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A note on how to measure hubbing practices in airline networks

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ABSTRACT

Benefits and costs associated to hubbing practices of airlines are still subject to much debate. In the previous literature, some standard spatial concentration indices have been proposed to measure it. However, we show that these indices are "ill-defined" because they do not take into account the salient characteristic of hubbing: connecting passengers. The purpose of this research is to present a new methodology which avoids the pitfalls of other methods. Our new methodology also analyzes the level of concentration of the connecting passengers studying two different dimensions: hub airports and routes. Finally, we apply our methodology to some US carriers.

1. Introduction

Hub-and-spoke networks (H–S) made an unexpected appearance in the US airline after its deregulation in 1978 and nowadays, this network configuration is adopted by the majority of full-service airlines that operate in deregulated markets. During the past two decades, several works have studied H–S networks from different perspectives.[2] Hubbing indices, using standard concentration indices, have been proposed in the literature to analyze the type of networks that airlines operate (see for example, Saunders and Shepherd, 1993; Borenstein, 1992; Morrison and Winston, 1995; Reynolds-Feighan, 2001; Ghobrial and Kanafani, 1995; Burghouwt et al., 2003; Alderighi et al., 2007).[3] These studies have used Herfindahl indices, Theil entropy measures, Coefficient of Variation and Gini Index to summarize and contrast varying levels of concentration in air transport networks. Reynolds-Feighan (2001) compares and contrasts all of these measures for US airlines and suggests that the Gini index captures a particularly useful set of characteristics of carrier networks. Wojahn (2001) offers a good revision of other concentration indexes which have been applied to the air industry to analyze the network configuration of airlines. He shows that all concentration measures are highly and significantly correlated among each other.

Passengers evaluate the generalized travel costs for flying from city A to city B when they compare indirect vs. direct alternatives, so the network structure of the airlines also has an important impact on demand choices. In the recent period, the new entrant low-cost carriers have had a growing impact on fares and market shares at the larger airports and have generally tended to offer point-to-point direct service in contrast to the legacy 'hubbing' carriers (Windle and Dresner, 1999).

Thus, it is nowadays common to observe the coexistence of different network structures in the airline industry, ranging from pure point-to-point networks (P–P) of low-cost carriers to hub-and-spoke networks of full-service or legacy carriers.

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[2] See, for example, O'Kelly and Miller (1994), Campbell (1994), Toh and Higgins (1985), Kanafani and Ghobrial (1985), McShane and Windle (1989), Hansen (1997), Oum et al. (1995), Hong and Harker (1992), Adler (2001) and Martín and Román (2003, 2004).

[3] Other authors have used some kind of geographical measures of network structure which capture elements of the spatial configuration of individual airline networks. In this group of studies, we can include the use of temporal connectivity indicators proposed by Veldhuis (1997) and Burghouwt et al. (2003).

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These carriers concentrate their networks spatially on a small number of hubs, and operate daily banks of flights through these hubs in a synchronized way (Graham, 1995; Reynolds-Feighan, 2000). This synchronization tries to optimize the potential number of connections offered and the quality of these connections.

Most of the previous studies which have analyzed the structure of airline networks in Europe and the US have considered spatial concentrated networks as equivalents to hub-and-spoke networks. However, Burghouwt et al. (2003) concluded that spatial concentration measures are not suitable for tracing hub-and-spoke developments in Europe. European networks have been the consequence of bilateral air service agreements (ASAs). The ASAs pinned the national flag airlines in their national airports, and a substantial number of services at these airports only provided transfer connections coincidentally and not by the strategic behaviour of airlines.[4] A pre-deregulation European airline network is, therefore, not equivalent to a hub-and-spoke network as long as connection behaviour of passengers is not taken into account. Burghouwt and de Wit (2005) pay attention to the temporal dimension of a hub-and-spoke network, studying the potential connectivity, but the main question to be addressed remains unaltered. Can hub-and-spoke networks be analyzed by spatial concentration indicators or potential connectivity? On the contrary, shouldn't it be more adequate to use the number of connecting passengers to analyze the hubbing activity of airlines?

In this paper, we show that the use of standard concentration indices without analyzing the connecting behaviour of passenger should be avoided. In this paper, we also propose a new methodology to measure the hubbing behaviour of airlines taking into account two different dimensions: the number of connecting passengers and how these passengers are funnelled through the number of hubs also considering the number of alternatives (routes) in order to analyze multi-hub routes. We compare the results of our new methodology for a group of US airlines with the standard Gini index which has been used extensively in the past to measure the hubbing degree of airlines. We conclude that standard spatial concentration indices are not appropriate to study the degree of airlines' hubbing.

The rest of the paper is organized as follows: Section 2 presents a brief review about Gini Index; Section 3 develops a new methodology to measure the degree of airlines' hubbing through what we call the Hubbing Concentration Index (HCI); Section 4 presents an empirical exercise for US carriers where we compare the results of our new methodology with the ones obtained by the ill-defined spatial concentration index and Section 5 concludes.

2. The GINI index

The Gini (GI) methodology was introduced in air transport analysis by Reynolds-Feighan (1998, 2001) for the measurement of spatial or market concentration in airline networks. It is a common measure of inequality between traffic shares (s_i) of each airport inside the network of the airline. Theoretically, GI can vary from 0 to 1 and is calculated according to Eq. (1). However, the last figure can never be reached because a carrier can never concentrate more than 50% of the passengers at any airport. Thus, the maximum value that GI ($\mathrm{GI}_{\max}$) can reach depends on the network size of the airline, and is represented by a situation in which all traffic is concentrated in a single segment between two cities, and the rest of the cities within the network are not serviced by the airline (see Eq. (2))[5]

$$\mathrm{GI} = \frac{1}{2n}\sum_{i=1}^{n}\sum_{j=1}^{n}(s_i - s_j) \tag{1}$$

$$\mathrm{GI}_{\max} = 1 - \frac{2}{n} \tag{2}$$

This dependence makes it very difficult to compare large and small carriers. In order to solve this problem, a normalized Gini index or a corrected version (NG) has been proposed by normalizing the actual GI by the $\mathrm{GI}_{\max}$ corresponding to the carriers' size. Thus, a NG value of 0 does represent an equally distributed network, where all airports have the same traffic share, and it is used to define a non-concentrated point-to-point structure. On the other hand, a value close to 1 does represent unequally distributed flows, where a few airports concentrate the majority of the whole traffic, and it has been used to define a very-concentrated hub-and-spoke network. Studying airlines' network configurations, Burghouwt et al. (2003) proposed NG as a method to correct the biased results produced by the size of the airline network (number of airports). They define the level of NG as the quotient of both measures GI and $\mathrm{GI}_{\max}$, respectively. They argue that in contrast to the use of the standard GI, NG index makes it possible to compare the spatial structure of airline networks independent from network size.

[4] In the US, another good example is Southwest Airlines. In this case, the own company claims not to be a hub-and-spoke carrier, and in fact it does not sell connecting tickets but still has a number of airports where it concentrates traffic (e.g. Chicago Midway, Las Vegas and Baltimore/Washington International).

[5] This is an unrealistic situation because it is necessary to include some zero-traffic airports inside the network. This maximum value represents the greatest inequality in a situation where the whole traffic of the airline is equally distributed between two airports, and the rest of the airports included in the network do not receive any traffic at all. Here, we highlight that GI was first introduced to study income distributions, and in income analysis researchers do require that all zero-income people be included in the sample. However, this situation can not be easily generalized to our case, because it is difficult to argument that any zero-traffic node belongs to a network. In fact, as we see below the vagueness of the figures obtained by the application of normalized Gini indices should be avoided by lack of representativeness.

3. Methodology: a new proposal to measure the hubbing behaviour of airlines

In this section, we propose a new method which solves the problems associated with the use of spatial concentration indices. Our new method is based on two different dimensions. First we measure the number of passengers who make some onward connection to get to the final destination; secondly, we analyze how the passengers, who make connections, are funnelled through the hubs[6] of the network by measuring the concentration of the hubbing and routing. Thus, it is necessary to separate the behaviour of airlines concentrating a high share of passengers in a single airport with no connections. In this case, such airport should not be considered as a "hub" but as a mere "technical base". On the other hand, when the proportion of passengers making an onward connection is near to one, this result will be interpreted as an important share of connecting passengers, and the network structure of the airline is close to the one characterized by H–S networks. This result will rarely correspond to a non-concentrated structure, emphasizing the concept of spatial concentration as a necessary [but not sufficient] condition for the existence of H–S networks. For this reason, high spatial concentrated networks have been considered as H–S networks, and in fact if there is no evidence of connecting passengers in the routes of the airlines, this should not be the case.

In the definition of our new indicator, we start with a measure to study the hubbing behaviour at each of the markets of the airline. This is analyzed as follows:

$$H_{\mathrm{ab}} = \underbrace{C_{\mathrm{ab}}}_{\text{hubbing-connecting share}} \times \underbrace{w_{\mathrm{ab}}}_{\text{concentration within connecting passengers}} \tag{3}$$

The RHS of Eq. (3) is composed of two different elements which account for the percentage of passengers who connect in a single market, and then this figure is weighted according to some measure of concentration regarding all the possible ways to fly from city A to city B. In this way, it allows us to isolate those routes which are not directly serviced and normalize them according to the level of concentration.

We propose, for its simplicity, the Hirschmann–Herfindahl index as a weighting factor through all the possible ways to fly from city A to city B:

$$w_{\mathrm{ab}} = \cdot \sum_{i=1}^{n} s_{i,\mathrm{ab}}^2 \tag{4}$$

where $s_{i,\mathrm{ab}}$ is the traffic share of each airport i, where some passenger is connecting in the route ab.

Finally, the HCI is calculated according to the weighted hubbing index of the routes of the airline:

$$\mathrm{HCI} = \sum\sum \bar{w}_{ij} H_{ij} \tag{5}$$

The indices of the summation $i-j$ represent each of the routes of the airline and $\bar{w}_{ij}$ is the traffic share of the route.

4. An empirical application: the case of the US domestic carriers

In this section, we apply our new hubbing measure (HCI) to analyze the hubbing structure of a representative set of US carriers in their domestic markets. In order to analyze potential differences between different airlines, both national and regional airlines have been included in our study. The database has been obtained from the "Origin and Destination Survey" database from the BTS (Bureau of Transportation Statistics), which includes a 10% sample of all tickets sold in the first quarter of 2005 in the US for the reporting carriers. Data include origin, destination and other itinerary details of passengers transported which are important to our purpose such as, the intermediate stops. We also calculate the normalized Gini index in order to compare the performance of both methodologies.

Results are presented in Table 1. It can be seen that NG indices are really ill-defined to measure the hubbing structure of airlines because:

- NG indices tend to overestimate the hubbing behaviour of airlines because one half of the sample lies in the interval [0.8–0.9].
- Up to five carriers, among those of lower HCI (with less than 5% of connecting passengers), could be wrongly labelled as hubbing airlines according to their NG (greater than 0.6 in all the cases).
- Another five carriers with less than a 0.7% of connecting passengers (P–P carriers) present NG indices that vary from 0.45 to 0.82. So again, it can be seen that NG indices could misguide the conclusion about the hubbing structure of an airline.
- According to the NG index, Aloha Airlines and Delta Airlines should be included in the same subset with respect to its hubbing behaviour. As shown in Martín and Voltes-Dorta (2008, in press), the only thing Delta and Aloha share in common is a very high level of concentration, information from which it is impossible to draw any conclusion about hubbing.

[6] Fotheringham and O'Kelly (1989) defined a hub as a "type of facility located in a network in such a manner so as to provide a switching point for flows between other interacting nodes" (p. 171).

Table 1
HCI and NG indices

Carrier name	Code	Points served	Origin destination passengers	Flight stage passengers	Connecting share	NG	HCI
American Airlines	AA	171	1 405 158	1 909 995	0.342	0.798	0.265
Aloha Airlines	AQ	17	79 736	84 819	0.061	0.821	0.052
Alaska Airlines	AS	160	308 022	367 177	0.177	0.898	0.141
JetBlue Airways	B6	27	304 488	321 066	0.054	0.675	0.052
Continental Airlines	CO	242	693 092	920 872	0.313	0.854	0.254
Independence Air	DH	43	96 017	128 007	0.332	0.620	0.329
Delta Airlines	DL	227	1 606 523	2 421 996	0.479	0.811	0.342
Frontier Airlines	F9	75	130 806	165 900	0.267	0.800	0.263
Airtran Airways	FL	44	261 684	345 015	0.317	0.582	0.297
Allegian Air	G4	15	16 782	16 786	0	0.458	0
Hawaiian Airlines	HA	44	94 738	112 722	0.182	0.920	0.168
America West Airlines	HP	91	411 558	550 008	0.327	0.770	0.253
North American Airlines	NA	7	1 941	1 953	0.006	0.724	0.006
Spirit Airlines	NK	16	117 629	117 762	0.001	0.538	0.001
North West Airlines	NW	261	807 474	1 207 842	0.464	0.835	0.349
Sun Country Airlines	SY	38	38 321	38 330	0	0.824	0
ATA Airlines	TZ	72	124 713	142 123	0.138	0.850	0.119
United Airlines	UA	217	1 075 049	1 569 613	0.424	0.831	0.308
US Airways	US	196	765 707	1 112 326	0.439	0.845	0.298
Southwest Airlines	WN	76	1 589 317	1 811 257	0.137	0.612	0.096
Casino Express	XP	85	2 180	2 180	0	0.619	0
Midwest Airlines	YX	49	75 556	79 276	0.169	0.703	0.167

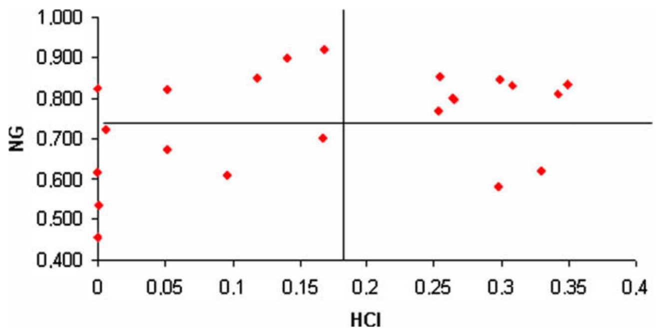

Fig. 1. Hubbing concentration index vs. normalized Gini.

Regarding NG as an ordinal measure, a more effective way to show all the key points that have been aforementioned is to plot each carrier using both indicators (Fig. 1). It is not strange to realize that both rank orderings (NG and HCI) are not necessarily correlated. We use the Spearman's Rank Correlation test,[7] and obtain 0.35. Thus, there is not any strong positive correlation between both methodologies, revealing the inappropriateness of these standard spatial indicators which have been used in the past. So, if we try to measure the hubbing behaviour of airlines by studying it through "standard spatial concentration" indices, the results and conclusions could be wrong and it is recommended to use measures as the one proposed here or the share of connecting passengers which was proposed by Ghobrial and Kanafani (1995).

When we compare our measure with the one proposed by Ghobrial and Kanafani, using the Spearman's Rank Correlation Test, we obtain a value of 0.975 indicating that the connecting share index and the HCI are almost perfectly positively correlated. Nevertheless, once we reached a clear definition of "hubbing" and how to measure it, we expected that HCI could also be used as a measure to further investigate the importance of traffic through each of the equivalent "hub-route" for each airline.[8] Thus, the dynamic evolution of HCI and Ghobrial–Kanafani indices could be used to analyze if airlines are concentrating more or less traffic, and whether this concentration presents an impact on unitary costs of airlines.

[7] The Spearman's Rank Correlation is a technique used to test the direction and strength of the relationship between two variables, which is obtained using the rank orderings of the variables.

[8] The equivalent 'hub-route' number can be obtained by the ratio of the number of connecting passengers (Ghobrial–Kanafani index) and the HCI. This equivalent number is higher as there are more different possibilities to connect for each route.

5. Conclusions

We have seen that among many different problems which exist to measure the hubbing degree of the networks of airlines, lack of adequate data is probably the most important and crucial. Airline statistics do not usually provide enough disaggregate information of the complete trip in order to know all the legs flown by passengers. For this reason, most of the studies are based on standard spatial concentration indices, such as Gini index, to analyze network configurations of airlines.

However, we have shown some important evidence which proves the inappropriateness of standard spatial concentration indicators in measuring "hubbing" behaviour of airlines, by developing a proper methodology to compare its results. Our HCI index takes into consideration the connection behaviour of passengers, and as long as cost conditions impose some geographical concentration, we should weight the hubbing behaviour of airlines by its own concentration. For this reason, we have measured the quality of airline-hubbing considering also the degree of concentration within the connecting passengers.

One of the core aspects of what has been written in the past about hubbing is how the network configuration of airlines affect costs. In fact, some researchers argue that, if two airlines have the same Flight/Stage matrices, there is not any empirical evidence to be inclined into thinking that the airlines present some cost advantages if one has more hubbing than the other. However, this is an assumption which needs to be empirically tested.

In some hub airports the costs associated with luggage handling for connecting passengers are very different from those passengers who start or end their trip in the airport. In fact, Easyjet in Europe does not check your luggage to the final destination when passengers are making some connection at a hub airport; obliging passengers to take the luggage and check it again in the hub airport. Some operational procedures for hubbing airlines are more critical in terms of waves-in and waves-out than for point-to-point airlines, and costs associated to missing connections need also to be contemplated.

Besides, from the demand side it is clear that the products (markets) are non-homogenous. For this reason, the profit function for these two airlines can also be different. The disutility for having connections is something that yield management units of airlines know very well.

In summary, airlines decide their network configuration seeking the profit maximization and it is well known that hubbing-concentration affects this objective function. As we have shown, standard spatial concentration indices, like Gini index, present many shortcomings analyzing the network configurations. For this reason, we introduce a new methodology which corrects the problems associated with the use of the previous measures.

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