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How air transport connects the world – A new metric of air connectivity and its evolution between 1990 and 2012

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ABSTRACT

To understand as to how scheduled air services link a region to other markets, we develop connectivity and hub centrality metrics. These metrics measure the quality of all scheduled air services in terms of frequency, detours, layover time and destination quality using a valuation scale being derived from observed passenger behavior. By computing yearly scores for 1990 to 2012, we analyze the geography of and trends in worldwide connectivity and hub centrality. While we observe significant growth of aggregate connectivity, the trends are heterogeneous with regard to the type of connectivity as well as time and location.

1. Introduction

Air transport connections enable interaction on a global scale, thereby catalyzing globalization (Hummels, 2007) and spurring social and economic development (Lakshmanan, 2011). Consequently, there is a significant societal interest to analyze air transport networks in terms of the connections which airports offer to potential users in its surrounding regions.

Researchers have evaluated air transport networks and their connections with different approaches as summarized in recent reviews by Zanin and Lillo (2013) and Burghouwt and Redondi (2013). While Zanin and Lillo (2013) focus on analyses of network structure and overall network performance, Burghouwt and Redondi (2013) specifically address "connectivity" and "centrality". They define connectivity as the degree of connection between nodes (airports) in a network and centrality as the significance of transfer points in forming indirect connections. In their review, Burghouwt and Redondi (2013) distinguish several metrics, including metrics based on shortest and quickest connection paths (e.g. Malighetti et al., 2008; Paleari et al., 2010; Shaw and Ivy, 1994; Zhang et al., 2010) as well as metrics computed by summing connection quality over all available connections (e.g. Burghouwt and de Wit, 2005; Veldhuis, 1997). However, they do not discuss the relative merits of these metrics.

While "shortest and quickest path" analyses study overall network quality through optimal connections, "connection quality-weighting" approaches focus on the "value" of each connection as perceived by passengers. The latter approaches consider all available connections for reaching each available destination and use a set of assumptions to compute the "connectivity value" of each link. Connectivity values are derived from the relative quality of each connection in terms of passengers' efforts in traveling on that connection (i.e. flight duration and layover time). Transaction-specific idiosyncrasies such as

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tastes or fares, which vary among potential passengers and impact on each passenger's itinerary choice, are not considered since they cannot be aggregated to the route level, yet.

To date, no analysis exists which evaluates "quality-weighted" connectivity and/or centrality at the world's airports with the help of a model, which considers all scheduled flight connections and derives the "value" of each connection from observed passenger behavior. Such a model is developed in this paper. We also compute yearly connectivity scores for all airports worldwide so as to analyze global connectivity and centrality trends between 1990 and 2012. This period is of particular interest since it covers major changes in the industry by means of deregulation and liberalization in different world regions, and the emergence of global airline alliances and new airline business models.

The remainder of this paper proceeds as follows: In Section 2, the building blocks of the metrics are outlined. Section 3 parameterizes the metrics. Global trends in connectivity and centrality between 1990 and 2012 are analyzed in Section 4. Section 5 concludes.

2. Building blocks of the model

Following "connection quality-weighting" approaches (Burghouwt and de Wit, 2005; Veldhuis, 1997), we compute connectivity and centrality by assessing the quality of each air travel opportunity. For this purpose, we assess three different levels (Fig. 1):

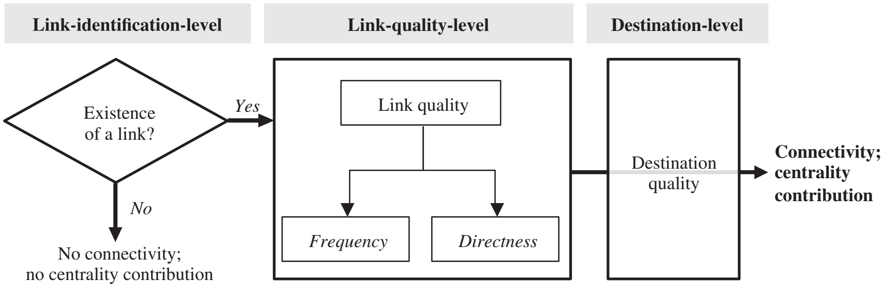

Fig. 1. Building blocks of the connection quality-weighting approach.

First, at the "link-identification-level", we identify available links at each airport. Since air transport is mostly scheduled transport, links are formed through (a series of) scheduled flights. We do not follow shortest and quickest paths approaches (Malighetti et al., 2008; Paleari et al., 2010; Shaw and Ivy, 1994; Zhang et al., 2010), but identify all connections, which are available to passengers at each airport. In so doing, we follow our objective to evaluate connectivity and centrality of the entire network.

Second, the "link-quality-level" assesses the "connectivity value" of each connection. As shown in the itinerary choice literature (Coldren and Koppelmann, 2005; Hsiao and Hansen, 2011), a connection's quality is driven by its frequency and its directness. While the value of higher frequencies results from a reduction in schedule delay, the directness of a flight connection is a function of detours and layovers which both cause disutility to the passenger. As discussed above, transaction-specific idiosyncrasies such as tastes or fares are not considered.

Third, the "destination-level" is used to account for the economic value of a connection in terms of the interaction potential, to which a connection provides access. Most analyses of air transport networks (e.g. Paleari et al., 2010; Shaw and Ivy, 1994) do not consider this dimension since they evaluate traffic patterns and overall network performance. In line with the Economic Geography literature (Redding, 2010), we model destination quality so that we meet our objective of assessing connection quality. In turn, our connectivity metric draws upon the accessibility concept as defined in the land-use and planning literature (Hansen, 1959; Harris, 1954). In particular, it is similar to transport-induced accessibility metrics, which map the level of potential interaction accessible through transport from a specific location (Geurs and van Wee, 2004).

3. The model

3.1. The connectivity model

In line with destination-quality weighting approaches (Burghouwt and de Wit, 2005; Veldhuis, 1997), the Global Connectivity Index (GCI) sets out to measure the quality and quantity of all available connections, which are available to passengers at a specific airport during a defined time period. To compute the Global Connectivity Index score $GCI_{a,t}$ for an airport a in year t, let $D_{a,t}$ be the set of all destination airports that can be reached from airport a in year t and $\mathcal{R}_{a,t}$ be the set of all routings which are available at airport a in year t. Assuming the connectivity metric to be the sum of potential destinations' quality weighted by properties of each routing, we yield Eq. (1).

$$GCI_{a,t} = \sum_{r \in \mathcal{R}_{a,t}} \alpha_{r,t} f_{r,t} w_{d_r,t} \quad (1)$$