,11	EWR	87,6%	1,29	0,98	1,03	0,98	LHR	84,8%	ATL	84,3%
12	MUC	31,3%	3,6	3,25	1.055,3	91,9	1,15	LHR	92,4%	1,84	0,97	1,04	0,96	CDG	89,3%	FRA	88,8%
13	DUS	27,9%	2,8	3,41	1.056,5	93,9	1,12	LHR	93,3%	2,33	0,96	0,96	0,99	CDG	90,6%	FRA	89,3%
14	ZRH	26,2%	2,9	3,29	1.060,4	88,4	1,12	LHR	95,6%	2,33	0,96	1,06	0,97	CDG	94,0%	FRA	90,8%
15	DUB	25,9%	2,6	3,38	1.013,2	98,1	1,10	LHR	85,7%	2,46	0,97	0,95	1,02	AMS	80,4%	CDG	79,2%
16	BRU	25,2%	2,7	3,30	1.045,9	96,0	1,11	CDG	93,1%	2,39	0,97	0,99	1,00	LHR	92,2%	FRA	90,0%
17	YUL	23,4%	2,6	3,37	991,6	96,9	1,11	LHR	82,3%	2,21	0,97	0,95	0,99	CDG	77,4%	FRA	77,4%
18	MSP	21,6%	3,3	3,35	1.097,5	95,2	1,14	ORD	90,1%	1,56	0,97	1,05	1,00	LHR	89,0%	EWR	86,6%
19	IAD	21,3%	2,5	3,45	1.076,7	96,1	1,13	EWR	88,9%	2,03	0,97	0,95	0,98	ORD	86,5%	JFK	86,1%
20	MAD	20,4%	4,4	3,18	1.039,9	96,0	1,15	LHR	87,4%	1,34	0,98	0,98	0,97	CDG	84,2%	JFK	75,9%
21	CVG	19,6%	2,6	3,29	1.053,2	89,3	1,12	EWR	91,0%	1,95	0,98	1,13	0,97	LHR	90,3%	ORD	89,9%
22	DFW	19,6%	4,8	3,26	1.108,1	95,0	1,15	ORD	91,9%	1,07	0,97	1,09	0,94	ATL	89,0%	EWR	86,9%
23	MAN	19,0%	2,4	3,52	1.040,3	88,9	1,11	LHR	88,2%	2,82	0,97	0,99	1,01	AMS	82,4%	EWR	78,6%
24	CPH	18,5%	2,7	3,33	1.070,7	96,7	1,17	LHR	94,6%	2,39	0,97	1,01	0,97	AMS	92,2%	FRA	90,0%
25	IAH	17,3%	4,4	3,16	1.104,2	97,5	1,17	ORD	92,3%	1,35	0,97	1,03	0,92	ATL	88,8%	LHR	86,3%
26	LGW	16,7%	2,3	3,25	1.044,7	98,7	1,13	LHR	85,3%	2,64	0,97	0,95	0,99	CDG	83,0%	JFK	82,4%
27	SEA	15,7%	5,1	3,30	1.150,9	105,3	1,17	LHR	86,5%	1,56	0,99	0,88	1,00	AMS	76,5%	FRA	75,5%
28	DEN	13,4%	3,4	3,51	1.155,5	112,8	1,13	ORD	93,6%	1,56	0,98	0,90	0,98	LHR	88,5%	CDG	85,8%
29	LAX	13,2%	4,9	3,23	1.155,6	99,7	1,16	LHR	87,6%	1,28	1,00	0,92	0,96	JFK	85,1%	ORD	83,2%
30	FCO	13,1%	4,7	3,17	1.054,1	87,4	1,11	CDG	97,5%	1,75	0,97	1,04	0,93	LHR	94,2%	FRA	91,4%

Table 7. Top 30 hubs with their three main competitors for the NA-EU market, considering only those O-D connections with travel times <= 120% of the quickest alternative. The ranking is by the fraction of O-D pairs having at least one connection passing through a given airport, weighted by offered seats at the origin and destination airports. Legend: see the legend of table 2.

	Asia– Europe O-D							1° competitor						2° competitor		3° competitor	
Rank	**Code**	**O-D (%)**	**Freq. (f)**	**Average no. step**	**Travel Times (tt)**	**Waiting time (wt)**	**Routing Factors (rf)**	**code**	**O-D (%)**	**f ratio**	**tt ratio**	**wt ratio**	**rf ratio**	**code**	**O-D (%)**	**code**	**O-D (%)**
1	FRA	76,1%	5,1	3,31	1.227,5	108,8	1,13	CDG	79,6%	0,96	1,02	0,89	1,03	AMS	73,4%	LHR	71,5%
2	CDG	63,4%	5,2	3,34	1.284,1	101,3	1,15	FRA	95,6%	1,03	0,99	1,11	0,97	LHR	79,8%	AMS	79,8%
3	AMS	60,7%	3,8	3,36	1.320,0	117,5	1,13	FRA	92,1%	1,44	0,99	0,94	1,00	CDG	83,3%	LHR	76,9%
4	LHR	56,2%	5,0	3,40	1.322,1	96,7	1,15	FRA	96,8%	1,03	0,98	1,13	0,96	CDG	90,0%	AMS	83,1%
5	MUC	55,9%	4,1	3,58	1.320,5	101,5	1,12	FRA	95,0%	1,40	0,97	1,10	1,00	CDG	89,8%	LHR	81,0%
6	PEK	47,1%	5,2	3,34	1.162,5	103,0	1,13	FRA	82,4%	1,10	0,98	0,99	1,01	CDG	73,8%	AMS	71,9%
7	HEL	45,2%	2,5	3,55	1.222,9	108,4	1,10	FRA	90,4%	2,34	0,99	1,00	1,02	CDG	81,3%	AMS	74,4%
8	VIE	42,4%	3,0	3,74	1.377,1	100,6	1,13	FRA	95,8%	2,00	0,96	1,13	1,01	CDG	90,4%	MUC	85,8%
9	ZRH	40,4%	3,6	3,68	1.386,7	99,0	1,12	FRA	97,9%	1,70	0,96	1,14	0,99	CDG	91,3%	LHR	88,2%
10	CPH	37,6%	3,0	3,83	1.386,7	101,7	1,13	FRA	94,9%	2,03	0,96	1,07	1,00	CDG	89,9%	AMS	87,0%
11	FCO	35,3%	3,1	3,61	1.381,6	103,8	1,14	FRA	96,7%	2,13	0,97	1,03	0,97	CDG	93,2%	LHR	88,8%
12	BKK	34,2%	4,4	3,47	1.372,9	104,0	1,13	FRA	87,5%	1,23	0,99	1,07	0,98	CDG	76,9%	AMS	76,5%
13	ICN	32,9%	3,1	3,54	1.273,1	104,5	1,13	FRA	87,5%	1,46	0,98	1,02	1,00	CDG	79,6%	PEK	76,0%
14	HKG	30,1%	4,0	3,43	1.396,3	107,3	1,14	FRA	88,6%	1,19	0,99	1,03	0,97	CDG	81,6%	AMS	78,4%
15	PVG	29,5%	3,4	3,50	1.282,2	104,8	1,21	FRA	87,5%	1,73	0,97	0,98	0,97	PEK	86,7%	CDG	83,2%
16	DUS	29,2%	2,8	3,99	1.400,2	95,4	1,13	FRA	97,5%	2,22	0,96	1,16	0,99	CDG	95,1%	MUC	87,9%
17	DXB	28,2%	2,8	3,26	1.298,8	134,8	1,11	FRA	87,6%	1,97	0,99	0,77	1,00	CDG	78,4%	AMS	76,3%
18	SVO	27,4%	2,4	3,66	1.196,0	107,3	1,11	FRA	93,0%	2,50	0,96	1,04	1,04	CDG	84,3%	MUC	79,8%
19	BRU	27,3%	2,5	4,05	1.424,3	99,8	1,13	FRA	99,4%	2,52	0,95	1,12	0,99	CDG	96,8%	LHR	90,2%
20	ARN	25,9%	2,5	4,01	1.340,4	95,2	1,12	FRA	94,2%	2,31	0,96	1,15	1,02	CDG	88,6%	AMS	83,0%
21	MXP	24,1%	2,6	3,95	1.499,7	103,9	1,13	FRA	97,5%	2,46	0,95	1,05	0,98	CDG	94,7%	LHR	90,9%
22	TXL	24,1%	2,2	4,16	1.423,9	95,4	1,14	FRA	95,8%	2,81	0,95	1,14	1,00	CDG	91,8%	MUC	87,7%
23	IST	22,9%	2,0	3,75	1.452,2	123,5	1,11	FRA	97,0%	3,50	0,96	0,87	1,01	CDG	92,4%	LHR	89,4%
24	SIN	22,7%	5,0	3,42	1.484,2	112,8	1,12	BKK	95,6%	0,88	1,00	0,95	0,97	FRA	87,1%	AMS	80,1%
25	NRT	22,5%	2,7	3,46	1.382,2	118,8	1,19	FRA	86,9%	1,79	0,98	0,88	0,95	CDG	80,2%	ICN	77,2%
26	PRG	20,8%	2,1	4,23	1.475,3	99,3	1,14	FRA	97,4%	2,90	0,95	1,12	1,00	CDG	95,9%	LHR	88,7%
27	KIX	18,7%	3,7	3,56	1.263,4	98,8	1,18	ICN	86,1%	0,88	1,02	0,91	0,97	FRA	82,0%	LHR	72,3%
28	GVA	17,3%	2,5	4,27	1.493,8	97,2	1,13	FRA	98,8%	2,27	0,95	1,22	0,99	CDG	97,6%	LHR	93,5%
29	KUL	17,2%	3,8	3,61	1.490,7	114,6	1,12	BKK	95,6%	1,34	0,98	0,85	0,98	SIN	90,1%	FRA	90,1%
30	HAM	15,3%	2,5	4,31	1.537,2	93,3	1,14	FRA	98,8%	2,61	0,94	1,25	0,98	CDG	97,1%	LHR	93,3%

Table 8. Top 30 hubs with their three main competitors for the AS-EU market, considering only those O-D connections with travel times <= 120% of the quickest alternative. The ranking is by the fraction of O-D pairs having at least one connection passing through a given airport, weighted by offered seats at the origin and destination airports. Legend: see the legend of table 2.

	Latin America– Europe O-D							1° competitor						2° competitor		3° competitor	
Rank	**Code**	**O-D (%)**	**Freq. (f)**	**Average no. steps**	**Travel Times (tt)**	**Waiting time (wt)**	**Routing Factors (rf)**	**code**	**O-D (%)**	**f ratio**	**tt ratio**	**wt ratio**	**rf ratio**	**code**	**O-D (%)**	**code**	**O-D (%)**
1	CDG	67,2%	4,5	3,01	1.099,6	96,0	1,10	MAD	83,3%	0,79	1,002	1,14	1,00	FRA	76,0%	LHR	66,0%
2	MAD	66,1%	3,7	2,94	1.092,6	106,9	1,11	CDG	84,7%	1,25	0,98	0,88	0,99	FRA	67,2%	AMS	58,2%
3	FRA	55,5%	3,7	3,23	1.146,2	99,4	1,12	CDG	92,1%	1,34	0,98	0,98	0,98	MAD	80,1%	LHR	74,2%
4	LHR	47,8%	3,7	3,42	1.166,7	91,4	1,12	CDG	92,6%	1,38	0,97	1,01	1,00	FRA	86,0%	MAD	80,2%
5	AMS	46,8%	3,1	3,30	1.157,9	102,9	1,11	CDG	90,2%	1,60	0,96	1,00	0,99	FRA	81,6%	MAD	81,6%
6	LIS	32,7%	2,4	3,19	1.066,0	97,8	1,07	CDG	78,6%	1,80	0,99	0,99	1,03	MAD	75,3%	GRU	62,8%
7	ZRH	32,6%	2,4	3,50	1.197,4	93,4	1,11	CDG	96,9%	2,16	0,94	1,05	0,99	FRA	90,1%	MAD	89,8%
8	MUC	32,0%	2,8	3,46	1.202,4	89,2	1,13	CDG	93,1%	1,88	0,95	1,09	0,97	FRA	92,6%	MAD	83,3%
9	BCN	31,9%	1,9	3,56	1.170,9	104,1	1,11	MAD	93,9%	2,35	0,95	1,02	0,99	CDG	88,6%	FRA	69,2%
10	GRU	31,2%	4,4	3,20	1.142,7	102,2	1,10	CDG	81,3%	1,03	0,98	0,95	0,97	MAD	76,1%	LIS	65,0%
11	MIA	27,7%	3,2	3,19	1.114,4	102,2	1,18	CDG	79,2%	1,40	0,97	0,95	0,98	MAD	71,1%	ATL	68,7%
12	ATL	26,6%	2,7	3,09	1.136,5	107,4	1,14	CDG	80,6%	1,64	0,98	0,84	1,01	LHR	79,8%	JFK	73,9%
13	JFK	25,8%	3,2	3,06	1.105,0	107,1	1,14	CDG	83,8%	1,37	0,99	0,85	1,02	LHR	78,6%	ATL	76,3%
14	DUS	25,2%	2,4	3,69	1.213,0	93,8	1,11	CDG	97,9%	1,91	0,93	1,01	0,99	FRA	90,7%	MAD	88,4%
15	MXP	25,0%	2,1	3,47	1.208,1	99,6	1,11	CDG	96,3%	2,37	0,95	0,97	0,98	MAD	90,5%	FRA	89,7%
16	EWR	24,9%	2,6	3,14	1.114,3	108,9	1,12	CDG	82,1%	1,60	0,98	0,83	1,03	JFK	77,8%	ATL	76,2%
17	FCO	23,7%	2,9	3,23	1.172,2	94,7	1,12	CDG	96,6%	1,88	0,96	0,98	0,97	MAD	92,8%	FRA	90,7%
18	GIG	22,7%	3,9	3,44	1.159,2	97,4	1,10	GRU	85,8%	1,04	1,00	1,09	1,02	CDG	80,7%	MAD	74,3%
19	BRU	21,7%	2,0	3,60	1.216,4	94,2	1,12	CDG	97,1%	2,49	0,93	1,05	1,00	FRA	90,4%	MAD	87,8%
20	IAH	20,4%	4,2	3,29	1.142,8	100,2	1,11	CDG	81,4%	1,02	0,96	1,00	1,01	LHR	79,6%	FRA	79,0%
21	GVA	19,8%	1,9	3,67	1.225,3	91,0	1,12	CDG	96,5%	2,35	0,93	1,07	0,99	MAD	94,9%	FRA	85,4%
22	SSA	18,8%	1,4	3,56	1.181,9	117,4	1,07	GRU	82,4%	2,51	0,96	0,77	1,06	CDG	81,7%	MAD	77,8%
23	CNF	17,4%	1,5	3,93	1.202,1	84,4	1,12	GIG	85,6%	1,91	0,96	1,12	0,99	GRU	85,5%	LIS	82,4%
24	ORD	16,7%	2,3	3,40	1.159,8	105,7	1,12	LHR	91,0%	1,52	1,00	0,89	1,00	CDG	88,9%	ATL	86,4%
25	DFW	16,2%	3,3	3,52	1.170,0	99,0	1,14	ATL	87,5%	0,83	0,98	1,13	0,96	IAH	87,4%	LHR	83,6%
26	LYS	15,4%	1,5	3,75	1.225,1	93,1	1,12	CDG	99,0%	3,05	0,93	0,99	0,99	MAD	93,6%	FRA	86,3%
27	VIE	13,9%	2,0	3,62	1.262,9	95,9	1,13	CDG	97,8%	2,57	0,93	1,02	0,97	FRA	96,4%	MAD	93,1%
28	CPH	13,5%	2,1	3,60	1.230,0	95,5	1,14	CDG	96,7%	2,05	0,93	1,00	0,96	FRA	93,8%	LHR	91,2%
29	PRG	13,0%	1,6	3,70	1.253,8	96,8	1,12	CDG	98,5%	3,16	0,93	0,97	0,97	FRA	94,5%	MAD	91,9%
30	YYZ	12,9%	1,6	3,71	1.215,2	94,2	1,12	CDG	92,1%	2,63	0,95	0,87	1,02	LHR	87,6%	MAD	84,9%

Table 9. Top 30 hubs with their three main competitors for the LA-EU market, considering only those O-D connections with travel times <= 120% of the quickest alternative. The ranking is by the fraction of O-D pairs having at least one connection passing through a given airport, weighted by offered seats at the origin and destination airports. Legend: see the legend of table 2.

	Asia– North America O-D							1° competitor						2° competitor		3° competitor	
Rank	**Code**	**O-D (%)**	**Freq. (f)**	**Average no. step**	**Travel Times (tt)**	**Waiting time (wt)**	**Routing Factors (rf)**	**code**	**O-D (%)**	**f ratio**	**tt ratio**	**wt ratio**	**rf ratio**	**code**	**O-D (%)**	**code**	**O-D (%)**
1	LAX	65,7%	4,2	3,44	1.417,3	108,5	1,14	SFO	76,0%	0,65	1,02	1,03	0,99	NRT	73,5%	ICN	64,2%
2	NRT	65,5%	3,7	3,39	1.345,6	106,2	1,10	LAX	74,4%	1,05	1,02	1,00	1,04	ICN	74,3%	SFO	64,1%
3	ICN	55,6%	2,9	3,44	1.397,1	116,0	1,11	NRT	87,6%	1,39	0,97	0,92	1,00	LAX	77,1%	PVG	68,7%
4	SFO	55,5%	2,9	3,70	1.474,7	111,4	1,13	LAX	91,3%	1,51	0,98	0,96	1,01	NRT	76,1%	ICN	67,2%
5	ORD	53,7%	4,0	3,45	1.481,1	105,0	1,11	LAX	77,2%	1,12	0,99	1,05	1,02	DTW	74,4%	NRT	72,7%
6	DTW	48,7%	3,7	3,58	1.455,9	108,6	1,11	ORD	82,1%	1,12	0,99	0,96	0,99	LAX	77,2%	NRT	73,3%
7	YYZ	45,2%	3,4	3,52	1.479,4	102,3	1,10	ORD	80,2%	1,37	0,99	0,98	1,00	JFK	75,5%	DTW	74,5%
8	JFK	45,0%	4,0	3,30	1.493,5	107,6	1,12	ORD	81,4%	1,04	1,00	0,95	0,99	EWR	78,9%	YYZ	75,8%
9	PVG	44,4%	3,0	3,53	1.433,1	114,0	1,13	NRT	86,0%	1,39	0,97	0,92	0,98	ICN	85,1%	LAX	77,7%
10	YVR	44,4%	2,7	3,68	1.420,0	98,3	1,10	LAX	86,1%	1,95	0,97	1,10	1,04	NRT	77,9%	SFO	77,4%
11	ATL	43,3%	4,5	3,46	1.513,9	95,8	1,14	ORD	87,4%	0,92	0,98	1,09	0,96	LAX	79,3%	DTW	78,5%
12	SEA	42,0%	3,0	3,75	1.440,8	113,8	1,11	LAX	90,9%	1,73	0,97	0,92	1,04	SFO	83,5%	NRT	79,1%
13	DFW	42,0%	3,4	3,58	1.518,5	102,3	1,13	LAX	89,9%	1,42	0,97	1,09	0,99	ORD	83,1%	SFO	80,8%
14	EWR	39,9%	3,2	3,35	1.529,2	113,7	1,11	JFK	89,0%	1,39	1,00	0,96	1,00	ORD	83,3%	YYZ	77,8%
15	PEK	39,7%	4,0	3,35	1.390,3	103,0	1,10	NRT	82,8%	1,11	0,97	1,01	1,01	ICN	82,8%	PVG	80,2%
16	MSP	35,9%	2,6	3,73	1.510,1	100,7	1,12	DTW	84,3%	1,61	0,98	1,12	1,00	LAX	84,1%	ORD	82,4%
17	HKG	32,6%	3,4	3,55	1.509,1	111,2	1,14	NRT	84,8%	0,95	0,97	1,04	0,98	ICN	82,6%	LAX	77,8%
18	IAH	32,0%	3,0	3,62	1.550,2	102,6	1,14	LAX	91,2%	1,71	0,96	1,05	0,98	ORD	86,8%	SFO	83,0%
19	LHR	25,3%	3,4	3,49	1.563,0	102,2	1,16	JFK	85,1%	1,46	0,99	0,97	0,96	EWR	78,7%	ORD	76,0%
20	KIX	25,1%	2,2	3,57	1.356,0	114,8	1,13	NRT	97,7%	1,91	0,97	0,92	0,98	LAX	75,6%	ICN	75,4%
21	CVG	24,2%	2,4	3,98	1.584,3	98,8	1,11	ORD	91,4%	2,07	0,96	1,10	0,99	DTW	88,2%	JFK	84,7%
22	PDX	23,7%	2,4	4,09	1.470,9	113,5	1,11	LAX	96,2%	2,30	0,95	0,99	1,03	SFO	86,3%	SEA	81,6%
23	TPE	23,5%	2,3	3,74	1.487,0	113,2	1,13	NRT	87,1%	1,68	0,96	0,99	0,97	ICN	85,2%	LAX	79,8%
24	CLE	22,9%	2,4	4,03	1.546,8	98,1	1,12	ORD	90,1%	2,15	0,96	1,08	0,99	DTW	88,3%	YYZ	86,6%
25	IAD	22,6%	2,3	3,96	1.611,2	101,4	1,13	ORD	94,3%	2,21	0,96	0,98	0,97	YYZ	87,7%	DTW	86,3%
26	FRA	21,4%	2,6	3,51	1.579,6	110,0	1,16	LHR	90,8%	1,35	1,00	0,89	1,00	JFK	87,8%	EWR	82,7%
27	DEN	20,8%	2,3	4,06	1.582,3	108,5	1,14	LAX	94,5%	2,32	0,94	1,05	0,99	SFO	88,3%	ORD	79,2%
28	CDG	20,4%	2,9	3,64	1.603,8	103,9	1,16	LHR	91,4%	1,26	0,98	0,95	0,99	JFK	87,4%	FRA	85,9%
29	BOS	19,7%	2,9	3,93	1.601,4	101,1	1,12	JFK	87,4%	1,75	0,95	1,07	0,98	ORD	87,2%	YYZ	85,9%
30	SAN	18,2%	2,1	4,37	1.586,5	91,1	1,11	LAX	99,7%	2,54	0,93	1,18	1,00	SFO	95,4%	DFW	75,5%

Table 10. Top 30 hubs with their three main competitors for the AS-NA market, considering only those O-D connections with travel times <= 120% of the quickest alternative. The ranking is by the fraction of O-D pairs having at least one connection passing through a given airport, weighted by offered seats at the origin and destination airports. Legend: see the legend of table 2.

Airport code	Country Code	City name
AF		
CAI	EG	Cairo
CMN	MA	Casablanca
CPT	ZA	Cape Town
JNB	ZA	Johannesburg
LOS	NG	Lagos
NBO	KE	Nairobi
AS-SW		
ADL	AU	Adelaide
AKL	NZ	Auckland
BKI	MY	Kinabalu
BKK	TH	Bangkok
BLR	IN	Bangalore
BNE	AU	Brisbane
BOM	IN	Mumbai
CAN	CN	Guangzhou
CCU	IN	Kolkata
CGK	ID	Jakarta
CHC	NZ	Christchurch
CJU	KR	Jeju
CKG	CN	Chongqing
CMB	LK	Colombo
CSX	CN	Changsha
CTS	JP	Sapporo
CTU	CN	Chengdu
DEL	IN	Delhi
DLC	CN	Dalian
DPS	ID	Bali
FUK	JP	Fukuoka
GMP	KR	Seoul
HAK	CN	Haikou
HAN	VN	Hanoi
HGH	CN	Hangzhou
HKG	HK	Hong Kong
HKT	TH	Phuket
HND	JP	Tokyo
HYD	IN	Hyderabad
ICN	KR	Seoul
ITM	JP	Osaka
KHH	TW	Kaohsiung
KHI	PK	Karachi
KIX	JP	Osaka
KMG	CN	Kunming

Airport code	Country Code	City name
KOJ	JP	Kagoshima
KUL	MY	Kuala Lump
MAA	IN	Chennai
MEL	AU	Melbourne
MFM	MO	Macau
MNL	PH	Manila
NGO	JP	Nagoya
NKG	CN	Nanking
NRT	JP	Tokyo
OKA	JP	Okinawa
PEK	CN	Beijing
PER	AU	Perth
PUS	KR	Busan
PVG	CN	Shanghai
SGN	VN	Ho Chi Minh
SHA	CN	Shanghai
SHE	CN	Shenyang
SIN	SG	Singapore
SUB	ID	Surabaya
SYD	AU	Sydney
SZX	CN	Shenzhen
TAO	CN	Qingdao
TPE	TW	Taipei
TSA	TW	Taipei
URC	CN	Urumqi
WLG	NZ	Wellington
WUH	CN	Wuhan
XIY	CN	Xian
XMN	CN	Xiamen
EU		
AGP	ES	Malaga
ALC	ES	Alicante
AMS	NL	Amsterdam
ARN	SE	Stockholm
ATH	GR	Athens
BCN	ES	Barcelona
BGO	NO	Bergen
BGY	IT	Milan
BRS	GB	Bristol
BRU	BE	Brussels
BUD	HU	Budapest
CDG	FR	Paris
CGN	DE	Cologne

Airport code	Country Code	City name
CIA	IT	Rome
CPH	DK	Copenhagen
CTA	IT	Catania
DME	RU	Moscow
DUB	IE	Dublin
DUS	DE	Dusseldorf
EDI	GB	Edinburgh
FCO	IT	Rome
FRA	DE	Frankfurt
GLA	GB	Glasgow
GVA	CH	Geneva
HAJ	DE	Hanover
HAM	DE	Hamburg
HEL	FI	Helsinki
IST	TR	Istanbul
KBP	UA	Kiev
LED	RU	S.Petersburg
LGW	GB	London
LHR	GB	London
LIN	IT	Milan
LIS	PT	Lisbon
LPA	ES	Las Palmas
LPL	GB	Liverpool
LTN	GB	London
LYS	FR	Lyon
MAD	ES	Madrid
MAN	GB	Manchester
MRS	FR	Marseille
MUC	DE	Munich
MXP	IT	Milan
NAP	IT	Naples
NCE	FR	Nice
ORY	FR	Paris
OSL	NO	Oslo
OTP	RO	Bucharest
PMI	ES	Palma Mall
PMO	IT	Palermo
PRG	CZ	Prague
STN	GB	London
STR	DE	Stuttgart
SVO	RU	Moscow
TLS	FR	Toulouse
TXL	DE	Berlin

Table 111a. List of airports.

Airport code	Country Code	City name	Airport code	Country Code	City name	Airport code	Country Code	City name
VCE	IT	Venice	ATL	US	Atlanta	PHL	US	Philadelphia
VIE	AT	Vienna	AUS	US	Austin	PHX	US	Phoenix
VLC	ES	Valencia	BDL	US	Hartford	PIT	US	Pittsburgh
WAW	PL	Warsaw	BNA	US	Nashville	PVD	US	Providence
ZRH	CH	Zurich	BOS	US	Boston	RDU	US	Raleigh/Durham
LA			BUF	US	Buffalo	RNO	US	Reno
AEP	AR	Buenos Air	BUR	US	Burbank	RSW	US	Fort Myers
BOG	CO	Bogota	BWI	US	Baltimore	SAN	US	San Diego
BSB	BR	Brasilia	CLE	US	Cleveland	SAT	US	San Antonio
CCS	VE	Caracas	CLT	US	Charlotte	SEA	US	Seattle
CGH	BR	Sao Paulo	CMH	US	Columbus	SFO	US	San Francisco
CNF	BR	Belo Horiz	CVG	US	Cincinnati	SJC	US	San Jose
CUN	MX	Cancun	DAL	US	Dallas	SLC	US	Salt Lake City
CWB	BR	Curitiba	DCA	US	Washington	SMF	US	Sacramento
EZE	AR	Buenos Air	DEN	US	Denver	SNA	US	Santa Ana
GDL	MX	Guadalajara	DFW	US	Dallas	STL	US	Saint Louis
GIG	BR	Rio De Jane	DTW	US	Detroit	TPA	US	Tampa
GRU	BR	Sao Paulo	EWR	US	Newark	YEG	CA	Edmonton
LIM	PE	Lima	FLL	US	Fort Lauderdale	YOW	CA	Ottawa
MEX	MX	Mexico City	HNL	US	Honolulu	YUL	CA	Montreal
MTY	MX	Monterrey	HOU	US	Houston	YVR	CA	Vancouver
POA	BR	Porto Alegre	IAD	US	Washington	YYC	CA	Calgary
PTY	PA	Panama City	IAH	US	Houston	YYZ	CA	Toronto
SCL	CL	Santiago	IND	US	Indianapolis			
SJU	PR	San Juan	JAX	US	Jacksonville			
SSA	BR	Salvador	JFK	US	New York			
TIJ	MX	Tijuana	LAS	US	Las Vegas			
UIO	EC	Quito	LAX	US	Los Angeles			
ME			LGA	US	New York			
AUH	AE	Abu Dhabi	MCI	US	Kansas City			
BAH	BH	Bahrain	MCO	US	Orlando			
DMM	SA	Dammam	MDW	US	Chicago			
DOH	QA	Doha	MEM	US	Memphis			
DXB	AE	Dubai	MIA	US	Miami			
JED	SA	Jeddah	MKE	US	Milwaukee			
KWI	KW	Kuwait	MSP	US	Minneapolis			
MCT	OM	Muscat	MSY	US	New Orleans			
RUH	SA	Riyadh	OAK	US	Oakland			
THR	IR	Tehran	OGG	US	Kahului			
TLV	IL	Tel Aviv-Yafo	ONT	US	Ontario			
NA			ORD	US	Chicago			
ABQ	US	Albuquerque	PBI	US	Palm Beach			
ANC	US	Anchorage	PDX	US	Portland			

Table 121b. List of airports.

Figures

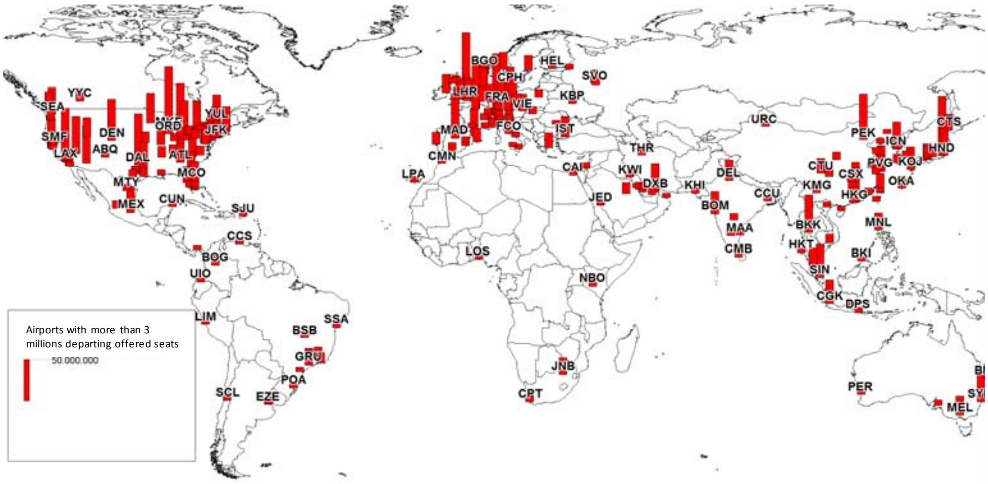

Figure 1. Geographic distribution and seats offered in 2008 by the considered airports.

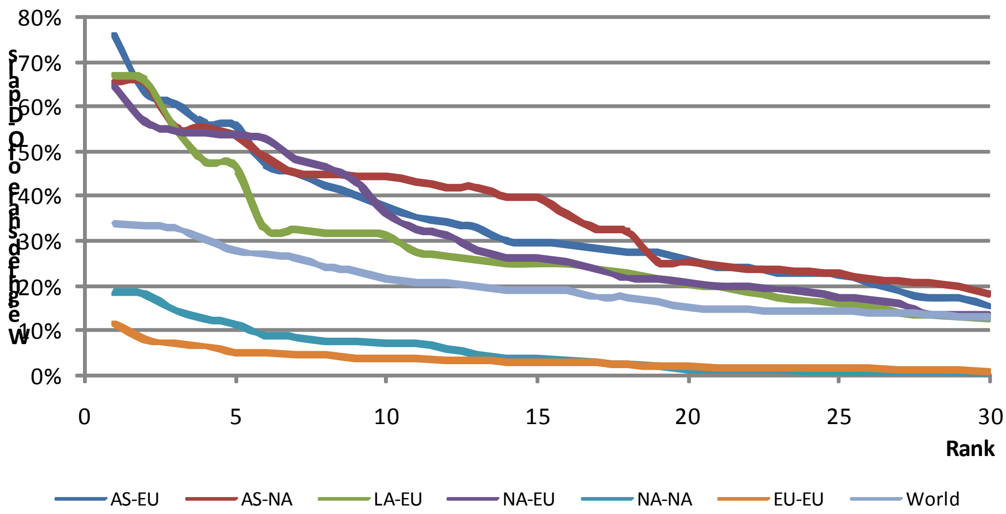

Figure 2. Share of weighted O-D connections for the most important hubs in analyzed markets.

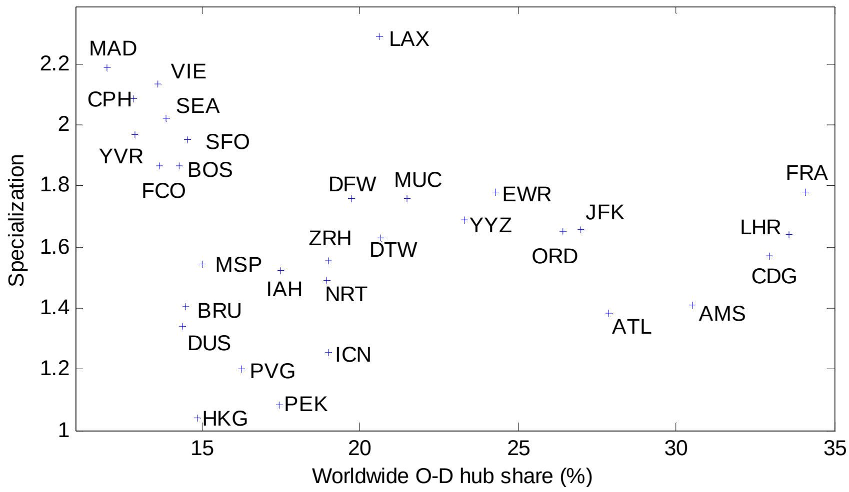

Figure 3. The thirty largest weighted O-D shares, as shown in table 2, are plotted against a hub specialization index. The latter is defined as the ratio between the share in the most relevant market and the average share over all O-D markets in which the hub offers connections.