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A comparison of indirect connectivity in Chinese airport hubs: 2010 vs. 2015

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A B S T R A C T

Airport hubs' indirect connectivity is important for any aviation network. Indirect connectivity describes the capacity of airport hubs to provide indirect connections over the airline network. As the Chinese aviation industry has experienced development, this paper offers a comparative analysis of indirect connectivity for Chinese airport hubs between 2010 and 2015. We investigate wave-system structures, weighted indirect connectivity (WIC) and indirect connections of the top ten airport hubs in China. In the spatial analysis, this paper surveys the spatial patterns of indirect connections at four important airport hubs. Beijing-Capital airport has strong indirect connectivity worldwide. Pudong and Hongqiao airports worked together to maximize the spatial coverage of Shanghai. Guangzhou-Baiyun airport has sufficient indirect connections across southern China, and it intends to expand its spatial influence into northern cities.

1. Introduction

The Chinese aviation industry has developed in recent years; it has experienced a stable 9% per year increase in the rate of total passengers (China statistical yearbook, 2016). Some airport hubs then emerged. The top 10 airports served more than 55 percent of passengers in 2010. That percentage decreased to 46 percent in 2015 under air deregulation. The flight schedules of these airport hubs influence approximately half of the traffic flow across the Chinese airline network. Hence, the main goal of this paper is to examine the temporal operation of these airport hubs and their connectivity.

The Chinese aviation market and the connectivity amongst airport hubs have been influenced by air deregulation (Wang et al., 2016). Zhang and Round (2008) emphasized that flight scheduling is important in the process of air deregulation in China. For example, airline companies have freedom of scheduling and tighter flight schedules, under air deregulation in Korea and Brazil (Sun, 2015; Oliveira et al., 2016). Because airline companies had to maintain their competitiveness by offering good quality indirect flights at airport hubs, wave-system structures were adopted for flight scheduling. Burghouwt and de Wit (2005) found that wave-system structures were implemented or intensified in the European market under air deregulation. However, few studies to date have examined wave-system structures in Chinese airport hubs. To this end, this paper's first objective is to examine whether Chinese airports have adopted wave-system structures in scheduling.

The second objective is to evaluate the weighted indirect connectivity and spatial distribution of indirect connections at airport hubs in China. Consistent with the study of wave-system structures, this indicator represents the overall performance of flight schedules. Danesi (2006) evaluated the weighted indirect connectivity of large airlines and reported the number of possible indirect connections at European hubs. However, the spatial distribution of indirect connections has not been studied. This research will use a spatial analysis to compare whether airport hubs win or lose indirect connectivity in China between 2010 and 2015.

The paper is organized as follows. Section 2 provides the literature review. Section 3 introduces the period studied and dataset. Section 4 provides the analysis of wave-system structures. Section 5 investigates the weighted indirect connectivity of airports in 2010 and 2015 and then examines the spatial patterns of indirect

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connections via four airport hubs. Section 6 presents the conclusions from the study.

2. Literature review

Aviation markets across the world have gradually experienced deregulation. For example, the United States started experiencing this from the 1970s (Baumol, 1977), the European Union from 1988 (Brueckner and Pels, 2003), China since the 1980s in (Wang et al., 2016). Related studies concluded that aviation markets were more concentrated and, therefore, many airport hubs emerged under deregulation. Bania et al. (1998) provided evidence that the deregulation process affected the spatial configuration of airlines. Following this stream, many studies have investigated the spatial configuration under deregulation, such as the structure changing from a point-to-point system to a hub-and-spokes structure, the concentration of the supply at airport hubs, and the inequality in traffic share of hubs (Alderighi et al., 2007; Dobruszkes et al., 2011; Martin and Voltes-Dorta, 2009; Zhang et al., 2010).

Isolated from the influence of air deregulation, the spatial configuration of airline networks can still affect the market share, robustness, and hierarchy of airports (Calzada and Fageda, 2014; Du et al., 2016a, 2016b). Moreover, studies have examined the accessibility of airline networks and network centrality for the global market (Reynolds-Feighan and McLay, 2006; Guimerà et al., 2003). Studies investigating spatial configuration in the airline network have focused on connectivity, which depends on the number of nodes, edges, and direct connections amongst airports (Paleari et al., 2010; Redondi et al., 2011; Barthélemy, 2011).

Airport hubs are responsible not only for concentrating passenger traffic into central distribution points but also for ensuring that most passengers can connect at a hub for a continuing flight. This is one difference between point-to-point networks and hub-and-spoke networks (Cook and Goodwin, 2008). However, studies on the connectivity of airport hubs have not evaluated whether passengers have indirect options and adequate connecting time at airports. The number of indirect connections and their quality may improve the attractiveness of hub airports because effective transfers only slightly delay total travel time and passengers benefit from low fares (Burghouwt and de Wit, 2005). In such cases, passengers generally prefer to travel via a hub airport. Therefore, direct connections from medium-sized airports to other medium-sized airports have increasingly been replaced by indirect connections via a hub airport.

In terms of the temporal dynamics of airline networks, some studies have considered weighted networks based on the number of flights from schedules (Bonnefoy and Hansman, 2007; Bagler, 2008). For example, Zhang and Round (2008) mentioned the significance of flight scheduling in traffic concentration in their review of the air deregulation process in China. Sun (2015) investigated air deregulation in Korea's aviation market and found that the patterns of flight schedules were clustered. Oliveira et al. (2016) argued that the consequences of air deregulation were tight flight schedules based on an empirical study of Brazil and Shaw et al. (2009) surveyed the quality of direct connections from the temporal perspective.

Veldhuis (1997) proposed an indicator that measures the number of connectivity units; the paper explained that the quality of indirect connections depended on inflight time and transfer time compared to non-stop travel time. Indicators to measure indirect connectivity have been proposed in previous studies (Burghouwt and de Wit, 2005; Danesi, 2006), which investigated flight schedules of European airport hubs. Following these studies, Li et al. (2012) examined the performance of a dual-hub network via indirect connectivity. Furthermore, studies measuring connectivity of network carriers have reported that alliance strategies in the aviation market strengthened connectivity (Malighetti et al., 2008; Hsu and Shih, 2008; Suau-Sanchez and Burghouwt, 2012). In brief, many studies have investigated the temporal configuration of airline networks in various markets, but few such studies have been conducted in China.

3. Data processing

This paper focuses on a comparative analysis between 2010 and 2015 when Chinese aviation market has experienced market-driven consolidation (Wang et al., 2016). In addition, some airport hubs exceeded their capacity after 2010. For instance, the annual traffic volume at Beijing-Capital airport was beyond its capacity in 2012 and the number of passengers served by Shanghai-Pudong airport exceeded its capacity in 2015. Recently, airport hubs have dealt with a huge number of passengers; for example, Shanghai-Hongqiao airport served more than 39 million passengers in 2015. The second reason for this comparative analysis is that some airport expansion projects were completed before 2010; for example, the second terminal of Shanghai-Pudong airport has been in service since 2008. As the previous Baiyun airport was located around the city center in Guangzhou, its capacity could not satisfy the increasing demand. Thus, Baiyun airport was moved to the suburban area of Guangzhou in 2004. Table 1 shows the top ten airport hubs in 2010 and 2015 in China. Based on the annual number of passengers, their rankings change slightly. This paper will focus on the performance of these airports.

In the selection of airport hubs and airlines, we survey flight waves for airlines with high market share because the temporal resource at airports highly depends on airline companies. For instance, an airline company may have a flexible temporal configuration at the base airport, but it is difficult for airlines with low market share to adopt a wave-system structure for scheduling due to the small number of flights and the limited temporal resource. According to the number of flights, China Southern Airlines (IATA code: CZ), China National Aviation Holding Company (i.e., Air China; IATA code: CA), and China Eastern Airlines (IATA code: MU) have taken a dominant position in the Chinese aviation market. In total, the market occupancy of the 'Big Three' airlines was 62.95 percent in 2010 and 56.40 percent in 2015. Note that their market occupancy at airport hubs has decreased under air deregulation.

In addition, some Chinese airlines have cooperated or merged to obtain better temporal resource at airports under market-driven consolidation (Wang et al., 2016), such as sharing flight codes and operating flights together. China Eastern and Shanghai Airlines (IATA code: FM) have kept a strategic cooperation since 2010 and Air China has cooperated with Shenzhen Airlines (IATA code: ZH) for years. Hence, this paper will analyze flights of China Eastern and Shanghai Airlines, Shenzhen Airlines and Air China. If two flights share the same flight code and are operated through strategic cooperation, they are combined as one flight in the analysis.

We source the annual data of flight schedules by week (Data Source: Official Aviation Guide database, i.e., OAG) in 2010 and 2015. Since Saturday is one of the busiest days of the week in the Chinese aviation market, all Saturday flights (annual average) are selected. Then we classify the flights on Saturday by airlines and prepare the dataset of flights as summarized in Table 1. Some flights may have different time slots during different seasons but they are all included in the annual flight schedule. In our analysis, we keep one of the seasonal flights with the highest annual frequency.