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Aviation supply and demand in the São Paulo and Rio de Janeiro systems evolution: An exploratory study

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Abstract

Aim/purpose – Multiple factors affect a passenger's origin and destination airport choice. This study explores some of the leading indicators associated with performance in cities with more than one airport. Two important Multi-Airport Systems (MAS) in Brazil were the object of this study: São Paulo (Congonhas and Guarulhos) and Rio de Janeiro (Santos Dumont and Galeão), the most significant demand-generating centers in the country and the most critical distribution centers of flights from South America.
Design/methodology/approach – Using public databases presenting the evolution of supply and demand from 2013 to 2018, the evolution of flights, and the sales by airlines in the same period, we estimated a linear model using panel data on a multiple linear regression with fixed effects.

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Findings – One of the results observed is that competition between airlines positively affects prices for consumers, the industry, and tourism, which is vital for the country.
Research implications/limitations – The limitation of the findings is the lack of current data.
Originality/value/contribution – In filling the gap in the literature on the evolution of supply and demand in the Brazilian aviation market, the study evaluates some of the leading indicators associated with performance in cities with more than one airport.

Keywords: aviation supply and demand, evolution, Brazil, São Paulo, Rio de Janeiro, airports.
JEL Classification: R40, R41, R10, O54, C19.

1. Introduction

The strong growth of the aviation sector over the last few decades is directly related to the development of the economy and the times of peace and globalization. More than one airport in the same region contributes to the socioeconomic development of the catchment area (Fiuza & Martins Pioner, 2009). This situation creates more significant business opportunities, better regional infrastructure for the region, and fewer airports' growth constraints (Bonnefoy, 2010). It also diversifies the number of passengers' options and allows companies better organization, favoring the air system's competition and stability. Brazil comprises three metropolitan areas considered multi-airport regions: São Paulo, Rio de Janeiro, and Belo Horizonte. These regions are significant economic and population centers in the country. The Brazilian airline sector has undergone several changes over the past few years, the main one being the deregulation experienced in the 1990s, followed by its tariff liberalization in the early 2000s. Those changes ended the reference prices defined by the aeronautical authority and allowed price discrimination broadly. The legislation change entitled the emergence of new Brazilian airlines with different marketing strategies from traditional companies: GOL (founded in 2001), its low-cost model, and Azul (founded in 2008). The new regulatory scenario, combined with the changes in demand during the 2000s, also led to new routes, increased competition, a drop in the average value of airfares, and increased passenger transport.

With more than one airport in Brazil, regions concentrate around 65% (2019)[1] of all demand and supply in the Brazilian airline sector. This percentage has grown over the last few years, especially after 2012. The share of the São Paulo and Rio de Janeiro regions in Brazil's overall domestic supply and demand composition has increased considerably since 2012, from 60% to approximately 65% in 2019.

[1] https://www.ontl.epl.gov.br/mapas

Previous studies (Borenstein, 1989; Ishii et al., 2009; Loo, 2008) regarding the impact of greater market concentration on prices do not contemplate changing supply in a substitute airport for a metropolitan region in another given airport's pricing composition. Multiple factors affect a passenger's origin and destination airport choice.

This study explores some of the leading indicators associated with performance in cities with more than one airport in São Paulo (Congonhas – CGH and Guarulhos – GRU) and Rio de Janeiro (Santos Dumont – SDU and Galeão – GIG), the most significant demand-generating centers in the country, and the most critical distribution centers of flights from South America. These indicators can influence passengers' choices and offers, contributing to several stakeholders in the entire air process (authorities, airports, and airline companies).

The rest of this paper is divided into the following sections. Section 2 highlights the literature review; Section 3 presents the study's methodology, followed by Section 4 with findings, results, and discussion. We offer the conclusions in Section 5.

2. Literature review

2.1. Multi-Airport Systems

Multiple Airport Regions (MAR), Multi-Airport Systems (MAS), or Multi-Airport Cities (MAC) are a group of two or more major commercial airports in a metropolitan area (Nayak, 2012); a major commercial airport visited by at least two million passengers per year (Sun et al., 2017), without regard to ownership or political control over individual airports (de Neufville, 2004; Wang et al., 2008). Perdana and Moxon (2014) state that airports compete in a metropolitan region to serve air traffic regardless of ownership or political (GRU Airport, 2020) influence. The airport is part of a MAS if it is close to an existing major/primary airport or if local authorities officially designate it (de Neufville, 1995). According to Attaalla (2019), MAS is two or more airports focusing on civil and commercial traffic, serving urban areas, and increasing passenger numbers.

Two specific mechanisms are responsible for a single-airport system becoming a multi-airport: an existing airport emerges as a secondary airport of the region and the construction of a new airport, where passenger and aircraft traffic is partially or transferred in its totality mentioned by Bonnefoy (2008). Many cities are served by more than one airport, usually to avoid congestion. The multi-airport system may be built to meet specific uses in other cities, such as dividing international and domestic flights (Attaalla, 2019).

2.2. Key factors that influence passengers' and airlines' choices in Multi-Airport Systems

According to Harvey (1987), Doganis and Graham (1987), de Neufville (1995), Cohas et al. (1995), and Windle and Dresner (1995), a series of service features affect passengers' choice of airports: easy access (Harvey, 1987; Hess & Polak, 2005; Ishii et al., 2009; Pels et al. 2003); frequency and schedule of air services (Ishii et al. 2009; Loo, 2008); regularity and punctuality of operations; airfares and the presence of a low-cost carrier, especially for leisure passengers (Dresner et al., 1996; Hess & Polak, 2005); type of service – whether direct or connecting flights (de Souza, 2010); loyalty programs and the presence of a specific airline at a given airport (Dobruszkes et al., 2011; Gjerdåker et al., 2008) and borders between countries (Paliska et al., 2016).

Regarding airlines' and airport authorities' choices, one of the factors explored is the size (and degree of homogeneity) of a given airport's catchment area, as seen in Lieshout (2012, p. 27). Its size depends on the factors that drive the passengers' choice of the airport (accessibility, fares, and frequency of flights) compared with other airports in the area. This area's size will also impact the airport market share and the primary or secondary airport classification. A region's degree of heterogeneity (demand, income, and destination profiles sought) affects the catchment area, adding uncertainty and oscillating time and space (Lieshout, 2012).

Despite more than one airport in a region, they do not necessarily substitute – this was the result of the paper of Brueckner et al. (2014) study, concluding that not all airports in the same region are replaceable and will impact the performance of the other airport. Brueckner et al. (2014) highlighted three significant factors to explain the degree of substitutability: shuttle service between airports and the city center, the mix of services between airports and the type of market served, and the nature of the trip.

2.3. Multi-Airport Systems worldwide

The North American market usually emerges as one of the leading centers for these studies, not only due to the presence of several regions with more than one airport in the United States but also due to the diversity of these regions, competition, and availability of data, as mentioned by Attaalla (2019) and Abreu et al. (2017). Some examples of studies performed in this market are Başar and

Bhat (2004), Pels et al. (2003), Hess and Polak (2005), and Ishii et al. (2009). Other relevant MAS studies are performed in England. Specifically, the Greater London area, as seen by Pels et al. (2009) and Hess and Polak (2005), with six operational airports, which, according to Chandrakanth (2015), are the busiest airports globally, both in terms of aircraft and passenger volume. Many other MAS were studied, such as Japan (Usami et al., 2017), Hong Kong (Loo, 2008), Taiwan (Yang et al., 2014), and South Korea (Jung & Yoo, 2016).

2.4. Multi-Airport Systems in Brazil

Airports are distributed uniformly throughout Brazilian territory, as all major cities have at least one airport. However, only a few airports with regularly scheduled flights and routes along the country's coast, where most of the population is concentrated, exist (Agência Nacional de Aviação Civil [ANAC], 2016). De Oliveira Dias and de Oliveira Albergarias Lopes (2019) stated that São Paulo has the country's most significant airport network and the highest number of passengers transported. Both cities are considered the most important in entering and exiting the country with Rio de Janeiro since they concentrate most on Brazil's international flights (Brito, 2017).

Air travel between Rio de Janeiro and São Paulo (a 40-45 minutes flight) was set in the early days of Brazilian commercial aviation. The high frequency only intensified after World War II, as the aircraft supply became larger and cheaper (Abreu et al., 2017). Until 1959, the shuttle network model was implemented between SDU and CGH airports. This air connection is among the world's four busiest connections, with 40 thousand annual flights. In the first year of operation of the shuttle flights, 388,000 passengers were transported, while in 2019, 26.5 thousand passengers were transported daily (Infraero, 2019). According to ANAC (2019a, 2019b), the average ticket fare in 2018 was BRL 262.31.

In 2018, the Brazilian National Civil Aviation Secretariat (SAC/Minfra) studied the profile of the shuttle-flight passenger, described as mainly business travelers: 56% are male, and 44% are female; 40.5% are between 31 and 45 years old, and 50.6% of the passengers are traveling for work/studies (Infraero, 2019).

Santos Dumont Airport (SDU), founded in 1936 and currently administrated by Infraero, was the first airport to offer commercial/civil flights exclusively in Brazil. It is one of the busiest airports in the country due to two main factors: the shuttle flights between Rio – São Paulo and being strategically located in the city center, close to headquarters of large companies and financial institutions, and the port area that provides easy access for passengers, especially for those traveling on business. Tom Jobim International Airport – Galeão (GIG), founded in 1952, is the second busiest airport in Brazil in international traffic, managed by the RIOgaleão concessionary. It is located in Rio de Janeiro, about 20 kilometers from the city center. It has the largest airport site in total area, and the most massive commercial runway in the country, making it the most crucial gateway for Rio de Janeiro (RIOgaleão, 2020). Moreno and Müller (2003) studied the M.A.S. of São Paulo in the São Paulo Metropolitan Region (C.G.H. and G.R.U.).

Congonhas Airport (CGH) was founded in 1936, is managed by Infraero (n.d.) and located 8.7 kilometers from the city center. It has the most significant traffic of executives in the country, with passengers annual capacity of 17.1 million (Infraero, 2019), due to its proximity to São Paulo's financial center, shuttle flights with Rio de Janeiro, and essential connections to Brasília (BSB), Belo Horizonte (CNF), Porto Alegre (POA) and Curitiba (CWB).

Guarulhos International Airport (GRU), founded in 1985, is managed GRU. The airport concessionary comprises three connected terminals and one cargo terminal 24 hours/day.

2.5. The relation between supply, demand, network definition, and price formation

A widely studied subject by economists is price formation, the relationship between market structures, and their impact on prices. One of the main factors in price composition is the impact of greater market concentration on prices. The relationship found in all studies always points to an inverse relationship between competitiveness and prices: the higher the level of competition, the lower the level of average prices practiced; the more concentrated, the higher the intermediate (Infraero, n.d.) price level (Bilotkach & Lakew, 2014; Borenstein, 1989; da Cunha, 2020; Gerardi & Shapiro, 2009).

However, those studies do not contemplate the impact of changing supply in a substitute airport B, for example, for a metropolitan region in the pricing composition of airport A. To define the best network strategy, the airlines will have to undergo different market, fleet, and market segment analyses to evaluate the best schedule combination and network structure for their customer, considering: Market Analysis, Long Term Schedule Planning, and Fleet Evaluation.

Airlines can use different network structure models to meet the diverse needs of their markets. All regular passenger operations worldwide converge into one of the three construction models: hub and spoke, point-to-point and shuttle, and network operation (Boeing, 2019; Cook & Goodwin, 2008).

Hub and spoke

This model is mainly used by traditional airlines (legacy carriers) that have one or more destinations as a large distribution center for flights (hubs) spread across a region and serve them different destinations (spokes), generating connectivity between cities of different sizes and geographic regions) (Doganis, 2012). Hub and spoke modes help more origin and destination routes through a single hub base, expand the attractiveness of schedules for destinations already served, generate a more competitive product, and create economies of scale. Challenges include operational constraints, difficulty in expansion, and future investments.

Point to point and shuttle

This model is most used by low-cost (LCC) and ultra-low-cost (ULCC) airlines. Its main characteristic is the system's simplicity aiming at direct flights between different cities, avoiding connections and complex structures. It is common to find this model in regions of high demographic density, with greater income distribution and vast geographical distances. It is commonly applied by companies in the United States and Europe, and regions in Asia. The simplicity of these companies' fleets is essential to maintain low costs and a higher operating margin. The main advantages of this model are shorter total travel time, lower dilution of the average fare, and lower unit cost. The main disadvantage of this network construction model is the inherent risk of operating in markets without a feed of any other place, which generates pressure for individual routes. Besides, developing countries may not have enough demand and income distribution to guarantee this air network model's success. "Most LCC's try to combine low fares with high frequencies, attracting corporate market' (Doganis, 2005, p. 384).

Shuttle markets can be a variation within the two network construction models presented. In this model, companies allocate resources to operate dense markets with daily frequencies, connecting banks or local customers. It mainly serves the high demand for corporate customers traveling between two cities, usually in the same country, but there are shuttle cases between different nations. The high frequency of flights in shuttle markets is the most crucial advantage since it guarantees the company a competitive position with corporate customers, which are less price-sensitive and willing to pay higher fares on short notice due to the nature of the business trip. It is essential to highlight that the price level tends to be lower during off-peak hours. Corporate customers demand investments in more sophisticated and technological products, such as VIP lounges, seats with more space, onboard Wi-Fi connection, and responsive apps.

Network operation

This model's uniqueness is that companies serve different regions of the same country with hubs in privileged geographic locations to be present in all regions and have national relevance. The flights that link these hubs are called trunks routes. They are responsible for transporting the company's customers across its destinations, connecting regions and cities with no demand to support cross-country services sustainably in other countries.

Borenstein and Rose (1994) estimated the impact of market concentration on supply variables like frequency of flight between airports, airline market share, HHI of each location, and demand. Their finding indicated that a higher level of market concentration would result in less price dispersion. Gerardi and Shapiro (2009) suggested that a lower level of competition increases price dispersion. Da Cunha (2020, p. 26) concluded that Gerardi and Shapiro's results are similar to the Brazilian scenario, where "the increase in the level of market concentration gives companies greater power to discriminate prices, segmenting them more than in a scenario with increased competition."

3. Research methodology

Agência Nacional de Aviação Civil's [ANAC] official databases present the evolution of supply and demand flown in a specific period and the evolution of important KPIs (number of seats, number of passengers, ASK, and RPK). Three databases were used in the analysis. *Demanda e Oferta* (translated as "Demand and Supply"), the Cirium database[2] and the Microdados (ANAC, 2019a, 2019b) contain the evolution of demand and the average sold fare of the analyzed markets. *Microdados de tarifas aéreas* (translated as "airfare microdata"; ANAC, 2019a, 2019b), which includes sales made by airlines in a given period (year and month, airline, origin, destination, sold fare, and the number of seats sold). This database includes only fares sold without discounts, private fares, or frequent flyer programs. Its coverage ranges from 40% to 50% of all seats sold in the

1 https://www.cirium.com/

Brazilian domestic market. The analysis period includes the period between January 2013 and December 2018 because, during this period, there was no merger or acquisition involving the major airline companies in the country.

After all the data were stacked, all percentiles of sold seats for each market allowed us to evaluate the evolution of different price ranges. The final database is an unbalanced panel with sales information; the average sold fare, percentiles of fares considering the seats sold on the market, and time level. To evaluate the impact of changes in the competition scenario, the authors added supply information, such as the number of seats available, the competition level identified by the Herfindahl–Hirschman Index, and the complementary market's competition level.

This research seeks to answer the following questions:

Q1. What are the characteristics of the network model of the four airports?

Q2. What is the impact of variation in competition level on the substitute market price?

The authors evaluated the impact of the competition level on the average fare between markets using multiple linear regression. The researchers addressed the characteristics of the network model of the four airports with a view of the market and characteristics of accessibility to highlight the particularity of each airport.

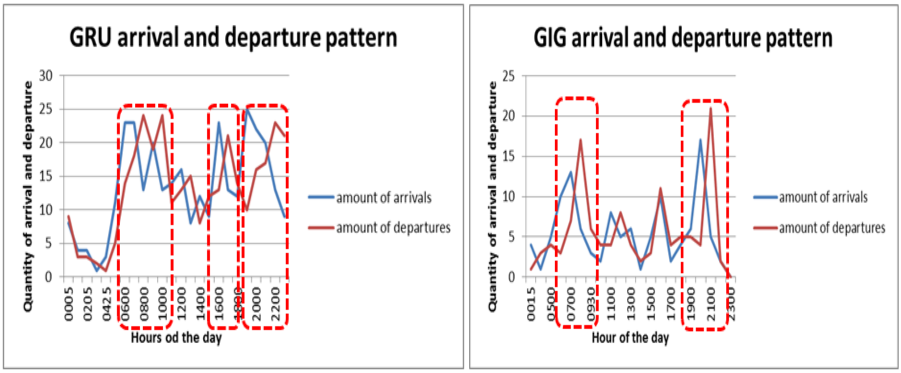
A linear model was estimated using panel data on a multiple linear regression with fixed effects to evaluate the impact of changes in the competitive scenario on the average price level. The panel data with a fixed effect approach is the estimation strategy in Gerardi and Sharpiro (2009). The authors evaluated the impact of the competition level on the average fare between markets. The data consisted of average fare and demand data from ANAC. The current and future months' supply levels obtained through O.A.G. AG / Diio were used to define the concentration level on a given route.

4. Research results & discussion

4.1. Network construction models in Brazil

In Brazil, the international airports in São Paulo and Rio de Janeiro are used as large centers for connections at the national and global levels, while the airports located more centrally in these large metropolises have point-to-point and shuttle model networks. In São Paulo and Rio de Janeiro, it is possible to notice different airport network strategies. At the airports of Guarulhos (GRU) and Galeão (GIG), the use of the hub and spoke models, respectively, is more clearly presented, as characterized by some peak movement of arrivals and departures along with some hours of the day (Figures 1 and 2). This means the airlines use these airports' structures to connect customers throughout their network and with partners' airlines.

Figure 1. An example of arrivals and departure patterns at G.R.U. and GIG



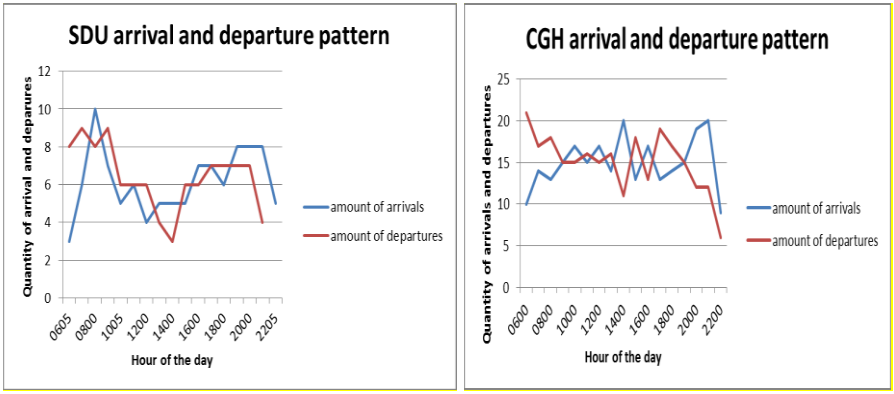
Source: Cirium database (2020) from September 2018.

An example of arrivals and departure patterns at GRU and GIG, the three largest airlines at these airports, shows strong capacity allocation trends in a hub and spoke model. Authors using the Cirium database from September 2018 (acccessed: March 2020).

However, at the major airports CGH and SDU, a point-to-point or shuttle structure are detected, mainly serving travelers' local demand to that city, characterized by the more uniform distribution of flight arrivals and departures throughout the day (Figure 2). Connection opportunities exist, as many flights at these airports can generate competitive routes for customers who want to connect from point A to point C via B, but are not intentional, as the main goal is to attract local flyers.

Example of arrivals and departures patterns at CGH and SDU, showing capacity allocation distributed more evenly throughout the day with no spoke in arrival and departure waves. Authors using the Cirium database from September 2018 (accessed: March 2020).

Figure 2. Example of arrivals and departures patterns at C.G.H. and S.D.U



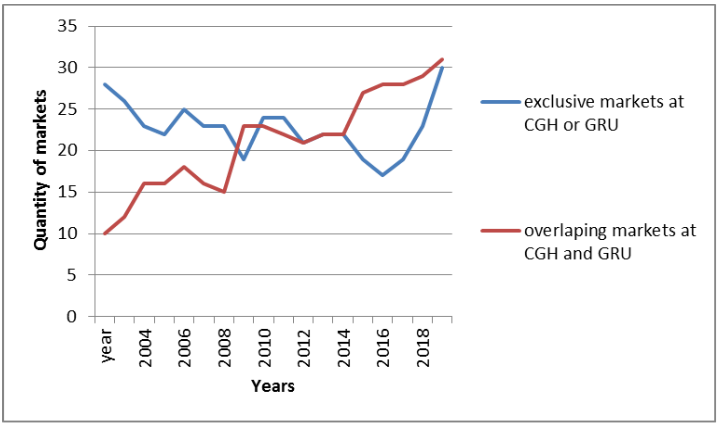
Source: Cirium database (2020) from September 2018.

Evolution of supply in São Paulo and Rio de Janeiro

As of April 2009, a restriction that limited the SDU airport to operations only on the CGH-SDU-CGH shuttle and flights to regional destinations with turboprop aircraft were lifted. This generated an increase in overlap markets between GIG and SDU, an increase in the number of goals by companies that already operated at the airport (TAM, G.O.L., Oceanair), and attracted the service of new companies operating jets to major national destinations, such as Webjet, Azul, and Trip. This movement greatly benefited the accessibility of new destinations to the central airport in Rio de Janeiro. In the following years, it generated the stagnation of domestic services at GIG airport, culminating in the withdrawal of some long-haul routes operated by Brazilian flag-carrier airlines since local traffic preference the SDU airport. The flow of customers connecting to other domestic destinations abroad at GIG was insufficient to support this investment.

In recent years, we can see that the number of destinations served nonstop in Rio de Janeiro has remained stable, with a reduction in the number of destinations served by GIG. In São Paulo, the trend was the opposite of Rio de Janeiro's. The number of markets with direct service to the city increased for routes operated in the overlap and exclusive markets (Figure 3). The town gained new services to destinations previously not operated directly, even with the number of overlapping routes growing.

Figure 3. Quantity of nonstop destinations from São Paulo improving from both airports



Source: Cirium database (2020) from September 2018.

The quantity of nonstop destinations from São Paulo is improving from both airports. The overlapping markets from CGH and GRU also grew during the last few years.

Over 43 million customers were transported to 103 global destinations at GRU in 2019. About 65% of the passengers were on domestic flights, accounting for more than 28 million people. GRU is a significant flight distribution center for the largest national airlines, the main gateway to Brazil with international destinations, and powered over 53 domestic cities with more than 370 daily departures. However, GRU's location is a negative factor in the passenger's need to travel to the central business destinations in São Paulo, given the distance from the airport to these centers. Even having a direct link with the metropolitan train line, the distance and complex logistics to reach the city's main points make the airport less attractive to a significant population.

As the second busiest airport in the country in terms of the number of passengers, CGH is the gateway to the South, Central, and West of São Paulo, with the largest population, commerce, offices, and wealth. The airport's location also serves the populous south shore. It is closer to expressways to the coast, making it attractive to customers destined for these areas. The airport operates on weekdays, with 100% of the commercial operations of scheduled air transport companies. In 2019 it handled 22,261,392 passengers (79% of the number of domestic passengers in GRU) in 243 daily departures. Even serving 15 fewer domestic destinations has 85% of GRU. domestic seating capacity.

CGH does not include any integration of modal to mass transportation by rails. A line under construction promises integration with the city's metro network, scheduled to open in 2022. As it is located between dense residential areas, there is a limitation on operation, and between 11 pm and 6 am, flight operations at the airport are prohibited.

In Rio de Janeiro, GIG is the main access point to the city, mainly for international passengers, with direct connections to 53 destinations, of which 26 are abroad. This airport handled 13,507,881 passengers in 2018, with 68% of customers coming from Brazil to 27 domestic destinations. Of all four airports evaluated, this has the lowest domestic seats per day (15,199).

The GIG airport is limited with access options since public security remains a significant concern for passengers, leading many customers to avoid using its facilities. The lack of safer and faster transport, such as a railway, also reduces travelers' attractiveness when choosing the airport.

Finally, SDU, the airport in Rio de Janeiro, is the smallest of the four evaluated. Just over nine million customers went through it in 2019, with nonstop services to 18 exclusively domestic destinations. This airport's main asset is its central location in the corporate center of the city of Rio de Janeiro in the downtown area. It is also close to major tourist attractions and preferred by corporate and leisure customers, even for convenience. Its facilities are relatively small, leading to less hassle for boarding and arriving. Also, there is a wide variety of shops and hotels nearby and a new shopping center with direct access to the passenger terminal. It is the only airport with a light rail line that quickly connects the passenger terminal to the city center region. It houses many offices and headquarters for major Brazilian companies and is the base for several multinationals. With these facilities, it has become the preferred airport for many travelers.

Table 1. Comparison between the four airports of the analysis

Specification	São Paulo		Rio de Janeiro	
	CGH	GRU	SDU	GIG
1	*2*	*3*	*4*	*5*
Total passengers	22,261,392	43,002,119	9,091,258	13,507,881
Domestic passengers	22,261,392	28,238,490	9,091,258	9,191,793
International passengers	–	14,763,629	–	4,316,088
Airlines operating	4	32	4	22
Non-stop destinations	38	103	18	53
Non-stop destinations (domestic only)	38	53	18	27
Daily departures	243	379	140	118
Daily departures (domestic only)	243	285	140	87
Daily seats	39,811	72,893	20,374	21,987

table 1 cont.

1	*2*	*3*	*4*	*5*
Daily seats (domestic only)	39,811	49,815	20,374	15,199
Average seat per departure (domestic only)	164	174	146	174
Terminals	1	3	1	1
Size of all passenger terminals (in square meters)	64,579	192,000	19,000	280,000
Train or subway lines serving the airport	0	1	1	0
Average distance from main corporate districts (in kilometers)	12	39	13	19
Operating hours	6am-23pm	24 hours	6am-23pm	24 hours

Table 1 consolidates information regarding traffic, passenger movement, destinations served, amount and size of airport terminals, accessibility, distance from main places of interest in the cities, and operating curfew.

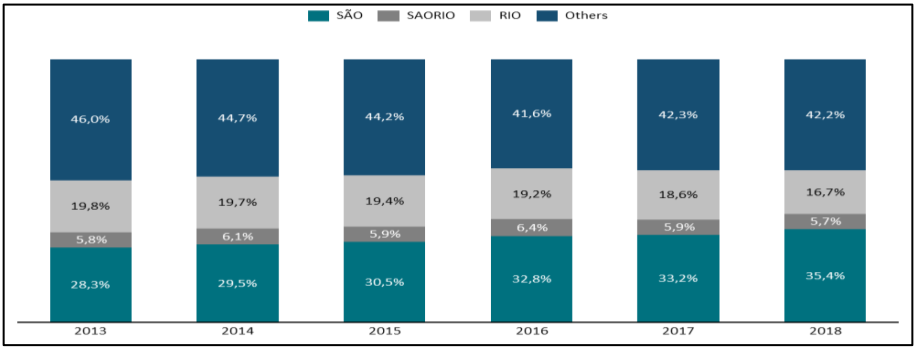
The study of the demand

Between 2013 and 2018, we saw a reduction of about 25% in the total volume of passengers sold, leaving 52 million passengers in 2013 to 38.5 million in 2018. When comparing the available number of passengers with that of passengers transported, the number of passengers transported in 2018 in the domestic market is 4% higher than that transported in 2013. This difference in trend between numbers is due to conceptual differences between both bases and, mainly, by sampling aspects. Conceptually, the Fares Microdata refers to the number of tickets sold in a given origin and destination pair. The number of passengers transported made available in the ANAC Demand and Offer reports refers to passengers flown on flights. In addition to the difference between sold and flow passengers, ANAC's Demand and Supply base considers passengers who have made a connection more than once.

With the intensification of competition over the last few years and with the maturity and greater segmentation of pricing strategies by airlines, the volume of discounted fares and/or in private segments (leisure or corporate agencies) grew more than the sale of fares in a public environment. This explains why we see a drop in the number of passengers sold while the Brazilian air market was stable in terms of total demand.

When we observe the evolution of the market share of SAO (origin or destination) in the composition of the total demand sold, we see a growth in participation from 28.3% in 2013 to 35.4% in 2018, while the participation of RIO and other markets declined during the period. However, the demand share between São Paulo and Rio de Janeiro, the country's busiest and most relevant market, remained stable, corresponding to about 6% of the volume of passengers sold, as shown in Figure 4.

Figure 4. Evolution of passengers sold from 2013 to 2018

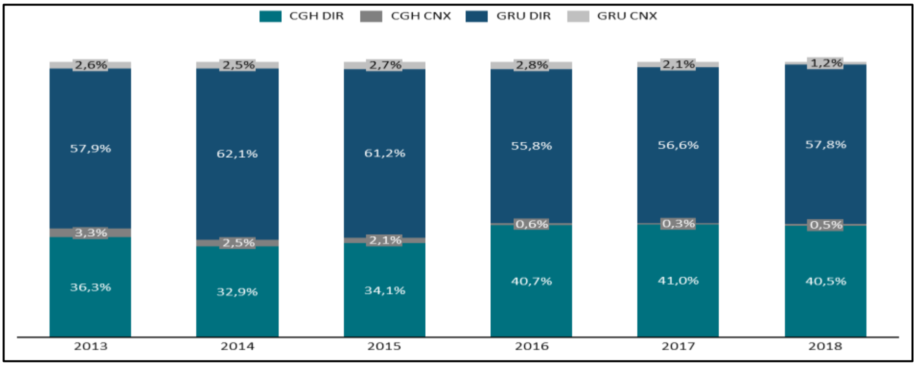


Source: ANAC (2019a, 2019b).

São Paulo: Evolution of demand and the average rice

São Paulo's share, excluding connections between SAO-RIO, increased between 2013 and 2018. As shown in Figure 5, there was a growth in the share of markets that originate or are destined for CGH, especially between 2015 and 2016. This is due to the diversification of the airport's offer, with changes in its operational restrictions.

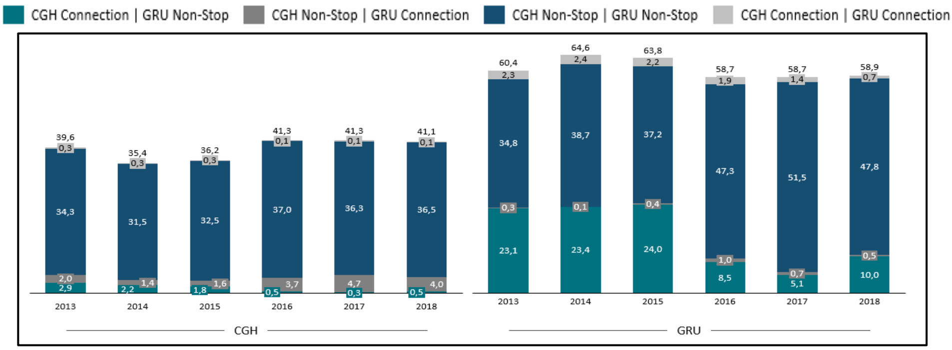
Figure 5. Demand sold composition – SAO – domestic market – by airport



Source: ANAC (2019a, 2019b).

The growth in demand in markets with nonstop CGH service happened in markets with an overlap of nonstop GRU. supply, as shown in Figure 6. In 2015, 69.7% of all demand in São Paulo (except SAO-RIO) was in markets where CGH and GRU had nonstop service (32.5% in CGH and 37.2% in GRU). This number grew to 84.3% in 2016 (37.0% in CGH and 47.3% in GRU).

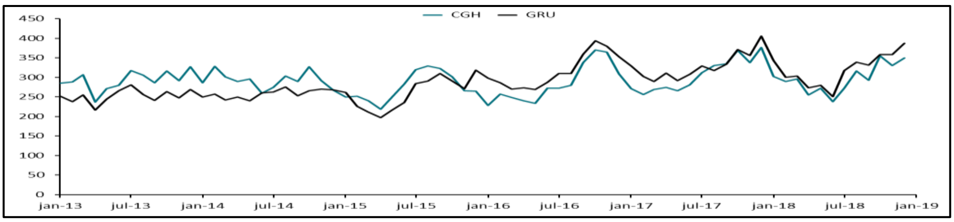
Figure 6. Demand sold composition – SAO – domestic market – by airport



Source: ANAC (2019a, 2019b).

This growth in participation in markets with direct overlap between CGH and GRU was due to the following markets: CGH-REC (Recife), CGH-FOR (Fortaleza), CGH-BEL (Belém), CGH-MCZ (Maceió), CGH-JPA (João Pessoa), CGH-NAT (Natal), and CGH-SLZ (São Luiz). Until 2015, those markets were only operated on a nonstop GRU. basis (demand from/to CGH should make some connection at some airport). In 2016, with the CGH offer's diversification, they started to be operated directly from CGH. Thus, the share of markets operated directly by GRU in the total composition of demand declined from 25.8% in 2015 to 9.0% in 2016. Considering only the markets that directly overlap between CGH and GRU (except SAO-RIO), we see that the average price of GRU's nonstop markets that overlap with direct services of CGH became higher than that of CGH markets in 2016 (Figure 7).

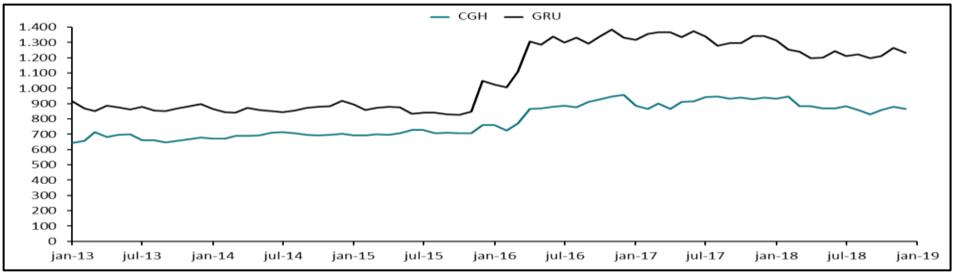
Figure 7. Average fare evolution – SAO – ANAC – domestic market



Source: ANAC (2019a, 2019b).

The average rate for CGH was about 15% higher than the GRU in 2013 and 2014. This difference was reversed, with GRU surpassing CGH and CGH rates getting close to 7% below the GRU. However, the stage length of GRU passengers are higher than that of CGH, as the market mix is different between airports, as seen in Figure 8.

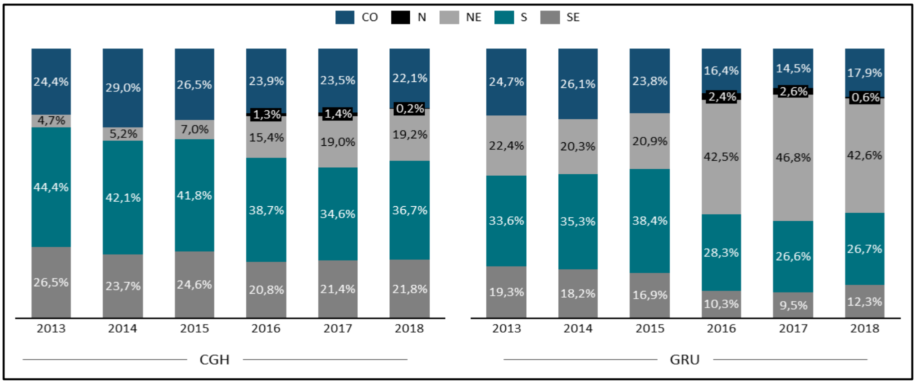
Figure 8. Passenger stage length – SAO



Source: ANAC (2019a, 2019b).

The average stage of GRU is about 40% higher than CGH, mainly due to the greater volume and participation of long segments than in comparison with CGH, which has a greater volume of demand concentrated in shorter stretches – and corporate, such as CGH-CWB (Curitiba), CGH-POA (Porto Alegre), and CGH-CNF (Confins). Figure 9 shows the evolution of demand by each airport's air region. The average GRU stage.

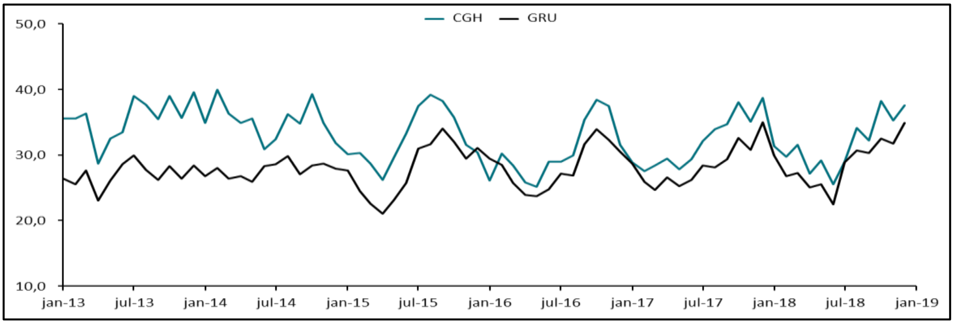
Figure 9. Passenger distribution by region – SAO – only nonstop and overlapped markets



Source: ANAC (2019a, 2019b).

As it has a higher average stage, it is natural that the average GRU rate is higher than CGH. To compare the evolution of the tariffs practiced in each of the airports is essential to evaluate the average yield's evolution, which weighs the average rate by distance, correcting it to the same average stage (of 1,000 km). The yield of CGH is approximately 10% higher than that of GRU (Figure 10).

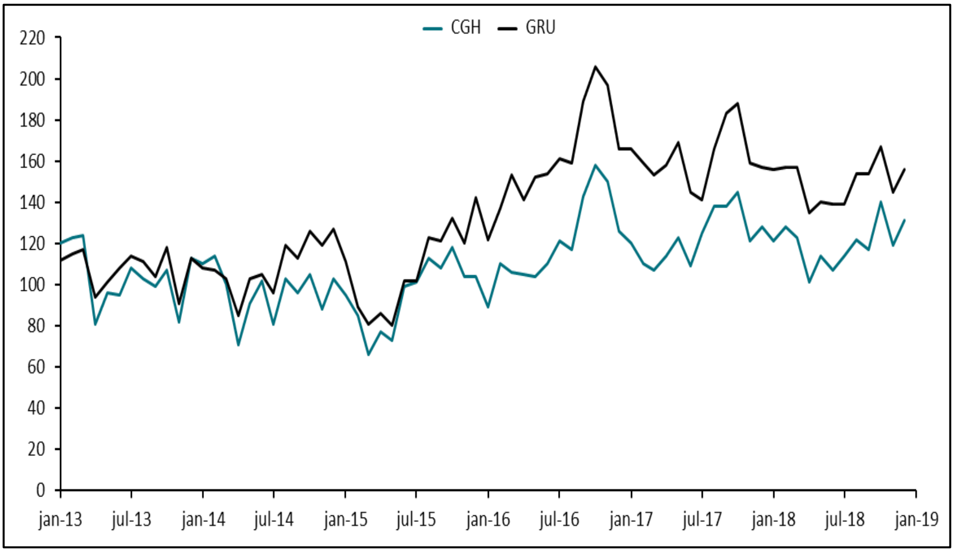
Figure 10. Yield adjusted by a stage length of 1,000 km – SAO – BRL cent



Source: ANAC (2019a, 2019b).

In Figure 11, we see how the average rate in the first decile of the demand distribution evolved: in January 13, 10% of all rates sold to the overlapping CGH markets were below BRL 120; in GRU, 10% of all rates sold to overlapping markets with CGH were below BRL 112.

Figure 11. Average fare: Demand's first decile – SAO – BRL



Source: ANAC (2019a, 2019b).

In Table 2, we present the evolution of the difference between the average yield adjusted to an average stage of 1,000 km between CGH and GRU for all deciles:

Table 2. Evolution of the difference in adjusted yield (average stage = 1,000 km) between CGH and GRU per decile

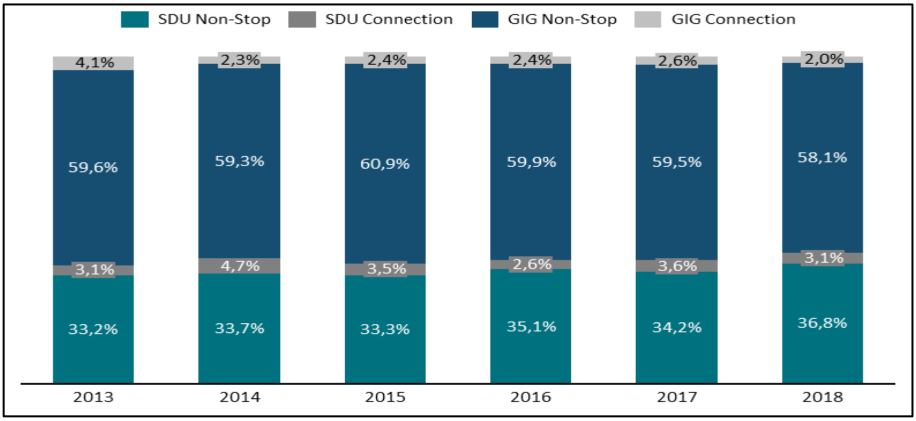
Decile	2013	2014	2015	2016	2017	2018
10%	23.3%	9.6%	9.1%	7.0%	10.7%	11.6%
20%	22.7%	12.8%	8.1%	6.7%	11.2%	11.8%
30%	20.2%	14.0%	8.6%	6.0%	11.0%	9.4%
40%	23.2%	18.2%	9.0%	6.1%	13.4%	8.5%
50%	35.7%	25.8%	13.0%	6.6%	16.4%	9.8%
60%	47.9%	37.3%	16.5%	6.9%	19.3%	13.7%
70%	59.7%	48.3%	23.0%	14.3%	25.0%	17.4%
80%	64.0%	57.5%	35.7%	33.5%	38.5%	28.3%
90%	67.9%	60.8%	47.1%	61.3%	61.5%	52.0%
Total	**30.8%**	**27.1%**	**17.6%**	**7.7%**	**12.5%**	**9.9%**

Source: Authors' own research based on ANAC (2019a, 2019b); Cirium database (2020).

The difference between the adjusted ield of the cheapest rates for CGH and GRU is narrowing (23.3% in 2013 and 11.6% in 2018). Interestingly, the difference between the yields of the highest deciles remains greater, particularly in the 90% percentile. The difference in the adjusted average yield of CGH and GRU was 52% in 2018. With that, the prices among the most inelastic passengers (higher prices) are higher in CGH than in GRU, indicating the preference of CGH for passengers willing to pay higher fares.

Unlike São Paulo, the demand mix between SDU and GIG airports remained relatively stable, with small changes in the number of destinations offered and overlapping. Figure 12 shows how the demand distribution between SDU and GIG airports by type of service has evolved steadily over time.

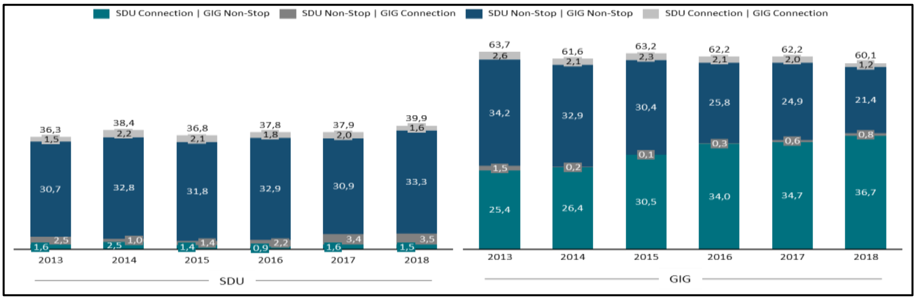
Figure 12. Demand sold composition – RIO – ANAC – domestic market – by airport



Source: ANAC (2019a, 2019b).

When analyzing the evolution in each airport's participation by type of overlap and service between airports, we saw a significant behavior change, the growth of the participation of markets with nonstop GIG services in markets where the SDU. the airport only serves with connection (Figure 13).

Figure 13. Demand sold distribution – RIO – ANAC – domestic market – by type of service GIG and SDU

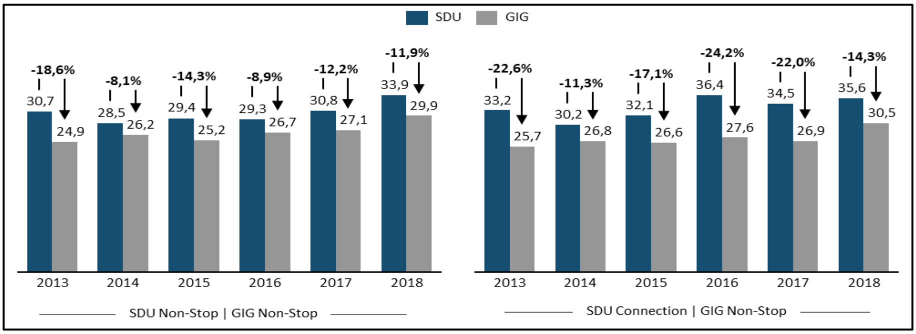


Source: ANAC (2019a, 2019b).

In addition to this growth in market share that only has a connection service since SDU, it is important to highlight two other points: for those markets that overlap between nonstop SDU and GIG services, SDU's share grew. Unlike São Paulo, where around 80% of ex-SAO-RIO demand is concentrated in markets overlapping direct service between its two airports, a smaller share of demand is concentrated in these overlapping markets, falling by around 65% in 2013 to 55% in 2018.

When we analyze the evolution of the adjusted average yield of GIG and SDU in those markets that offer direct service at both airports, we see that the difference between both airports is narrowing (the yield of GIG was 18.6% lower than that of SDU in 2013 and this difference dropped to –11.9%) due to the growth of the average GIG Yield. This reduction in the Yield difference between GIG and SDU is associated with: i) increased competition in the SDU; ii) an increase in the GIG concentration level in 2018 (the GIG HHI went from around 0.37 in 2013 to close to 0.5 in 2018) and; iii) improvement in the infrastructure of the GIG airport. There was also a reduction in the price difference between GIG airport and SDU for those markets where GIG has a nonstop service and the service since SDU involves a connection: the average adjusted Yield of GIG was 22.6% lower than that of SDU in 2013. It decreased to –14.3% in 2018 (Figure 14). Despite the drop, the price difference between SDU and GIG for these markets is still greater than where both airports have direct flights. This difference is due to the natural dynamics of prices and Revenue Management, which tends to charge a higher price for those markets with a connection due to the dynamics of bid price and displacement risk of selling a connection.

Figure 14. Yield evolution adjusted by type of service GIG and SDU – per year – BRL cent



Source: ANAC (2019a, 2019b).

We then analyzed the differences between the adjusted yield of GIG vs. CGH by percentile (Table 3) for the markets that have direct flights at both airports. It is possible to see a trend similar to that of São Paulo: reductions in the price differences of the percentile fares lower and equal differences or lower falls for the highest percentiles. The price difference between SDU and GIG for markets where both airports offer direct service has fallen more for the lower fares than higher fares.

Table 3. Evolution of the difference in aadjusted yield (average stage = 1,000 km) between CGH and GRU per decile

Percentile	2013	2014	2015	2016	2017	2018
10%	–28.2%	–14.3%	–15.6%	–8.2%	–15.6%	–8.8%
20%	–28.2%	–13.4%	–17.9%	–7.0%	–12.4%	–9.2%
30%	–31.8%	–12.7%	–17.8%	–6.9%	–13.6%	–10.5%
40%	–32.6%	–15.8%	–21.5%	–7.2%	–12.8%	–9.5%
50%	–35.3%	–19.2%	–24.3%	–9.1%	–15.1%	–9.5%
60%	–35.2%	–20.0%	–25.6%	–8.7%	–16.0%	–11.9%
70%	–32.1%	–21.4%	–26.0%	–11.6%	–18.3%	–14.9%
80%	–27.1%	–21.0%	–26.8%	–18.9%	–21.4%	–18.4%
90%	–24.8%	–20.1%	–25.9%	–22.1%	–28.4%	–23.9%
Total	–18.6%	–8.1%	–14.3%	–8.9%	–12.2%	–11.9%

Source: Authors' own research based on ANAC (2010a, 2019b); Cirium database (2020).

As SDU is a more central airport with easy access to Rio de Janeiro's shopping centers, more inelastic passengers with a more corporate profile are willing to pay higher prices to fly in SDU compared to GIG, which requires a greater displacement.

4.2. Impact of variations in the level of competition on substitute market prices

To estimate whether the relationship between price and supply variations at a substitute airport remains and answer Q2, we used the following regression for markets that have a direct overlap:

$$\mathbf{ln}(\boldsymbol{AVG_{PRICE_{mt}}}) = \boldsymbol{\theta_0} + \boldsymbol{\alpha} * \mathbf{ln}(\boldsymbol{HHI_{mt}}) + \boldsymbol{\beta} * \mathbf{ln}(\boldsymbol{HHIsubstitute_{mt}}) + \boldsymbol{\gamma_m} + \boldsymbol{u_t} \quad (1)$$

where:

$\boldsymbol{AVG\_PRICE_{mt}}$ = average price sold in a given market in a given month,
$\mathbf{ln}(\boldsymbol{IHH_{mt}})$ = HHI indicator level log for a given market and month (this variable allows us to assess the level of concentration of supply in a market),
$\mathbf{ln}(\boldsymbol{IHHsubstitute_{mt}})$ = the HHI log of the substitute market (for example: if the evaluated Market is GRU-FOR, the substitute market will be the CGH-FOR).

The variables $\boldsymbol{\gamma_m}$ and $\boldsymbol{u_t}$ are fixed market and time effects (the fixed effects allow us to isolate temporal aspects – such as increased costs, seasonality, and price shocks – and exclusive marketing aspects of a respective market concentration level. The effects were estimated only for markets with nonstop flights from the markets treated throughout this text (CGH, GRU, GIG, and SDU). The estimates obtained for equation (1) (Table 3) confirm what has been expected in the literature that an increase in market concentration is related to an increase in the average tariff practiced in a given market (Bilotkach & Lakew, 2014; Borenstein, 1989; da Cunha, 2020; Gerardi & Shapiro, 2009). Furthermore, an increase in market concentration in a substitute market is related to an increase in the average price of a market. This effect is statistically different from zero (both are) and reinforces the impact of substitute airports on the average price, highlighting the need to study this effect when assessing price composition (da Cunha, 2020).

Table 4. Estimates for AVG_PRICE_mt

	AVG_PRICE_{mt}
$\ln(HHI_{mt})$	0,270 (0,0613)
$\ln(HHIsubstitute_{mt})$	0,145 (0,0378)

Note: Robust Standart Error was adjusted for 92 clusters (markets), shown under the estimative between ( ).

Another important observation refers to the magnitude of the coefficient: an increase in direct competition in the market has an impact greater than that found for an increase in competition from a substitute market. The average price for a market is reduced by 2.7% if there is a 10% reduction in the concentration level of a market and by 1.4% if there is a 10% reduction in the concentration level of a substitute market.

5. Conclusions and areas for future work

This study explored some of the leading indicators associated with performance in cities with more than one airport in the São Paulo and Rio de Janeiro systems. Brazilian aviation has gone through decades of growth. The study revealed an increase in destinations served in overlapping in MAC, with cities, especially in Brazil's Northeast, South, and Southeast regions, gaining more relevance in the connection of the four airports studied.

The study also revealed that large metropolises' main airports have a higher Yield than those farther away from corporate centers, but the price difference between them on the same routes reduces over time. Also, the evolution of pricing levels was different between the percentiles: the lowest fares are closer to cheaper values regardless of the airport of choice in MAC, while the more expensive fares available for short-term purchases remain distant. This statement corroborates that customers who have more flexibility look at lower prices. In contrast, the customer who buys at the last minute pays more for central airports' amenities and privileges. Research revealed that increased overlap routes in MACs were healthy for competition between airports and airlines over the years.

Areas for future research include a study of the consequences to the airline market in terms of general consumer volume, flight occupancy rate, fare values, and the mix of classes sold. In addition, we recommend a study on the interaction between these indicators airports of the same MAC from 2019 when AVIANCA Brasil, which had relevant importance in the two airports of SAO and RIO, had its operation suspended and, later, was declared bankrupt. Other competitors partially replenished this company's offer after a few months. In this way, it would be possible to assess the immediate impact on demand and price after the shock of a company's bankruptcy and which indicators were most affected when the offer started to be replenished.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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