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Competition and Sustainability Development of a Multi-Airport Region: A Case Study of the Guangdong–Hong Kong–Macao Greater Bay Area

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Abstract: A new era in the development of multi-airport regions (MARs) has been in China, especially in the construction of global urban areas such as the Guangdong–Hong Kong–Macao Greater Bay Area (GBA). In order to better understand competition and provide significant advice to support sustainable development of Chinese MARs, this paper takes the GBA-MAR as an example, and then explores the competition between airports in this multi-airport region based on route level and its impact on passenger airport choice using three liner models. According to our findings, competition is concentrated on a few air routes in the Northeast–East Coastal region and the Asia-Pacific region, in which all three airports operate. Although the domestic market of the GBA-MAR has been relatively mature, the international air transport market is still left with considerable room, which is also reflected in connections to the world's cities and tourist destinations. In addition, the research also found that different airport brands created by route type significantly affected passenger airport choice. Overall, the study revealed that whether from a supply or demand aspect, competition between airports in a multi-airport region—not just airline competition in a single airport—is an important topic.

1. Introduction

Multi-airport regions have gradually become the sustainable development mode of air transport under the constraints of land use and noise: The expansion of large hub airports is gradually restricted, especially in global city regions [1–3]. Since reform and opening up, China's air transportation has maintained rapid growth and has been the largest air transport market in the Asia-Pacific region [4,5]. Substantial air traffic volume and rapid integration in urban regions have catalyzed the emergence and development of the three most famous world multi-airport regions in China, which include Beijing, Shanghai, and Hong Kong [6].

The Hong Kong multi-airport region, also known as the Guangdong–Hong Kong–Macao Greater Bay Area multi-airport region (GBA-MAR), is important infrastructure in the development and implementation of the "Belt and Road", which also has been recognized by the Chinese government, and an official plan is being formulated to promote the cooperative development of this multi-airport region. As a new national strategy, the GBA is an area of 55,904 km² in South China. Administratively, it consists of 11 municipalities, as shown in Figure 1. They are Guangzhou, Shenzhen, Foshan, Dongguan, Huizhou, Zhongshan, Jiangmen, Zhuhai, and Shiuhing in Mainland China (called the Pearl River Delta—PRD) and the Hong Kong and Macau Special Administrative Region (SAR) [7]. As listed

in the Table 1, there were already seven airports in this region by 2017 (a total of 20,122.3 million passengers), but only Hong Kong International Airport (HKG), Guangzhou Baiyun International Airport (CAN), and Shenzhen Bao'an International Airport (SZX) reached the "First Class Civilian Airport Standard" of the Civil Aviation Administration of China (CAAC), and the market share of all of these three airports was over 20%, for which they could be classified as the major airports in this multi-airport region [2,8,9]. Therefore, in terms of comparability, what we consider in the following are only the three major airports in the GBA, which can almost indicate the competition situation in this MAR. Furthermore, according to driving times and distances between airports, HKG–SZX is more compact than SZX–CAN or CAN–HKG. With the opening of the Hong Kong–Zhuhai–Macau Bridge in 2018, the links between two SARs and the mainland were further strengthened, which also improved surface accessibility between the three airports and intensified their competition. Thus, local government, airport, and airline authorities have a strong interest in seeking a cooperative and sustainable development path for the GBA-MAR.
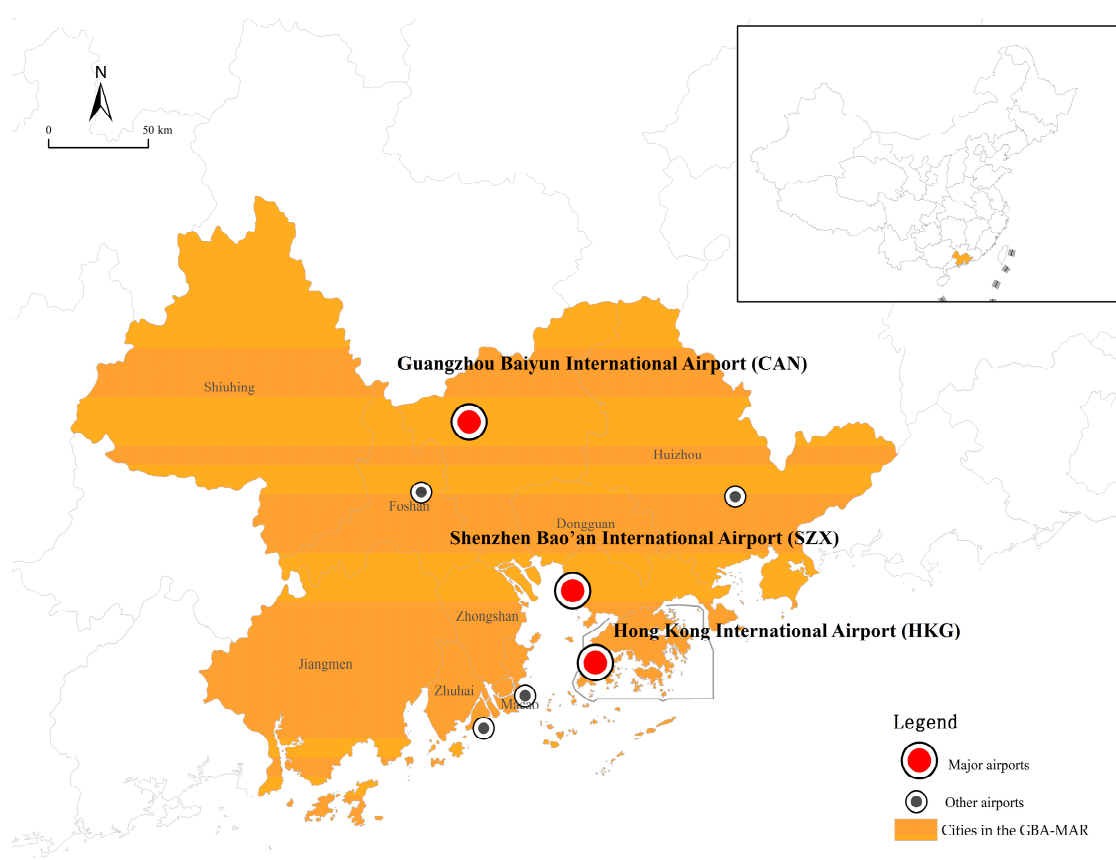

Figure 1. The Guangdong–Hong Kong–Macao Greater Bay Area multi-airport region (GBA-MAR).

Table 1. Distribution and traffic volume in the GBA-MAR in 2017.

Airport	Passenger Enplanement (Millions)	Market Share Within	Distances (km) and Driving Times (min)		
			HKG	CAN	SZX
HKG	72.0	35.8%		195.2 km/151 min	75.7 km/93 min
CAN	65.8	32.7%	195.2 km/151 min		131.3 km/100 min
SZX	45.6	22.7%	75.7 km/93 min	131.3 km/100 min	
Other airports	17.8	8.8%			
Total	20,122.3	100%			

Note: HKG is the code for the Hong Kong International Airport, CAN is the code for the Guangzhou Baiyun International Airport, and SZX is the code for the Shenzhen Bao'an International Airport.

However, how to coordinate airports within a MAR has always been a common dilemma from either the supply or demand perspective. From the perspective of supply, a range of research by geographers has focused on airline competition, especially after aviation liberalization implementation in Europe and America. This began with Taaffe (1958), who first analyzed airline competition in the U.S and its changes, along with the era of aviation liberalization [10]. Henceforth, the process of air deregulation and its impacts on airline competition, service, and pricing have raised the interest of many researchers [11–14]. Besides, competitive strategies, economies of traffic, and institutions are also considered when measuring air transport competition [15–17]. In addition to economic studies on the subject, geographers have taken considerable interest in connectivity, accessibility, and network complexity as ways to measure air transport competition [18–24]. Most of the time, the results have been spatially aggregated. A few research works, such as Van Geenhuizen et al. (2007) and Dobruszkes (2009), have made an effort to study competition at the city pairs level in Europe [25,26]. However, what was focused on in these studies were several airlines in one airport, but this did not automatically mean that the carriers operated the same air routes. Furthermore, competition at the city pairs level, especially for airports with overlapping hinterland and air routes, have largely been ignored in the geography of air transportation.

In terms of passenger demand for air transport, relative competition and services at airports within a MAR have greatly impacted overall connectivity, as well as passenger air travel behavior [5]. Research studying passengers' choice of multi-airport areas has been a popular topic since the 1970s, when the phenomenon of regional multiple airports attracted wide attention. The most comprehensive way to conduct travel behavior of passengers in multi-airport areas is to analyze travel times, cost, and other factors, but competition at the city pairs level in multiple airports with the same air routes in a MAR is not always included [27–32].

In brief, some studies may have investigated the aggregated level of competition, but few of them have been based on the air route level, not to mention consideration from both the supply and demand aspects. Moreover, as a special place in China, Hong Kong and Macau have always been neglected when researchers study Chinese airline competition and connectivity [33–40]. This paper summarizes the advanced mode of the competition of multi-airport regions and contributes by combining both the supply and demand perspective to systematically reveal the competition and substitution of airports in MARs. Taking the GBA-MAR as a case study, this paper highlights how much air transport markets have overlapped, how competitive these air transport markets have been, and implications for the substitution of airports from the passenger's point of view.

The rest of the article is divided into four parts. In the first, we address the methodology and data used. This is followed by a quantitative estimate of the level of competition using two different methods. Next, the geography of competition is presented according to region, air route, and nodal city. Third, we take the competition index as a factor and use aggregated data of passenger airport choice to analyze the functional differentiation of three airports. Finally, we try to provide some competition and coordination advice to regional authorities.

2. Materials and Methods

As explained in Section 1, we explore both supply and demand aspects. From the supply perspective, this paper first recognizes the overlapping markets from the air route level and classifies these markets according to the number of operational airports. Then, the number of competitors and a market concentration index are used as measures to evaluate competition in three air transport market types. As a next step, the market concentration index is taken as a factor, along with fare, flights, airport access time, etc., to build three linear models, each for comparing the same routes in the overlapping air transport markets.

2.1. Measuring the Levels of Competition

In the existing measurements of competition on a route level, the number and the market share of competitors are two basic aspects [10,39,40]. In detail, the number of airlines and the Herfindahl–Hirschman Index (HHI) are the most commonly used, despite other indicators, such as different combinations of full-service airlines and low-cost airlines, the share of the biggest airline, entropy, etc. [26,41–44]. In order to measure competition comprehensively and avoid using indicators expressing similar information, two classic indexes are used here to evaluate the competition in the GBA-MAR.

2.1.1. Market Competition Index

The market competition index in each airport route is defined as the number of airlines operating there, which is written

$$C_i = \sum_{j=1}^{N} a_{ij},$$

where $a_{ij} = 1$ when an airline j operates any flight on air route i out of the three major airports in the GBA-MAR and $a_{ij} = 0$ otherwise; N is the number of airlines on air route i; and C_i is the sum of a_{ij} on air route i and reflects how many airlines operate in this market (Appendix C). This means that the higher the index is, the more competitive the market is. Meanwhile, for the sake of classification, we divided the values into four categories, i.e., $C_i = 1, 2, 3 \text{ or} \geq 4$, each representing a different level of competition [40].

2.1.2. Market Concentration Index

As an index of competition, the number of airlines overlooks the problem caused by potentially unequal distribution of air transport market shares among operators. To complement it, the Herfindahl–Hirschman Index (HHI) was used as the other comprehensive competition index indicating the concentration of a market. It is written

$$HHI_i = \sum_{j=1}^{N} S_{ij}^2 = \sum_{j=1}^{N} (f_{ij}/f_i)^2,$$

where f_i is the total flight volume on air route i; f_{ij} is the flight volume of airline j on air route i, here evaluated by flights; and S_{ij} is the market share of airline j on air route i within the three major airports in the GBA-MAR. On air route i, the HHI_i index ranges from 0 to 1, which can be divided into six categories at intervals of 0.2 to represent different levels of competition. If it equals 1, this means that only one airline serves this air route, representing a monopoly market (Appendix C). The other five intervals (i.e., 0.8–1, 0.6–0.8, 0.4–0.6, 0.2–0.4, and 0–0.2) respectively represent monopolistic competition, low competition, medium competition, high competition, and perfect competition [40,41,44].

2.2. Functional Differentiation of Airports

Airports in MARs should not only have geographic relationships, but should also have a consistent "functional" system [5,45]. Some academics have studied the possible impact of price changes at "airport a" on "airport b" when they have similar air transport markets, which can be used to partially demonstrate the correlations between airports in MARs [46–48]. Based on that, Fuellhart et al. (2013) extended the price model and used it to provide evidence that the relative number of passengers between two airports in a MAR varies in relation to variables associated with consumer air travel behavior [45]. Following those leads, here we developed three line models to assess the functional differentiation and possibility of substitution between airports with data of departures from the three major airports (the models were constructed for three combinations, i.e., HKG–CAN, HKG–SZX, and CAN–SZX). According to existing studies on air travel behavior, fares, frequency, airport access times,

and flight times are the dominant factors in passenger airport choices [27–32]. Thus, the models were constructed with relative levels of those factors and the HHI: Relative fares and flights per route for each airport combination (e.g., the fare on the route from origin HKG to destination PEK vs. the fare on the route from origin CAN to destination PEK), relative airport ground accessibility per route (e.g., the ratio between car driving time from the center of the GBA-MAR to HKG and the flight time on the route from origin HKG to destination PEK vs. the ratio between car driving time from the center of the GBA-MAR to CAN and the flight time on the route from origin CAN to destination PEK), relative level of competition (e.g., the HHI index on the route from origin HKG to destination PEK vs. the HHI index on the route from origin CAN to destination PEK), and route type (an indicator if the route is a domestic short-haul, domestic long-haul, international short-haul, or international long-haul route). The model was constructed and is stated as follows:

$$PR_{i\frac{a}{b}} = f(FA_{i\frac{a}{b}}, FQ_{i\frac{a}{b}}, HHI_{i\frac{a}{b}}, AST_{i\frac{a}{b}}, DSR_i, DLR_i, ISR_i, ILR_i) + \varepsilon,$$

where *a* and *b* are airports within the GBA-MAR, and the rest are the following:

- $PR_{i\frac{a}{b}}$ = the natural log of the ratio of passengers on air route *i* to or from airports *a* and *b* in 2017;
- $FA_{i\frac{a}{b}}$ = the natural log of the ratio of average fares on air route *i* to or from airports *a* and *b* in 2017;
- $FQ_{i\frac{a}{b}}$ = the natural log of the ratio of flights on air route *i* to or from airports *a* and *b* in 2017;
- $HHI_{i\frac{a}{b}}$ = the natural log of the ratio of *HHI* on air route *i* to or from airports *a* and *b* in 2017;
- $AST_{i\frac{a}{b}}$ = the natural log of the ratio of airport access time to flight time on air route *i* to or from airports *a* and *b*, where airport access time is measured as the car driving time from the GBA-MAR center to airport *a* or airport *b*, which was extracted from the "OpenStreetMap" on the first Monday in December 2017;
- DSR_i = indicator variable coded "1" if air route *i* is a domestic short-haul route;
- DLR_i = indicator variable coded "1" if air route *i* is a domestic long-haul route;
- ISR_i = indicator variable coded "1" if air route *i* is an international short-haul route; and
- ILR_i = indicator variable coded "1" if air route *i* is an international long-haul route.

The goal of the models was to assess the relationship between competition and relative numbers of passengers on the same route so that we could detect potential substitution from the results of passengers' airport choices. It is important to stress that those variables are the dimensions commonly used to characterize functions in airports and are calculated as ratios.

2.3. Data Processing

2.3.1. Official Aviation Guide (OAG) Flight Schedule

Our analyses of the supply of air services were carried out with the aid of OAG's databases, which included regularly scheduled services from or to the three airports in the GBA-MAR for each month in 2017. For each flight, the service on offer is described exhaustively, indicating origin, destination, the operating airline, code sharing, stopovers, flight time, flight distance, flights, number of seats, etc. All of the stopover air routes are split into two segments, and the data for cities with more than one airport are combined, finally involving 119 airlines, 1.1 million frequencies, and 221.2 million available seats in 294 directed markets.

2.3.2. Marketing Information Data (MIDT)

Data available from the MIDT were used to provide a broad assessment of the spatial associations of the airports within the GBA-MAR and to examine the extent to which they have geographic relationships consistent with a "functional" multi-airport region [5,45].

The original sources of information for the MIDT dataset were Global Distributions Systems (GDS), except for regular dimensions such as operation airline, origin, destination, distance, etc. The metrics, which are edited monthly, also include the number of passengers, cabins, average fare of total passengers, and total revenue. As the flight is an important factor influencing passenger choice, the provider of our data (OAG Traffic Analyzer) combined this dataset with monthly scheduled air services and added flights. However, there were still some limitations with the MIDT dataset that should be acknowledged. The overall level of traffic is edited monthly, so what the dataset indicated was the average level of passenger airport choice results, which contained 215,534 different itineraries and 71.1 million passengers departing from the GBA-MAR (referring to the three major airports).

3. The Supply Perspective: The Levels of Competition

3.1. Overlapping Air Transport Markets in the GBA-MAR

The overlapping air transport markets here mean that more than one of the three major airports within the GBA-MAR provide flights to the same city. Table 2 provides the details of the domestic and international overlapping air transport markets.

Table 2. The overlapping air transport markets of the GBA-MAR in 2017.

Type	Domestic Market		International Market	
	Routes	Flight	Routes	Flight
Monopoly	42	1.9%	85	9.7%
HKG			61	8.7%
CAN	33	1.5%	22	1.0%
SZX	9	0.4%	2	0.0%
Duopoly	60	11.3%	37	26.5%
CAN–HKG	5	1.0%	36	26.3%
SZX–HKG			1	0.2%
CAN–SZX	55	10.4%		
Tripoly	46	86.8%	24	63.8%
Total	148	100.0%	146	100.0%

Note: The codes for the airports are in Table 1.

We observed that in the GBA-MAR, the overlapping markets account for a high proportion both in the domestic and international air transport market, especially in the tripoly market. For the domestic market, there are 148 direct air routes in these airports: 60 air routes are operated in two airports (11.3% of flights), and more than 90% of them are operated both in CAN and SZX. Although the number of air routes in the tripoly market is less than in the duopoly market, the flights account for about 90%. In the international air transport market, the first element to highlight is that although just 24 air routes are operated by the three airports, the percentage of flights is over 60%. Meanwhile, there are 37 air routes operated by two airports (26.5% of flights), mainly in CAN and HKG. However, the picture is very different in the domestic market when it comes to a monopoly market. Over 50% of air routes are operated by just one airport, and they occupy about 10% of flights. HKG has an absolute advantage in this market.

In view of the above, although the three airports all play a role as hubs, CAN and HKG are respectively dominant in the domestic market and international market. Both the domestic and international tripoly markets are concentrated on a small number of air routes, especially the international market, with 24 air routes accounting for only 16.4%. Moreover, we found that SZX is already developed as a strong competitor in the domestic market, with the air route ratio between SZX and CAN at just 1.3. Correspondingly, CAN is in a similar position to SZX when it concerns the international market: The air route ratio between HKG and CAN in this market is 1.5, which indicates

that there is a big gap that exists in international air transportation between HKG and CAN. This gives SZX a chance to develop its own distinct international market.

3.2. Airline Competition in Overlapping Markets

Table 3 describes in detail different types of airline competition in the domestic market. An air transport market operated by more airports always means that more airlines compete in these markets, but this does not mean an equally increasing ratio. Airline competition in the duopoly market is still not obvious, for of the 60 air routes of this type, over 80% of flights are operated by one or two airlines. On the contrary, in the triboly airport operations market, 37 air routes are under the control of four airlines or more, which accounts for 83.6% of total domestic flights.

Table 3. Airline competition for the domestic air transport market in the GBA-MAR in 2017.

Type	Monopoly Airport Operation		Duopoly Airport Operation		Tripoly Airport Operation		Total	
	Routes	Flights	Routes	Flights	Routes	Flights	Routes	Flights
One airline	40	1.8%	22	3.7%	1	0.5%	63	6.0%
CZ	19	0.9%	15	2.8%	1	0.5%	35	4.2%
KA								
ZH	3	0.2%	2	0.2%			5	0.4%
LCC	1	0.0%					1	0.0%
Two airlines	2	0.1%	33	4.9%	2	0.7%	37	5.7%
CZ	2	0.0%	22	1.7%	1	0.1%	25	1.8%
KA					1	0.1%	1	0.1%
ZH			12	1.6%	1	0.3%	13	1.9%
LCC			6	0.3%			6	0.3%
Three airlines			3	0.9%	6	1.9%	9	2.8%
CZ			3	0.3%	5	1.2%	8	1.5%
KA					1	0.1%	1	0.1%
ZH			3	0.4%	2	0.1%	5	0.5%
LCC					2	0.1%	2	0.1%
More than three airlines			2	1.8%	37	83.6%	39	85.4%
CZ			2	1.0%	36	26.6%	38	27.6%
KA					17	4.2%	17	4.2%
ZH			2	0.2%	35	12.7%	37	12.9%
LCC			1	0.1%	33	3.9%	34	4.0%
Total	42	1.9%	60	11.3%	46	86.8%	148	100.0%
CZ	21	0.9%	42	5.8%	43	28.4%	106	35.1%
KA	0	0.0%	0	0.0%	19	4.4%	19	4.4%
ZH	3	0.2%	19	2.4%	38	13.1%	60	15.7%
LCC	1	0.0%	7	0.4%	35	4.0%	43	4.4%

Note: CZ is the code for China Southern Airlines, ZH is the code for Shenzhen Airlines, and KA is the code for Cathay Dragon; LCC represents low-cost airlines.

For the three largest base airlines in the domestic market, the position of the airport almost represents the position of the base airline in this airport, while China Southern Airlines is more than that. Over 55% of domestic flights are controlled by China Southern Airlines, Shenzhen Airlines, or Cathay Dragon. China Southern Airlines accounts for 35% of flights, mainly because China Southern Airlines is not only the largest base airline in CAN but also the second largest airline in SZX, representing the oligopolistic power of China Southern Airlines as one of the national airlines of China.

When we considered low-cost airlines, the largest market for low-cost airlines still belongs to the tripoly airport operation market, with four airlines or more. About 90% of air routes of this type of market were with low-cost airlines, but the corresponding market share was only 4.9%. This means that although low-cost airlines already participate in domestic competition in many air transport markets, it is only at a small scale, which is very different from the situation in the U.S. and Europe [49–53].

Table 4 describes airline competition in the international market. Most air routes in the tripoly airport operation market are at a high level of competition, but a number of air routes lack effective competition.

Table 4. Airline competition in the international air transport market in the GBA-MAR in 2017.

Type	One Airport		Two Airports		Three Airports		Total	
	Routes	**Flights**	**Routes**	**Flights**	**Routes**	**Flights**	**Routes**	**Flights**
One airline	67	5.1%	5	1.2%			72	6.4%
CX	9	1.3%					9	1.3%
CZ	5	0.2%					5	0.2%
ZH	1	0.0%					1	0.0%
LCC	10	0.4%					10	0.4%
							0	0.0%
Two airlines	14	2.7%	11	3.4%			25	6.1%
CX	5	1.0%	6	0.9%			11	1.9%
CZ			6	0.7%			6	0.7%
ZH							0	0.0%
LCC	6	0.6%					6	0.6%
							0	0.0%
Three airlines	4	1.9%	10	6.1%	2	3.2%	16	11.1%
CX	2	0.5%	6	2.2%	2	1.2%	10	3.9%
CZ			9	1.6%	2	0.8%	11	2.4%
ZH							0	0.0%
LCC	2	0.1%	1	0.2%			3	0.3%
							0	0.0%
More than three airlines			11	15.8%	22	60.6%	33	76.4%
CX			7	4.9%	13	13.7%	20	18.6%
CZ			11	3.0%	19	8.2%	30	11.2%
ZH					9	2.0%	9	2.0%
LCC			7	2.1%	15	11.2%	22	13.3%
							0	0.0%
Total	85	9.7%	37	26.5%	24	63.8%	146	100.0%
CX	16	2.8%	19	8.0%	15	14.9%	50	25.7%
CZ	5	0.2%	26	5.3%	21	9.0%	52	14.5%
ZH	1	0.0%	0	0.0%	9	2.0%	10	2.0%
LCC	18	1.1%	8	2.3%	15	11.2%	41	14.6%

Note: CX is the code for Cathay Pacific Airways Limited, which is the largest base airline in HKG for the international market. Note: The codes for other airlines are in Table 3.

A few airlines can monopolize the market operated by the three airports, which is different from the domestic market. About 90% of the air routes in this market are operated by four airlines or more, which accounts for 60.6% of flights. The shares of the flights in the other markets classified are all less than 5%.

For the largest base airlines and low-cost airlines, the performance is similar to the domestic market, but the dominant position of China Southern Airlines changes to Cathay Pacific Airways Limited (with less monopolizing power): 40.2% of flights are operated by China Southern Airlines or Cathay Pacific Airways Limited, and Shenzhen Airlines only participates in the operation of nine routes, accounting for 2.0% of flights. The market for low-cost airlines is also mainly in the overlapping markets operated by more than two airports: 15 low-cost air routes (11.2% of flights) are in the tripoly airport operation market, and the second biggest market for low-cost airlines (7 air routes, 2.1% of flights) is in the duopoly airport operation market. All of them are in a competitive environment (operation by four airlines or more), which is much larger compared to the market share of low-cost airlines in the domestic market.

3.3. Spatial Competition

3.3.1. According to Region

Based on Liu (2005), Table 5 provides disaggregated results for each of the three Chinese regions in 2017 (the Northeast and East Coastal region, the Middle and Near-Reach-West region, and the Far-Reach-West region) [54].

It was no surprise that the most competitive market is the tripoly airport operation market in the Northeast and East Coastal region. But a higher market share does not mean a higher level of competition, which is shown both in the Northeast and East Coastal region market and the Far-Reach-West region market. No matter the share of flights or the average number of airlines, the tripoly airport operation market occupies 87% of domestic flights and about six carriers operate per route, which is more outstanding than the duopoly airport operation market. Moreover, in the tripoly airport operation market, 59 air routes (61% of domestic flights) are to the Northeast and East Coastal region, followed by the Middle and Near-Reach-West region (77 air routes and 36% of domestic flights). The flight shares of both of these two regions are 10 times higher than in the Far-Reach-West region.

From a competition aspect, the Northeast and East Coastal region is the most competitive market, with average values of 0.621 on the HHI and four airlines, but this was not consistent with the regional results of the duopoly airport operation market and tripoly airport operation market. In the duopoly market, the Middle and Near-Reach-West region is the largest market, with 34 air routes and 6% of flights, but the average HHI is higher than the index of the other two regions, especially compared to the small market of the Far-Reach-West region (only 6.2% of domestic flights). Similarly, in the tripoly airport operation market, two air routes (1% of domestic flights) are the most competitive market (with a 0.278 HHI), but not in the Northeast and East Coastal region market (26 air routes and 57% of domestic flights). These results suggest that there are a few air routes in the west, but most of them are operated by three airlines, and their level of competition is relatively balanced. Correspondingly, although many air routes and flights are from GBA-MAR to the other two regions, most of the markets are still under the control of big airlines such as China Southern Airlines and Shenzhen Airlines.

Table 6 reveals the breakdown of the results for worldwide regions in 2017. Compared to the domestic market, the shares of the international market are distributed in a more average way, and the level of competition is relatively higher in all airport operation types. At present, Asia-Pacific is the major area for development and competition, which may be because of economic exchanges and tourism. In the top three biggest regional markets, i.e., Asia-Pacific, Europe, and North America, the tripoly airport operation type is at the highest competitive level, with an HHI of 0.284, 0.309, and 0.408. Although it as an important region for the implementation of the "Belt and Road" strategy, the flights between the GBA-MAR and the Middle East account for just 4% of flights (with 15 air routes), and the market is controlled by several airlines. Moreover, this also shows that Latin America is an empty space for the three airports connected to the world.

Table 5. Competition for the domestic air transport market of the GBA-MAR to/from three Chinese regions in 2017. HHI: the Herfindahl–Hirschman Index.

Airport Operation Type	Northeast and East Coastal Region			Middle and Near-Reach-West Region			Far-Reach-West Region			Total		
	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI
Monopoly	0.8% (13)	1	1.000	1.0% (25)	1	0.974	0.1% (4)	1	1.000	1.9% (42)	1	0.984
Duopoly	3.5% (20)	2	0.735	6.2% (34)	2	0.765	1.7% (6)	3	0.510	11.3% (60)	2	0.729
Tripoly	57.0% (26)	6	0.345	28.6% (18)	6	0.332	1.2% (2)	5	0.278	86.8% (46)	6	0.337
Total	61.2% (59)	4	0.621	35.8% (77)	3	0.732	3.0% (26)	3	0.635	100.0% (148)	3	0.680

Table 6. Competition for the international air transport market of the GBA-MAR to/from worldwide regions in 2017.

Airport Operation Type	North America			Africa			Europe			Asia-Pacific			Middle East			Total		
	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI	Flights (Routes)	Avg. Carrier	Avg. HHI
Monopoly	0.9% (6)	1	0.917	0.4% (3)	1	0.833	1.4% (13)	1	0.924	6.1% (53)	1	0.914	1.0% (10)	1	0.951	9.7% (85)	1	0.917
Duopoly	4.1% (5)	3	0.474	0.8% (3)	1	0.893	4.3% (6)	3	0.525	16.1% (19)	4	0.408	1.3% (4)	2	0.857	26.5% (37)	3	0.524
Tripoly	1.3% (1)	4	0.408				0.5% (1)	4	0.309	60.4% (21)	7	0.284	1.5% (2)	3	0.409	63.8% (24)	6	0.295
Total	6.3% (12)	2	0.690	1.2% (6)	1	0.863	6.1% (20)	2	0.774	82.6% (93)	3	0.669	3.8% (15)	1	0.890	100.0% (146)	3	0.715

3.3.2. According to Route

In order to further analyze the competition level based on route, Figures 2 and 3 highlight the connections that are operated by at least four airlines and characterized by an HHI less than the average value of the domestic or international market.
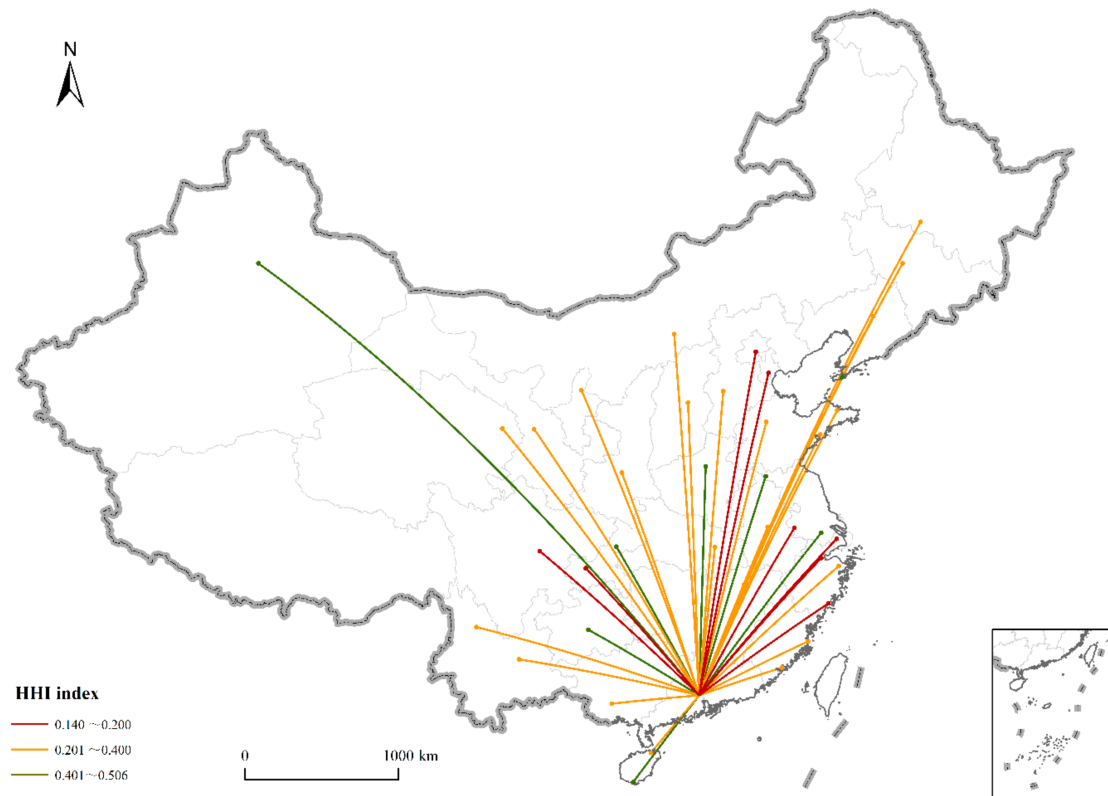

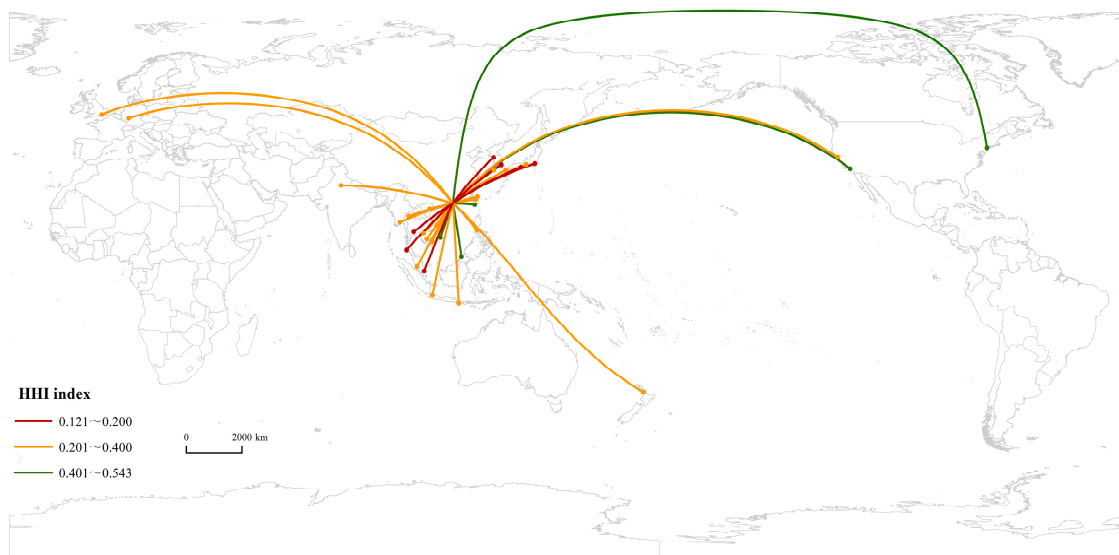**Figure 2.** Domestic competitive air routes ($HHI \leq 0.680, C_i \geq 4$).

Figure 3. International competitive air routes ($HHI \leq 0.715, C_i \geq 4$).

Among the remaining 39 air routes above a medium level, it is no surprise that MAR–Shanghai is the most competitive air route, with the smallest HHI (operated by 12 airlines) (Figure 2). Besides, one interesting result was that as a trunk air route at a large scale, MAR–Beijing is less competitive than seven

air routes, even including MAR–Chongqing and MAR–Chengdu in the Middle and Near-Reach-West region. Meanwhile, at a high level of competition, except for connections between the MAR and domestic major cities, tourist destinations such as Lijiang, Kunming, Haikou, and Xiamen are also in a significant environment. In contrast, as a famous travel city, the air route MAR–Sanya is one of the least competitive of these 39 air routes. One reason may be that because of increasing competition between air transport and the high-speed rail, this has led to the loss of passengers from civil aviation to high-speed rail, especially for a short-haul distance [55,56].

Just like the phenomenon in domestic air routes, we found that most of the air routes are at a high level of competition (Figure 3). All of the seven perfect competitive air routes are for the Asia-Pacific market, except one air route to Singapore, and the rest of the six air routes at this level of competition are all for Thailand, Korea, and Japan. Among these, the top three are MAR–Bangkok, MAR–Seoul, and MAR–Tokyo. This not only suggests intense economic and trade exchanges between China and these three cities, but also tells us the importance of these airports as transfer hubs for GBA–MAR when it develops world air transport networks. Meanwhile, in the less competitive markets (with an HHI from 0.2 to 0.6), air routes to various Asian cities such as Hanoi, Taipei, and Manila have begun to appear. Meanwhile, air routes to cities in Europe and North America, such as Frankfurt, Paris, San Francisco, Amsterdam, and Vancouver, have also become popular choices that airlines in these three airports are interested in.

Overall, for most air transport markets, the more airports that open routes, the more competitive these markets are. On that basis, two types of air routes dominate the map: On the one hand, connections between major urban regions, and on the other, tourist destinations. With limited time resources and airspace, these destinations have become the major targets for airports and airlines in the GBA-MAR.

3.3.3. According to Nodal Cities

As analyzed in Section 3.3.2, the major urban cities and tourist cities are the most competitive destinations for air transport in the GBA-MAR. In order to further explore connections in the GBA-MAR, we tried to find out the nodal cities that may influence future development and competition.

Generally speaking, the air transport connections between the GBA-MAR and nodal cities in the domestic market are much more complete than between the GBA-MAR and nodal cities in the international market (Figures 4 and 5). Meanwhile, competition in the domestic connections is more intense than in the international market, especially for air routes to short-haul cities.

In domestic air transport nodal cities, based on Wu et al. (2014) we selected 90 provincial nodal cities (or above this status) with civil airports [57]. Combined with the top 60 main tourist cities in 2017, 96 relatively important nodal cities with airports were concerned [58]. Figure 4 describes connections of the GBA-MAR with nodal cities in the domestic market. As is shown, the GBA-MAR already overall controls the key nodal cities in China's mainland. Of the 90 nodal cities (excluding cities within the GBA), 83 cities are connected with the MAR, and airports in the rest of the 7 cities all have a small capacity. Besides, 42 destinations are operated by the three airports, and most of these cities are in the Northeast and East Coastal region and the Middle and Near-Reach-West region, while Hohhot and Xining are the only two Far-Reach-West region nodal cities. Among the 27 cities with competition from two airports, 26 operate through CAN and SZX. We can also see the dominant status of CAN in the 14 cities operating through one airport. Furthermore, when we concern cities with both properties, 80% of them are competed for by three airports, and the rest of the 8 cities (Datong, Huangshan, Lianyungang, Nantong, Qinhuangdao, Weihai, Urumqi, and Yinchuan) also have air routes to or from two airports in the GBA-MAR.
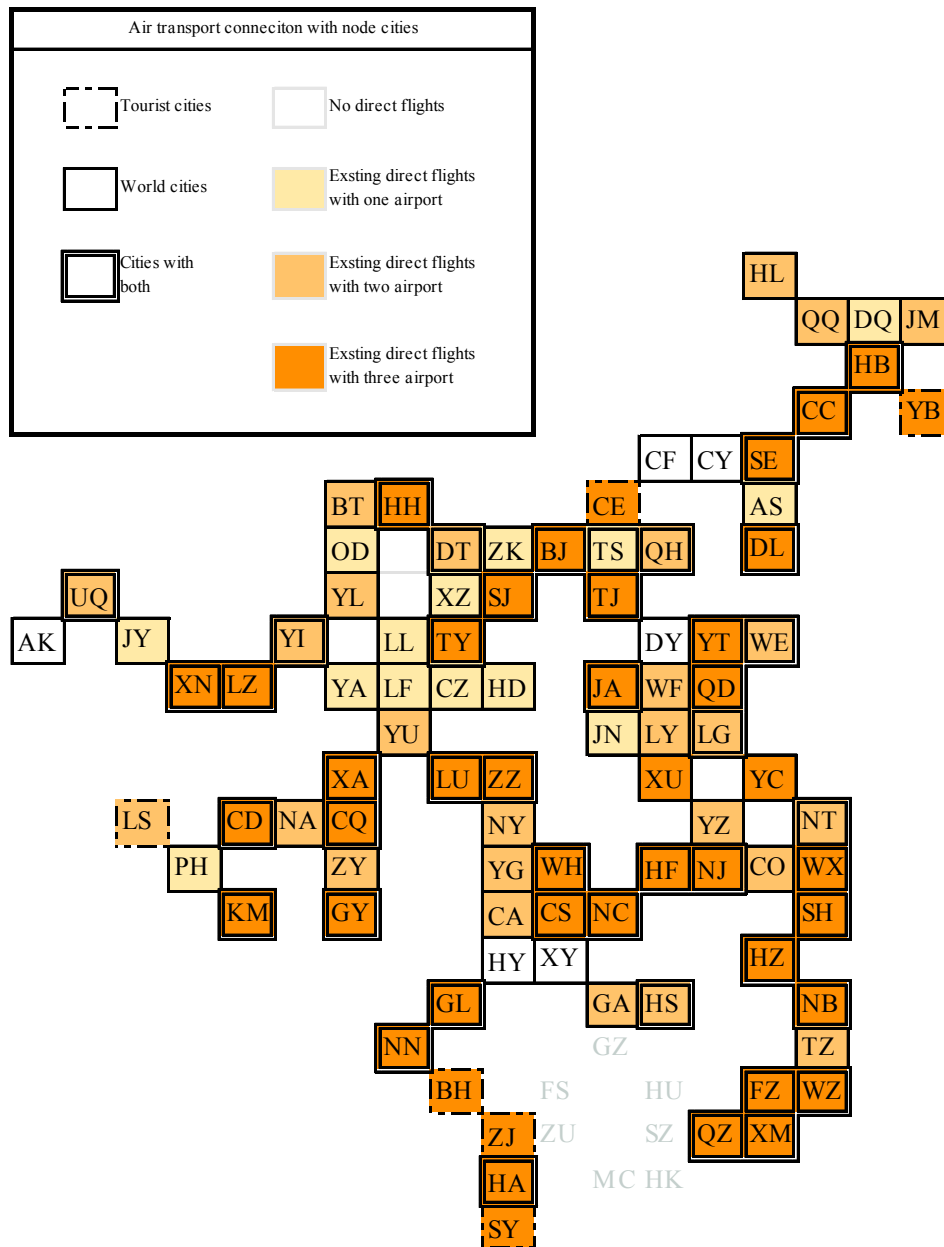
Figure 4. Connections with important nodal cities in the domestic market of the GBA-MAR. Note: Codes for cities are in Appendix A.

For the international air transport nodal cities, based on Taylor and Derudder (2016), there are 152 world cities out of 526 cities, and combined with the top 200 tourist cities from the report of global destination cities index by Mastercard in 2017, there are 151 relatively important nodal cities with airports that are concerned, except for Hong Kong and 4 world cities on the Chinese mainland [59,60]. Figure 5 describes the connections of the GBA-MAR with these world nodal cities in the international market.

Although over half of the 151 important nodal cities (including Taipei) have direct flights to the GBA-MAR, only 14 cities are connected to three airports. For the rest of the 54 cities, the connections with most cities are under the control of one airport. That connection performance becomes much worse when we focus on the 84 cities considered to be both world cities and travel destinations, where only 50 cities have direct flights to the GBA-MAR and over 40% of them are only connected to HKG. This means that these three airports depend heavily on other cities to connect to over 50% of the important nodal cities in the international market, especially CAN and SZX.
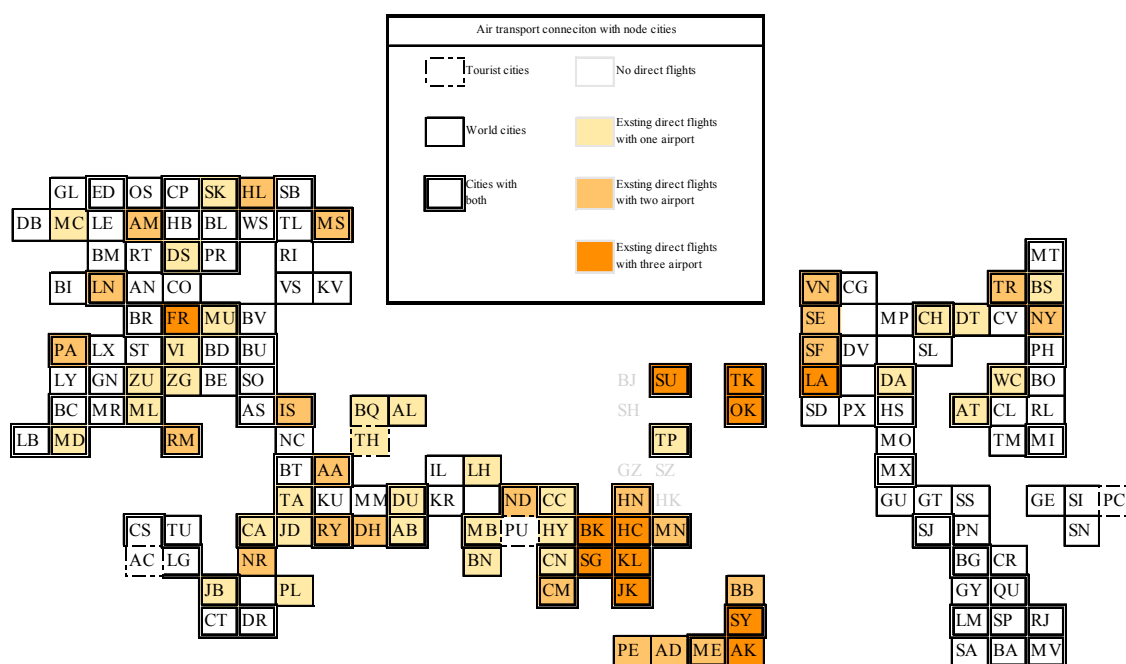

Figure 5. Connections with important nodal cities in the international market of the GBA-MAR. Note: Codes for cities are in Appendix B.

A number of world nodal cities have established air transport connections to GBA-MAR, but they are lacking in competition for the air routes to long-haul nodal cities. Nodal cities such as Bangkok, Ho Chi Minh City, Seoul, Tokyo, Osaka, Kuala Lumpur, Jakarta, Singapore, Sydney, Auckland, Taipei, etc., all have direct flights to three airports in the GBA-MAR. Other cities such as Hanoi, Manila, Brisbane, etc., also have existing direct air transport connections to two airports. However, many important nodal cities considered to be both world cities and tourist cities (short-haul) still only have direct air transport connections to one airport, such as Calcutta, Chennai, Mumbai, Abu Dhabi, etc. Abu Dhabi is a city that can also be a perfect transfer hub (like Dubai), but only HKG has established direct routes to it. In terms of cities farther away from the GBA-MAR, such as Beirut, Athens, Durban, Sofia, and Bucharest, none of them have a direct connection to the MAR.

4. The Demand Perspective: The Functional Differentiation of Airports

The model results for the GBA-MAR were varied (Table 7). Due to the lack of long-haul flight data in the domestic market, the dummy variable for domestic long-hauls was excluded. We found substantial relationships in passenger ratios between CAN–HKG (adjusted $R^2 = 0.827$) and SZX–HKG (adjusted $R^2 = 0.888$), but the adjusted regression for the model of SZX–CAN was much lower.

Table 7. Regression results for route level passenger ratios at airports in the PRD region.

Effect	CAN–HKG		SZX–CAN		SZX–HKG	
	Coefficient (t)		Coefficient (t)		Coefficient (t)	
Avg. fare	−0.620	(−2.897)	−0.182	(−0.649)	−0.216	(−0.791)
HHI	−0.417	(−1.679) ***	−0.154	(−0.496)	−0.386	(−1.419)
Car driving time	−0.455	(−1.307) *	−1.247	(−2.147) *	−0.086	(−0.358)
Flights	0.807	(9.638) ***	0.553	(3.895) ***	0.696	(8.407) ***
Dummy GND	−0.096	(−0.345)	−0.691	(−2.062) **	−0.197	(−0.635)
Dummy GJD	−0.180	(−0.458)	0.317	(0.776)	−0.194	(−0.380)
Dummy GJC	−0.288	(−0.887)	0.121	(0.354)	−0.632	(−1.719)
Constant	1.409	(1.255)	3.582	(1.901) **	0.534	(0.307) *
Number of observations	83		51		49	
Adjusted R^2	0.827		0.445		0.888	

*** Significance levels of 1%; ** significance levels of 5%; * significance levels of 10%.

In the models focusing on the same air routes in three different combinations, positive coefficients of flights were always significant, indicating a positive relationship between the relative level of traffic and the flight ratio. Besides, for the CAN–HKG model, both the fare ratio and the HHI of the air routes were significant. That is, as the relative fare on a route rises at CAN compared to HKG, the relative air route passenger traffic on that route drops at CAN (as we expected). At the same time, the smaller the HHI compared to HKG for air routes is, the higher the relative route passenger traffic from CAN is. This suggests that a higher level of competition at CAN attracts more passengers. Meanwhile, in the SZX–HKG model, except for the dominant effect of the flight ratio, we could see a significant negative effect in the type of long-haul international route, which suggested that if a passenger is on an international long-haul flight, he or she would rather choose HKG. Interestingly, we also found that type of route effect in the SZX–CAN model. The model showed a large negative effect on types of short-haul domestic routes, so this highlights the disadvantage of SZX when it competes with CAN in the short-haul domestic market. In addition, we found a significant effect for the access time ratio of car driving time, but this had no meaning, as the coefficient was counterfactual: This may be because the data used were not the actual access times of each passenger, but only the average access time from the regional center [7].

5. Discussion and Avenues for Further Research

This article aimed at gaining the first sight into air transport competition in the GBA-MAR, which is the first and most mature MAR in China. Considering the MAR as a whole, we focused on "geographically constant" competition at the air route level from the supply perspective, then discussed the functional differentiation of three combinations from the demand perspective. The study's main results are as follows:

- Most of the air transport markets are operated simultaneously by these three airports, which obviously improves the competition level. Meanwhile, among the three airports in the MAR, CAN is the dominant one in the domestic market, and HKG is the dominant one in the international market. This has been recognized by passengers and significantly influences their choices regarding SZX;

- When it comes to spatial competition, for the tripoly airport operation market, the Northeast and East Coastal region and the Asia-Pacific region are retrospectively the biggest markets for domestic air transport and international air transport in the GBA-MAR. Competition still affects only a limited number of air routes in these two regions. Moreover, as a significant factor in passenger choice, competition is an important topic for CAN in the future, especially compared to HKG;

- Looking at connections between the GAB-MAR and major urban cities or tourist destinations, we found that the air transport network has been relatively perfect, while the international air transport market of the MAR is still left with a lot of room. The main competition in the future will most probably come from the international market. Meanwhile, with newly built or expanded airports in Aksu, Chaoyang, Chengde, Chifeng, Dongying, Hengyang, and Xiangyang, future airport construction plans may stimulate more competition.

Based on the discussions above, and considering the sustainable development of MARs, some policy suggestions are provided:

- For the domestic market, Datong, Huangshan, Lianyungang, Nantong, Qinhuangdao, Weihai, Urumqi, and Yinchuan are destinations with low competition but important positions in the air transport network: They can be nodal cities in improving domestic air transport networks. Besides, since there are limits for low-cost airlines, the airlines established as the result of cooperation between big airlines and local governments may be more likely ways to improve competition in CAN and SZX than low-cost airlines in domestic markets because of government policies;
- Meanwhile, for international markets, we should break the predicament of relying on a few airports as transfer hubs and expand the reachable boundaries of the direct air routes of the GBA-MAR. Developing long-haul routes to European and American cities can be a way to solve competition concentrated only in the Asia-Pacific region. This is more important for SZX because of the "Framework Agreement on Strategic Cooperation for Promoting the High-Quality Development of Guangdong Civil Aviation", which was published by the Civil Aviation Administration of China (CAAC). Besides, combined with the "Belt and Road", the Middle East should also be included in the future development of the GBA-MAR.

In general, the model results are noteworthy and provide a good foundation to explore competition at the route level in airports in a MAR and its impact on passenger airport choice.

However, in term of using aggregated data, there were still some limitations to the analysis from a demand perspective: Lots of individual attributes, such as gender, age, occupation, income, and travel purpose, were not included. Average levels of airport access time and airfare were considered in the model, but not actual access time and the airfare for each person. Therefore, a detailed investigation considering both route level competition and other personal attributes can be explored in future research, which could help in understanding the effect of airport competition on heterogeneous people, so that local authorities, airports, and airlines can formulate more elaborate strategies to coordinate competition on various air routes and achieve the goal of sustainable development.

Appendix A

Table A1. List of domestic air transport nodal cities as world cities or tourist destinations with airports.

Name	Code	Name	Code	Name	Code	Name	Code
Aksu	AK	Haikou	HA	Nanchang	NC	Weihai	WE
Anshan	AS	Hailar	HL	Nanchong	NA	Wenzhou	WZ
Baotou	BT	Handan	HD	Nanjing	NJ	Wuhan	WH
Beihai	BH	Hangzhou	HZ	Nanning	NN	WuXi	WX
Beijing	BJ	Harbin	HB	Nantong	NT	Xiamen	XM
Changchun	CC	Hefei	HF	Nanyang	NY	Xi'an	XA
Changde	CA	Hengyang	HY	Ningbo	NB	Xiangyang	XY
Changsha	CS	Hohhot	HH	Ordos	OD	Xining	XN
Changzhi	CZ	Hong Kong	HK	Panzhihua	PH	Xinzhou	XZ
Changzhou	CO	Huangshan	HS	Qingdao	QD	Xuzhou	XU
Chaoyang	CY	Huizhou	HU	Qinhuangdao	QH	Yan'an	YA
Chengdu	CD	Jiamusi	JM	Qiqihar	QQ	Yanbian	YB
Chifeng	CF	Jiayuguang	JY	Quanzhou	QZ	Yancheng	YC
Chongqing	CQ	Jinan	JA	Sanya	SY	Yangzhou	YZ
Dalian	DL	Jining	JN	Shanghai	SH	Yantai	YT
Daqing	DQ	Kunming	KM	Shenyang	SE	Yichang	YG
Datong	DT	Lanzhou	LZ	Shenzhen	SZ	Yinchuang	YI
Dongying	DY	Lasa	LS	Shijiazhuang	SJ	Yulin	YL
Foshan	FS	Lianyungang	LG	Taiyuan	TY	Yuncheng	YU
Fuzhou	FZ	Linfen	LF	Taizhou	TZ	Zhangjiakou	ZK
Ganzhou	GA	Linyi	LY	Tangshan	TS	Zhanjiang	ZJ
Guangzhou	GZ	Luliang	LL	Tianjin	TJ	Zhengzhou	ZZ
Guilin	GL	Luoyang	LU	Urumqi	UQ	Zhuhai	ZU
Guiyang	GY	Macau	MC	Weifang	WF	Zunyi	ZY

Appendix B

Table A2. List of international air transport nodal cities as world cities or tourist destinations with airports.

Name	Code	Name	Code	Name	Code	Name	Code
Amman	AA	Cologne	CO	Lima	LM	Riga	RI
Abu Dhabi	AB	Cape Town	CT	London	LN	St Petersburg	SB
Adelaide	AD	Dallas	DA	Mumbai	MB	San Francisco	SF
Almaty	AL	Dublin	DB	Luxembourg	LX	Singapore	SG
Amsterdam	AM	Denver	DV	Lyon	LY	Rotterdam	RT
Athens	AS	Detroit	DT	Madrid	MD	San Diego	SD
Antwerp	AN	Doha	DH	Manama	MM	San Jose	SJ
Atlanta	AT	Durban	DR	Manchester	MC	Stockholm	SK
Buenos Aires	BA	Düsseldorf	DS	Melbourne	ME	San Juan	SN
Auckland	AK	Dubai	DU	Marseille	MR	San Salvador	SS
Baku	BQ	Edinburgh	ED	Miami	MI	Santiago	SA
Baltimore	BO	Frankfurt	FR	Milan	ML	Santo Domingo	SI
Barcelona	BC	Geneva	GN	Manila	MN	Sofia	SO
Budapest	BD	Hamburg	HB	Moscow	MS	Seattle	SE
Bogota	BG	Georgetown	GE	Minneapolis	MP	Sao Paulo	SP
Bangkok	BK	Glasgow	GL	Monterrey	MO	Seoul	SU
Belgrade	BE	Guadalajara	GU	Montreal	MT	Sydney	SY
Berlin	BL	Guatemala	GT	Munich	MU	Tel Aviv-Yafo	TA
Birmingham	BM	Guayaquil	GY	Montevideo	MV	St. Louis	SL
Bangalore	BN	Ho Chi Minh City	HC	Mexico City	MX	Tokyo	TK
Brussels	BR	Hanoi	HN	New Delhi	ND	Stuttgart	ST
Bratislava	BV	Helsinki	HL	Nairobi	NR	Taipei	TP
Brisbane	BB	Houston	HS	New York	NY	Toronto	TR
Bristol	BI	Istanbul	IS	Osaka	OK	Tallinn	TL

Table A2. *Cont.*

Name	Code	Name	Code	Name	Code	Name	Code
Boston	BS	Hyderabad	HY	Nicosia	NC	Tampa	TM
Beirut	BT	Islamabad	IL	Paris	PA	Vienna	VI
Bucharest	BU	Johannesburg	JB	Oslo	OS	Vancouver	VN
Cairo	CA	Jakarta	JK	Panama City	PN	Washington	WC
Calcutta	CC	Jeddah	JD	Philadelphia	PH	Warsaw	WS
Chicago	CH	Kuala Lumpur	KL	Perth	PE	Tunis	TU
Calgary	CG	Karachi	KR	Prague	PR	Zurich	ZU
Colombo	CM	Kiev	KV	Phoenix	PX	Accra	AC
Caracas	CR	Los Angeles	LA	Port Moresby	PL	Vilnius	VS
Chennai	CN	Kuwait City	KU	Quito	QU	Pune	PU
Charlotte	CL	Lisbon	LB	Rio Janeiro	RJ	Punta Cana	PC
Copenhagen	CP	Lahore	LH	Rome	RM	Zagreb	ZG
Casablanca	CS	Leeds (North Carolina)	LE	Riyadh	RY	Tehran	TH
Cleveland	CV	Lagos	LG	Raleigh	RL		

Appendix C

Table A3. List of notations.

Variable	Description
i	Air route
j	Service airline
N	Set of airlines in the GBA-MAR
a_{ij}	Dichotomous variable that takes "1" when the airline j operates any flight on air route i out of the three major airports in the GBA-MAR, and otherwise, it takes "0"
C_i	The number of airlines operating on air route i
HHI_i	The Herfindahl–Hirschman Index (*HHI*) of air route i
f_i	Total flight volume on air route i
f_{ij}	Flight volume of airline j on air route i
S_{ij}	Market share of airline j on air route i within the three major airports in the GBA-MAR
$PR_{i\frac{a}{b}}$	Independent variable, the natural log of the ratio of passengers on air route i to or from airports a and b
$FQ_{i\frac{a}{b}}$	Natural log of the ratio of flights on air route i to or from airports a and b
$FA_{i\frac{a}{b}}$	Natural log of the ratio of average fares on air route i to or from airports a and b
$AST_{i\frac{a}{b}}$	Natural log of the ratio of airport access time to flight time on air route i to or from airports a and b, and the airport access time is measured as the car driving time from the regional center to airports a or b
$HHI_{i\frac{a}{b}}$	Natural log of the ratio of the *HHI* on air route i to or from airports a and b
DLR_i	Dummy variable for air route i for a domestic long-haul route type, coded "1" if air route i is a domestic long-haul route
ILR_i	Dummy variable for air route i for an international long-haul route type, coded "1" if air route i is an international long-haul route
DSR_i	Dummy variable for air route i for a domestic short-haul route type, coded "1" if air route i is a domestic short-haul route
ISR_i	Dummy variable for air route i for an international short-haul route type, coded "1" if air route i is an international short-haul route

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